Title

Assessment of California MPO Travel Demand Forecasting Models

Authors
Handy, Susan
Kim, Keuntae
Byrd, Daniel

Publication Date
2024-10-01

DOI
10.7922/G2C53J6W

National Center for Sustainable Transportation
A USDOT University Transportation Center

Research Report

October 2024

Assessment of California MPO Travel Demand Forecasting Models

Susan Handy, Institute of Transportation Studies

Keuntae Kim, Institute of Transportation Studies

Daniel Byrd, Institute of Transportation Studies

ITS UCDAVIS Institute of Transportation Studies

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NCST-UCD-RR-24-24	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Assessment of California MPO Travel Demand Forecasting Models		**5. Report Date** October 2024
		6. Performing Organization Code N/A
7. Author(s) Susan Handy, Ph.D., https://orcid.org/0000-0002-4141-1290 Keuntae Kim, Ph.D., https://orcid.org/0000-0002-5877-1348 Daniel Byrd, M.S.		**8. Performing Organization Report No.** UCD-ITS-RR-24-81
9. Performing Organization Name and Address University of California, Davis Institute of Transportation Studies 1605 Tilia Street, Suite 100 Davis, CA 95616		**10. Work Unit No.** N/A
		11. Contract or Grant No. Caltrans 65A1035 USDOT Grant 69A3552344814
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE, Washington, DC 20590 California Department of Transportation Division of Research, Innovation and System Information, MS-83 1727 30th Street, Sacramento, CA 95816		**13. Type of Report and Period Covered** Final Research Report (June 2023 – September 2024)
		14. Sponsoring Agency Code USDOT OST-R

15. Supplementary Notes

DOI: https://doi.org/10.7922/G2C53J6W
This contract was funded by State Planning and Research (SP&R) funding.

16. Abstract

The goal of this project was to assess the capabilities of the travel demand forecasting models (TDMs) used by California's metropolitan planning organizations (MPOs) with respect to forecasting the increase in vehicle miles of travel induced by highway capacity expansion. An expert panel assisted with the development of review questions to be used in assessing the models. These questions were used to assess each of the models currently used by the eighteen MPOs in California based on information found in readily available documents. The assessment found that seven MPOs are using activity-based models, nine are using four-step, trip-based models, and two are using hybrid models. In general, the activity-based models do a better job of capturing possible induced travel effects. Only one model includes explicit feedback between the transportation system and land use patterns. The readily-available documentation of travel demand forecasting models in California is insufficient for fully understanding the variables included in each model component and the structure of feedbacks between components of the models.

17. Key Words Travel demand forecasting, travel demand models, induced travel		**18. Distribution Statement** No restrictions.	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 92	**22. Price** N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ABOUT THE NATIONAL CENTER FOR SUSTAINABLE TRANSPORTATION

The National Center for Sustainable Transportation is a consortium of leading universities committed to advancing an environmentally sustainable transportation system through cutting-edge research, direct policy engagement, and education of our future leaders. Consortium members include: the University of California, Davis; California State University, Long Beach; Georgia Institute of Technology; Texas Southern University; the University of California, Riverside; the University of Southern California; and the University of Vermont. More information can be found at: ncst.ucdavis.edu.

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, by a grant from the U.S. Department of Transportation's University Transportation Centers Program and, partially or entirely, by a grant from the State of California. However, the U.S. Government and the State of California assume no liability for the contents or use thereof. Nor does the content necessarily reflect the official views or policies of the U.S. Government or the State of California. This report does not constitute a standard, specification, or regulation. This report does not constitute an endorsement by the California Department of Transportation of any product described herein.

The U.S. Department of Transportation and the State of California require that all University Transportation Center reports be published publicly. To fulfill this requirement, the National Center for Sustainable Transportation publishes reports on the University of California open access publication repository, eScholarship. The authors may copyright any books, publications, or other copyrightable materials developed in the course of, or under, or as a result of the funding grant; however, the U.S. Department of Transportation reserves a royalty-free, nonexclusive and irrevocable license to reproduce, publish, or otherwise use and to authorize others to use the work for government purposes.

Acknowledgments

This study was funded, partially or entirely, by a grant from the National Center for Sustainable Transportation (NCST), supported by the U.S. Department of Transportation (USDOT) and the California Department of Transportation (Caltrans) through the University Transportation Centers program. The authors would like to thank the NCST, the USDOT, and Caltrans for their support of university-based research in transportation, and especially for the funding provided in support of this project.

Assessment of California MPO Travel Demand Forecasting Models

A National Center for Sustainable Transportation Research Report

Susan Handy, Institute of Transportation Studies, University of California, Davis

Keuntae Kim, Institute of Transportation Studies, University of California, Davis

Daniel Byrd, Institute of Transportation Studies, University of California, Davis

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Assessment of California MPO Travel Demand Forecasting Models

INTRODUCTION

California is home to 18 metropolitan planning organizations (MPOs), as required by federal policy. These MPOs are responsible for preparing the long-range regional transportation plan (RTP) for the region, as well as for the near-term programming of federal, state, and other transportation funding in regional transportation improvement programs (RTIPs). In preparing their plans, the MPOs employ travel demand forecasting models (TDMs) to assess the impact of proposed investments on congestion as well as air quality. These models take as inputs future land use and transportation scenarios to forecast the resulting patterns of travel, including vehicle traffic on roadways and the use of transit and other modes.

In California, the TDMs play an especially important role. Under Senate Bill 375, MPOs are required to develop Sustainable Communities Strategies (SCS) in conjunction with their RTPs. The SCSs explore alternative land use and transportation investment scenarios for the future. TDMs are used to demonstrate that the preferred scenario chosen for the RTP/SCS will meet the region's state-imposed targets for reductions in vehicle miles of travel (VMT) and greenhouse gas (GHG) emissions. This analysis is used in the assessment of the environmental impacts of the RTPs/SCSs, which are required to go through the environmental review process under the California Environmental Quality Act (CEQA). CEQA also requires the RTIPs to go through the environmental review process, in which VMT and GHG impacts are assessed for the slate of projects chosen for funding in the near-term. Finally, as a part of the project development process, specific transportation investments also go through the environmental review process under both CEQA and the National Environmental Protection Act (NEPA), with the former (but not currently the latter) requiring an assessment of VMT and GHG impacts.

To forecast the VMT and GHG impacts accurately, the travel demand models must fully account for the effect of changes in travel time on various aspects of travel behavior. Of particular concern is their ability to accurately forecast VMT induced by projects that expand highway capacity (Volker, Lee and Handy, 2020). Highway capacity tends to reduce travel times, at least initially, which can then lead travelers to make more trips, choose more distant destinations, switch to driving from other modes, change their choice of routes. They may also make different decisions about where to live and/or work, at the same time that businesses may make different decisions about where they locate. Over the longer term, projects that expand highway capacity can influence patterns of development, generally in the direction of lower density and more dispersed development. If TDMs do not fully account for these possibilities, they may underestimate postexpansion VMT, in which case they overstate the congestion-reduction benefits and understate the environmental impacts of capacity expansion.

The goal of this project was to assess the capabilities of the TDMs used by California's MPOs with respect to forecasting induced VMT. The first step was to develop criteria for assessing the models. The second step involved reviewing model documentation to assess each model relative to these criteria.

REVIEW QUESTIONS

The guidance provided in Caltrans' Transportation Analysis Framework (2020) provided a starting point for the development of the criteria by which the models were reviewed. As noted in the Framework, "some TDMs lack key elements for assessing induced travel. For example, some model systems do not have the capability to account for changes in origin-destination patterns, increases in trip generation rates, and changes in location and land use resulting from transportation investments" (pg. 18). The Framework provides a checklist for evaluating the adequacy of TDMs for estimating induced travel that include the following items: 1. Land use response to network changes, 2. Sensitivity of trip-making behavior to network travel times and travel costs. 3. Sufficiency of detail and coverage of modelled roadway and transit networks, 4. Network assignment processes, and 5. Model calibration and validation.

A panel of modeling experts (Table 1) was recruited to review the checklist and provide guidance on a set of questions to be used in reviewing the models for this project. The panel responded to a draft list of questions by offering refinements to the proposed questions and providing additional details to be examined. The questions were then revised based on their suggestions. Four versions of the review questions were shared with the panelists. The final list of questions for the review is provided in Appendix A.

Table 1. Expert Panel

Name	Organization
Leta Huntsinger	North Carolina State University
Michael Hyland	University of California, Irvine
Alex Karner	University of Texas
Brian Lee	Puget Sound Regional Council
Greg MacFarlane	Brigham Young University
Maren Outwater	Blue Door Strategy and Research
Ram Pendyala	Arizona State University
Elizabeth Sall	Urbanlabs

The first question asks whether each component of the model is sensitive to travel time, meaning that travel time is a variable in that component of the model. Theory suggests that travel time is likely to have some influence on each of the nine components listed in the question.[1] If a model component is not sensitive to travel time, it may lead to an underestimation of induced travel effects. Traditionally, TDMs have incorporated travel time in trip distribution and mode choice models but not trip generation models, in which case the model does not account for the effect of changes in travel times on the number of trips made. Auto ownership models, which are not a component of all models, have also not typically been sensitive to travel times. Travel times are a core factor in route assignment models, which assign vehicle trips to the roadway network based on shortest path (i.e., travel time) routes.

Travel times are generally represented as matrices of zone-to-zone travel times known as “skims,” but travel times are sometimes indirectly incorporated in submodels through the use of “logsum” measures. Activity-based models and some four-step models employ discrete choice models to predict the probability that an individual makes a given choice from a set of available choices. These models assume that this probability depends on the ratio of the utility of the given choice relative to the sum of the utilities across all available choices. Because these models take a logit form, the sum of the utilities across all choices is referred to as the “logsum.” For mode choice models, the utility of choosing a particular mode is assumed to depend on the travel times as well as travel costs and other factors. In this way, the logsum represents a composite measure of the qualities of the choices available. Incorporating the logsum from mode choice models into models that predict activities, auto ownership, trip frequency, destinations, and/or other “higher level” choices means that these choices are sensitive to travel times. This approach improves the behavioral integrity of the model (Bowman et al., n.d.).

The second question asks whether the zone-to-zone travel times as estimated by the full model (and thus reflecting congestion levels) are fed back into each model component that is potentially sensitive to travel time (Figure 1). This is also known as the “iteration” of travel times. Route assignment models have long involved some form of iteration to ensure that the number of trips assigned to each route is realistic from the standpoint of travel time and that an “equilibrium” assignment is found in which travel times are generally minimized (i.e., no traveler could reduce their travel time by switching routes). Traditional TDMs used assumed travel times (free-flow or congested) for the trip distribution and mode choice models, which may or may not have been similar to the travel times forecasted as a model output. A more recent practice is to iterate travel times back to mode choice models: in a second run of the model, forecasted travel times replace assumed travel times to produce new mode share estimates and, after route assignment, new forecasts of travel times. This process is repeated some number of times, either until the forecasts stop changing, that is, until they “converge,” or when a predetermined number iterations has been completed. Iterating back to trip distribution is less common, and feedbacks to trip generation, auto ownership, and land use forecasts are even less so.

[1] SACOG has transit pass and parking pass ownership submodels; SANDAG has a telecommuting decision submodel; MTC has ride-hailing submodel; SCAG includes ride-hailing in its mode-choice models and accounts for telecommuting in its work arrangement model.

The lack of such feedbacks means that the model does not fully capture the effects of changes in travel time and could lead to inaccurate estimates of induced travel.

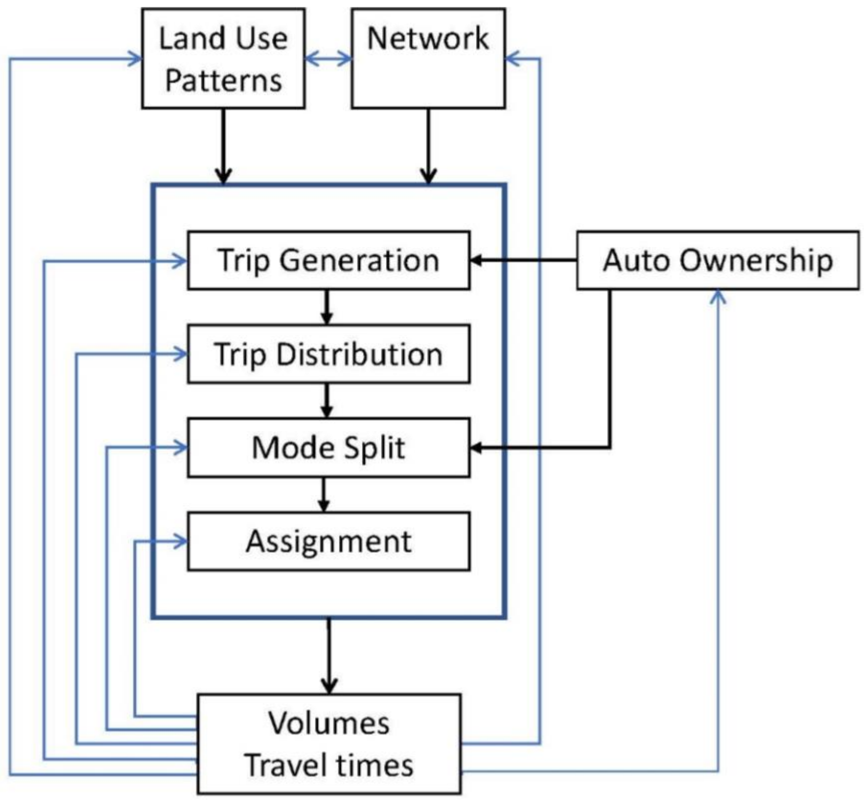


Figure 1. Possible Feedbacks (in blue) for Traditional 4-Step Models

The third question refers to the treatment of time (rather than travel time) in the model. Some models forecast peak period travel (AM and/or PM) rather than 24-hour travel. These models may not account for the possibility that travelers may shift from the peak period to off-peak periods in response to high levels of congestion. Models that do not account for this possibility may produce overestimates of congestion levels during peak periods, particularly for “no build” scenarios in which highway capacity is not expanded. Activity-based models typically simulate travel for 24-hour periods and include time-of-day or scheduling submodels that determine the departure time for trips; feedback of congested times to these submodules helps to ensure that the timing of trips in the model is sensitive to the timing of traffic congestion.

The fourth question addresses the assumptions behind the land use scenarios that are used as inputs to the model. A common practice in regional transportation planning, at least historically, is to use the same land use scenario for both the “build” and “no-build” transportation networks. This practice means that the model does not account for the fact that changes to the transportation network are likely to influence location choices in the near term and the location of new development over the long term. This omission can lead to inaccurate estimates of induced travel. In California, the Sustainable Communities

Strategy (SCS) that is required in conjunction with the federally-required Regional Transportation Plan (RTP) is typically chosen after an analysis of multiple land use scenarios, but these scenarios do not necessarily reflect the possible effects of proposed highway expansions.

Finally, the team looked for acknowledgement and discussion of the induced travel effect, that is, the phenomenon by which increases in highway capacity lead to an increase in VMT, above and beyond any future increases in VMT attributable to population increases.

MODEL REVIEW

Among California's 18 MPOs, nine use traditional 4-step models, seven employ activity-based models, and two currently use a hybrid of the two (Table 2). The 4-step models and activity-based models are structured differently, with the former estimating travel patterns in the aggregate and the latter simulating individual travel behavior. The review questions, however, are appliable to both types of models, the core question being: to what degree does the model account for the sensitivity of various aspects of travel behavior to changes in travel times?

For each of the MPOs, the research team located all available on-line documentation related to the model. The team reviewed the available documentation with respect to each of the review questions (Appendix A), focusing on the components of the model used in estimating household travel internal to the region (rather than freight travel, trips that start or end outside of the county, special generators such as airports, or other trips not related to internal daily household travel). In some cases, the documentation is not clear enough to answer the question or information is missing altogether.

The results of this review are summarized in Table 3. Summaries of the review for each model are provided in Appendix B.

Table 2. Overview of California MPO Models

MPO		Model Name	Model Type	Base Year	Platform
AMBAG	Association of Monterey Bay Area Governments	Regional Travel Demand Model (RTDM)	Hybrid	2015	TransCAD
BCAG	Butte County Association of Governments	Transportation Demand Forecasting (TDF) Model	4-step trip	2018	Cube
FCOG	Fresno Council of Governments	Fresno ABM	Activity-based	2014	Cube
KCAG	Kings County Association of Governments	MIP-1	4-step trip	2015	TP-Plus
KCOG	Kern Council of Governments	VMIP-2	4-step trip	2015	Cube
MCAG	Merced County Association of Governments	VMIP-2	4-step trip	2015	Cube
MCTC	Madera County Transportation Commission	VMIP-2	4-step trip	2018	Cube
MTC	Metropolitan Transportation Commission	Travel Model 1.5 (TM1.5)	Activity-based	2015	Cube, CT-RAMP
SACOG	Sacramento Area Council of Governments	SACSIM19	Activity-based	2016	Cube, DAYSIM
SANDAG	San Diego Association of Governments	ABM2+	Activity-based	2016	CT-RAMP
SJCOG	San Joaquin Council of Governments	VMIP-2	4-step trip	2015	Cube
SLOCOG	San Luis Obispo Council of Governments	Regional Travel Demand Model	Hybrid	2015	TransCAD
SBCAG	Santa Barbara County Association of Governments	SBCAG Travel Demand Model	4-step trip	2015	TransCAD
SRTA	Shasta County Regional Transportation Planning Agency	ShastaSIM 2.0	Activity-based	2010	Cube, DAYSIM
SCAG	Southern California Association of Governments	ABM	Activity-based	2016	CT-RAMP
StanCOG	Stanislaus Council of Governments	2022 RTP Model (VMIP-2)	4-step trip	2019	Cube
TCAG	Tulare County Association of Governments	VMIP-2	4-step trip	2015	Cube
TMPO	Tahoe Metropolitan Planning Organization	Tahoe Travel Model	Activity-based	2018	TransCAD

Table 3. Summary of Model Feedbacks

MPO	Land Use	Auto Ownership	Trip Generation	Trip Distribution	Mode Choice	Route Assignment
AMBAG	N	N	N	Y	Y	Y
BCAG	N	N	N	N	N	Y
FCOG	N	N	Y	Y	Y	Y
KCAG	N	N	N	Y	N	Y
KCOG	N	N	N	Y	Y	Y
MCAG	N	N	N	N	N	Y
MCTC	N	N	N	Y	Y	Y
MTC	Y	Y	Y	Y	Y	Y
SACOG	y	Y	Y	Y	Y	Y
SANDAG	Y	Y	Y	Y	Y	Y
SJCOG	N	N	N	Y	Y	Y
SLOCOG	N	N	N	Y	Y	Y
SBCAG	*	*	*	*	*	*
SRTA	N	Y	Y	Y	Y	Y
SCAG	N	Y	Y	Y	Y	Y
StanCOG	N	N	N	Y	N	Y
TCAG	N	N	N	Y	Y	Y
TMPO	N	N	N	N	N	Y

FINDINGS

Three types of models are used by California MPOs: four-step, trip-based models, activity-based models, and a hybrid of the two as a transition to full activity-based models (Table 2). The models employ several different platforms: TransCAD, Cube, TP-Plus, and CT-RAMP. Base years for the models currently in use range from 2014 to 2019 and thus reflect pre-Covid conditions, though some of the larger MPOs have taken steps to adjust their forecasts for post-Covid conditions.

Although each model is unique, several of the models share an overall approach but with local customizations. The eight MPOs in the San Joaquin Valley joined forces in the Model Improvement Program (MIP) in 2010. KCAG (King) continues to use its MIP-1 model, while KCOG (Kern), MCAG (Merced), MCTC (Madera), SJCOG (San Joaquin), StanCOG (Stanislaus) and TCAG (Tulare) use VMIP-2 models. BCAG (Butte) also has a four-step, trip-based model. On the central coast, AMBAG (Monterey), SLOCOG (San Luis Obispo), and SBCAG (Santa Barbara) have been working together to develop activity-based models. The SRTA (Shasta) ShastaSIM model and the new Fresno ABM use the same core demand model, DaySIM, as the SACOG (Sacrament) SacSIM model. The other three large MPOs – MTC, SCAG, and SANDAG – have unique ABMs that are similar in approach but differ in specifics. The ABM developed by TMPO (Tahoe) accounts for its unique context.

The traditional 4-step models have some but not all of the feedbacks needed to accurately capture the induced travel effect. All these models include feedbacks within their network assignment submodels. Some include feedbacks from assignment back to mode choice, but several of the models use static estimates of mode shares owing to the very low shares of modes other than driving in the region. All four-step models except BCAG and MCAG have feedback loops to trip distribution, but none have feedbacks to trip generation. These models either do not have auto ownership models or do not have feedbacks to their auto ownership models. The absence of these feedbacks could mean that these models underestimate induced VMT.

In contrast, activity-based models in nearly all cases include feedbacks of congested travel times to the key model components, including network assignment, mode choice, trip distribution, trip generation, and auto ownership. Generally, travel times are fed back to mode choice models, with the logsums from mode choice models fed back into other submodels. The feedbacks in the Tahoe ABM are more limited, as are the feedbacks in the two hybrid models. Overall, ABMs are likely to provide more accurate estimates of the induced VMT effects of highway capacity expansion.

The treatment of time differs between the four-step models and the ABMs. Four-step models generally estimate trips for a 24-hour period then allocate them to some number of designated time periods for the network assignment process using static percentages, though many of the model documents do not describe this allocation process. These models do not account for the possibility that trips shift in time in response to changing levels of congestion. ABMs also estimate trips for a 24-hour period but include models for trip departure time in short time intervals (from 1 minute to 15 minutes). Trips are aggregated to time periods for the route assignment process, but because travel times are fed back into the departure time models, the share of trips in a given period will change as estimated levels of congestion change.

In all cases, the estimates of trips generated by households living in the region are combined with estimates of trips starting and/or ending outside of but passing through the county and with estimates of freight trips. The network assignment models then assign all these trips to the network for specified periods of time, for example, AM peak period, mid-day, and PM peak period. As of the time of this review, all models use an equilibrium assignment procedure, with some variation in details such as maximum iterations and convergence criteria. The fine-grained temporal scale of some of the ABMs could enable the use of dynamic traffic assignment models in the future, as noted by both FCOG and SCAG.

Feedbacks to land use scenarios are limited for both four-step models and ABMs. Only MTC has a truly integrated land use – transportation model in which travel time estimates from the travel demand model are fed back into a land use model in an iterative process that ensures that the planned transportation investments are consistent with the land use scenario. SACOG and SANDAG describe a relatively rigorous process of matching transportation investments to land use scenarios in the development of the SCS. Several MPOs use UPlan, a scenario development tool that accounts for proximity to transportation facilities but not travel times. Most MPOs present different slates of transit and active travel investments for different land use scenarios but many are not explicit about whether highway investments differ across the scenarios. In other cases, the agencies do not explain whether the same or different land use scenarios are used when modeling the “build” and “no build” transportation plans. The potential effect of highway investments on land development patterns is rarely discussed.

The induced travel effect receives limited attention in both plans and model documentation. Of the large MPOs, MTC and SACOG both discuss and analyze the potential for highway capacity expansion to induce VMT, but SCAG and SANDAG do not directly address the issue. Of the smaller MPOs, most of those in the San Joaquin Valley discuss and analyze the possibility that their transportation plans could induce VMT, in some cases comparing their model results to estimates of induced VMT from the California Induced Travel Calculator (using a method reportedly developed by the consulting firm Fehr & Peers). These MPOs argue that the lack of congestion in their regions means that the induced travel effect would be minimal.

Many other aspects of the models that were not examined here are relevant to California’s efforts to reduce VMT and GHGs. These include the incorporation of bicycle and pedestrian networks and skims, procedures for off-model forecasts for policies that cannot be represented in the travel demand models, the treatment of external trips, and the modeling of freight travel. The treatment of telecommuting in the models will be especially important in the next round of models given the jump in remote working triggered by Covid.

The readily-available documentation of travel demand forecasting models in California is insufficient for fully understanding the variables included in each model component and the structure of feedbacks between components of the models. Only SANDAG provides all of the information sought for this review in its posted documentation. In some cases, available documents explain updates to previous models but do not describe the models themselves. The poor quality of the documentation limits the ability of researchers, agencies, and the public to understand and assess the travel demand forecasting models being used to create long-range regional transportation plans and select billions of dollars of transportation investments.

REFERENCES

Bowman, J.L., Bradley, M., & Childress, S. (n.d.). Mode Choice, Logsums, and Auto Ownership Model Estimation: SoundCast Activity-Based Travel Model for PSRC. https://www.psrc.org/media/2224

Caltrans. (2020). Transportation Analysis Framework. https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/sb-743/2020-09-10-1st-edition-taf-fnl-a11y.pdf

Volker, J. M., Lee, A. E., & Handy, S. (2020). Induced vehicle travel in the environmental review process. *Transportation Research Record*, *2674*(7), 468-479.

APPENDIX A: REVIEW QUESTIONS

(1) Is the component of the model (by trip purpose, where applicable) directly sensitive to network travel times and travel costs by mode? If so, what is the elasticity (if it can be determined)? Is the component indirectly sensitive (i.e., is it sensitive to a variable that is sensitive to travel time/cost)? Is the component sensitive to income? Does the effect of time vary by income (e.g., is there an interaction term for time x income)?

a. Auto ownership (if applicable)
b. Transit pass ownership (if applicable)
c. Parking pass ownership (if applicable)
d. Telecommuting decision (if applicable)
e. How often people travel: Trip or tour generation; trip or tour frequency
f. When people travel: travel period; departure time (if applicable)
g. Where they travel to: trip distribution; destination choice
h. What mode people use to get there: mode split; mode choice
i. What route they take: route assignment; route choice
    i. Does the route assignment model itself converge?

(2) If so, are the travel times as estimated by the full model (i.e., after route assignment) fed back into the model component (by trip purpose, where applicable)? If so, how many iterations are used? Is convergence ensured?

a. Auto ownership (if applicable)
b. Transit pass ownership (if applicable)
c. Parking pass ownership (if applicable)
d. Telecommuting decision (if applicable)
e. How often people travel: Trip or tour generation; trip or tour frequency
f. When people travel: travel period; departure time (if applicable)
g. Where they travel to: trip distribution; destination choice
h. What mode people use to get there: mode split; mode choice
i. What route they take: route assignment; route choice

(3) For models that use time periods (rather than 24-hours): What are the time periods? Are the numbers of trips within a given time period dependent on model-estimated levels of congestion as reflected in travel times? Does the model account for the possibility that congestion pushes trips into the shoulders of the peak periods?

(4) What land-use scenarios are used? To what degree and in what way are changes in travel times/costs owing to highway investments factored into the land-use scenarios? In

the RTP: If multiple land use scenarios are used, is the same highway network used for each?

(5) Does the documentation talk about induced VMT, i.e., does it acknowledge the fact that expanding highway capacity itself leads to an increase in VMT, above and beyond the increase in VMT stemming from population increases? If so, does the documentation acknowledge the model's limitations with respect to estimating induced VMT? What does it say?

APPENDIX B: MODEL REVIEW SUMMARIES

Association of Monterey Bay Area Governments: Regional Travel Demand Model

AMBAG adopted the 2045 MTP/SCS in June 2022. Appendix F of the 2045 MTP/SCS (a copy of Appendix F of the 2040 MTP/SCS) describes the development of the Regional Travel Demand Model. The trip-based, four-step model, developed by a consulting team of Caliper Corporation, Fehr & Peers, and Parsons Brinckerhoff, was estimated using data from the 2011-12 California Household Travel Survey and calibrated to 2015 conditions. As described in Appendix F, the model employs a more disaggregated approach than traditional four-step models, including the use of population synthesis to determine the socioeconomic variables for the trip generation model, person-based trip rates, a destination choice model, and a mode choice model. Land use characteristics are included in various model stages, and the model includes a transit network. These improvements are intended as the first stage of an upgrade to an activity-based model.

Travel Time Sensitivity and Feedbacks

The trip distribution, mode choice, and route assignment submodules are sensitive to travel time, though the trip generation submodule is not. The initial model run uses free-flow travel times, but estimates of travel times following route assignment are fed back into the model after trip generation and before trip distribution (see Figure 1 from Appendix F). The model is rerun with the congested travel times and the process is repeated until five feedback loops have been performed. The model employs "a highly convergent traffic assignment algorithm."

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Interaction between travel time/costs and income		
Auto Ownership	N/A	N/A	N/A	N/A	Estimated as a part of the synthetic population.
Trip Generation	No	No	No	F-8 to F-9	Person-based trip rates using synthetic population for seven trip purposes.
Trip Distribution	Yes	No	No	F-10	Destination choice model.
Mode Choice	Yes	Yes	No	F-10 to F-13	Nested logit-based mode choice model includes travel times and costs by mode. Separate models for peak and off-peak.
Route Assignment	Yes	Yes	No	F-16	

*2045 MTP/SCS Appendix F

Iterative Feedback Loops

<table>
<tr><th rowspan="2">Submodule</th><th colspan="3">Sensitivity of Submodules</th><th rowspan="2">Document Page(s)*</th><th rowspan="2">Notes</th></tr>
<tr><th>Feed-back</th><th>Max. Iterations</th><th>Ensuring convergence</th></tr>
<tr><td>Auto Ownership</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td></td></tr>
<tr><td>Trip Generation</td><td>No</td><td>N/A</td><td>N/A</td><td rowspan="4">2045 MTP/SCS 2045, Appendix F, F-18</td><td rowspan="4">The feedback loop goes back to the Trip Distribution submodule.</td></tr>
<tr><td>Trip Distribution</td><td>Yes</td><td rowspan="3">A total of 5 iterations</td><td rowspan="3">Not guaranteed</td></tr>
<tr><td>Mode Choice</td><td>Yes</td></tr>
<tr><td>Trip Assignment</td><td>Yes</td></tr>
</table>

*2045 MTP/SCS Appendix F

Time Periods

The model uses four time periods: a 3-hour AM peak period, a 3-hour PM peak period, a 7-hour mid-day period, and a 11-hour night period. Different travel times are used for peak and non-peak time periods. The model documentation does not explain how trips are assigned to time periods and makes no mention of the trips being pushed from one period into another one due to congestion and its resulting impact on travel times. Separate mode choice models are used for peak and off-peak periods.

Land Use Scenarios

UPlan was used to build land use scenarios based on public input. Land use scenarios are not based on estimates of travel times or changes to the transportation network.

Induced VMT

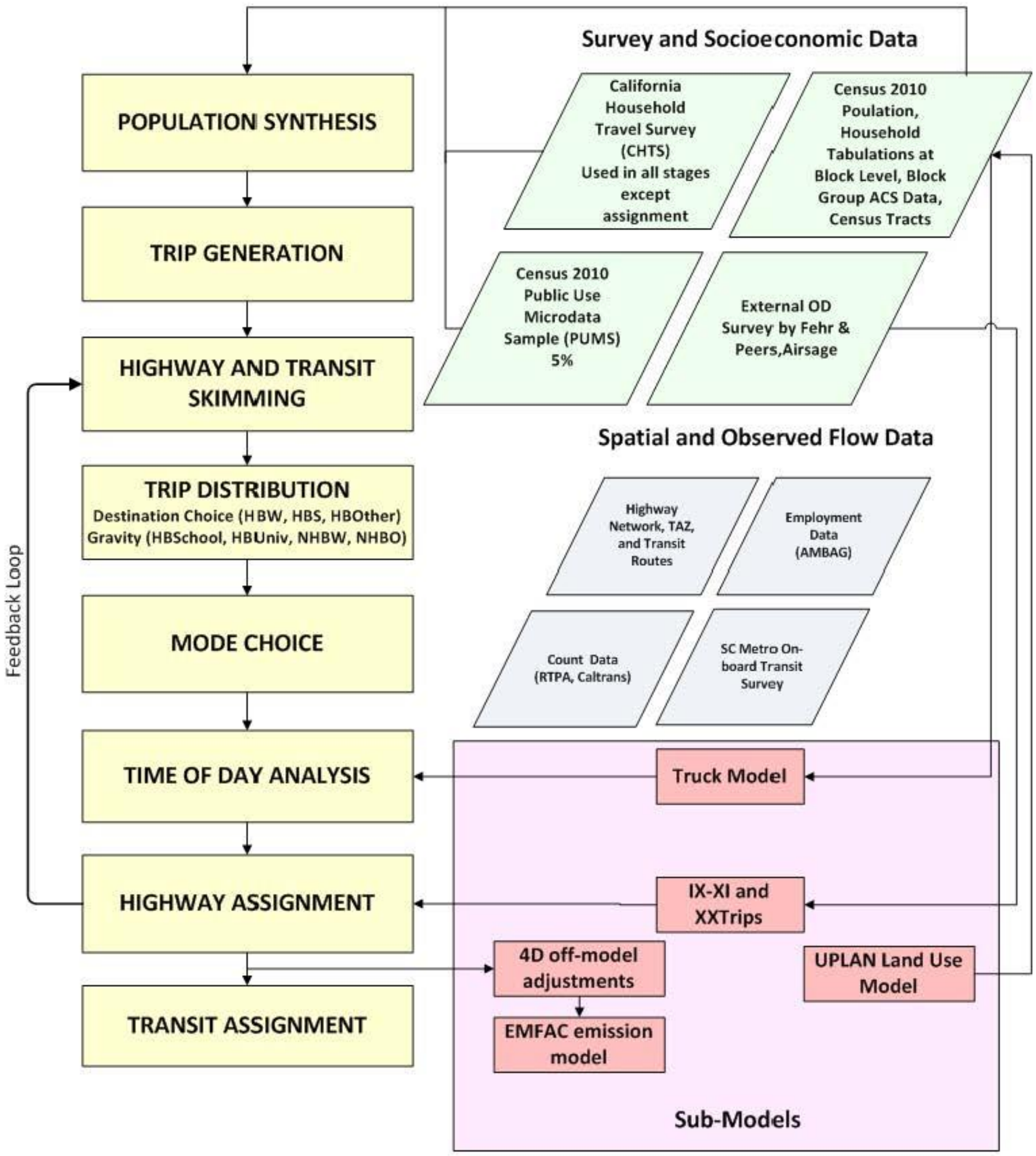
Sensitivity testing of the model concluded that "the model is appropriately sensitive" to travel times with respect to route assignment (p. F-10). The sensitivity of trip generation, distribution, and mode choice estimates to the influence of added roadway capacity was not tested. The concept of induced VMT and the model's ability to estimate it is not explicitly discussed.

Documents

2045 Metropolitan Transportation Plan & the Sustainable Communities Strategy. https://ambag.org/plans/2045-metropolitan-transportation-plan-sustainable-communities-strategy

2040 MTP/SCS Appendix F. https://www.ambag.org/sites/default/files/2020-01/13_AMBAG_MTP_SCS_AppendixF_PDFA.pdf

Figure F-1: Model Stream for Regional Travel Demand Model



Butte County Association of Governments (BCAG): Travel Demand Forecasting (TDF) Model

Butte CAG released its most recent Regional Transportation Plan in 2020. The development of the Travel Demand Forecasting (TDF) model, a trip-based, four-step model, is documented in a model development report released in September 2020, as well as a user guide released in August 2020. Both reports were prepared by Fehr & Peers and can be accessed from BCAG's webpage for the 2020 RTP. In addition to this TDM, BCAG also provides documentation for its land use allocation model, which was developed in-house. Several improvements over the previous version of the model were made, including a distinction between person trip and commercial truck trips, incorporation of salary and household income in work-trip distribution, accounting for what modes are allowed on each facility in trip distribution, and the use of a utility-based mode choice model.

Travel Time Sensitivity and Feedbacks

The model accounts for travel times in the trip distribution, mode choice, and route assignment submodules but not the trip generation or auto ownership submodules. Trip distribution is estimated using a gravity model that takes into account the match between the salaries of jobs and the incomes of workers. Estimated travel times are fed back into route assignment but not to earlier submodules.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	Yes	Yes	pp. 33-35	Auto availability is an input to trip distribution and mode choice. Includes ratio of average annual commute cost to income and
Trip Generation	No	No	Yes	pp. 24-32	Daily person-trip rates for seven trip purposes.
Trip Distribution	Yes	No	Yes	pp. 32-35	Gravity model accounts for salary and income for work trips.
Mode Choice	Yes	Yes	No	pp. 35-44	Based on multinomial logit model developed for the San Joaquin Valley MPOs. Income reflected in auto ownership. Separate models by purpose.
Route Assignment	Yes	Yes	No	p. 44	

* 2020 Model Development Report.

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	No	N/A	N/A	pp. 33-35	
Trip Generation	No	N/A	N/A	pp. 24-32	
Trip Distribution	No	N/A	N/A	pp. 32-35	
Mode Choice	No	N/A	N/A	pp. 35-44	
Route Assignment	Yes	Not specified	Yes	pp. 44-46	Details not provided.

* 2020 Model Development Report.

Time Periods

In the Trip Assignment phase of the four-step model, trips are classified and estimated for six time periods within a typical weekday (see Table 29). However, the report does not explain how trips are assigned to time periods and makes no mention of the trips being pushed from one period into another one due to congestion and its resulting impact on travel times.

Land Use Scenarios

BCAG's Land Use Allocation Model is described in Appendix 6-6a of the 2020 RTP/SCS. The model does not appear to account for travel times or directly reflect changes to the transportation network.

Induced VMT

Induced travel is discussed in the "Model Validation" section of the 2020 Model Development Report. The model's sensitivity to both short-term and long-term induced travel is considered. The long-term analysis compares the VMT for the RTP/SCS scenario (Scenario 3) with a scenario based on the RTP/SCS land use assumptions and the 2018 base network (Scenario 2), to estimate the increase in VMT from land use changes alone. The difference in VMT between Scenario 3 and Scenario 2 provides as estimate of "long-term induced travel from network changes alone" (p. 51). The report notes that the estimate is lower than an estimate based on elasticities from empirical research and argues, "Given the rural nature of Butte County congestion is limited and is unlikely to influence vehicle travel such that trip making would be suppressed… In other words, trip generation in the county is not constrained and trip rates tend to represent full demand levels" (p. 51). The report concludes that "the model appears to be appropriately sensitive to long term induced travel."

Documents

2024 RTP/SCS Update. https://www.bcag.org/PlansProgramsModel/RTP--SCS/2024-RTPSCS-Update/index.html

2020 RTP/SCS. https://www.bcag.org/PlansProgramsModel/RTP--SCS/2020-RTPSCS/index.html

BCAG 2020 RTP Travel Demand Model: Model Development Report. https://www.bcag.org/documents/planning/RTP%20SCS/2020%20RTP%20SCS/Appendices/Appendix%206-6b%20Final.pdf

Table 32: Induced Vehicle Travel Elasticity Scenarios

Model Scenario/ Components	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Model Framework	2018 RTP/SCS	2018 RTP/SCS	2018 RTP/SCS	2040 RTP/SCS
Network	2018 RTP	2040 RTP/SCS	2018 RTP	2040 RTP/SCS
Socioeconomic	2018 RTP	2018 RTP	2040 RTP/SCS	2040 RTP/SCS
Total VMT	4,869,563	4,873,926	5,503,619	5,527,618
Total Lane-Miles	7,020	7,069	7,020	7,069
VMT Per Lane-Mile	694	690	784	782

Source: Fehr & Peers, 2020.

p. 49, 2020 Model Development Report

Table 33: Short-Term Induced Vehicle Travel Elasticity Check

	Unconstrained	Constrained	Change
Lane Miles	7,020	7,069	0.69%
Total VMT	5,356,425	5,332,327	0.09%
Model VMT Change	4,363		
Literature VMT Change [1]	3,356 to 20,135		

Note:

1. The change in VMT is based on CARB research for short-term elasticity ranging from 0.1 to 0.6.

Source: Fehr & Peers, 2020.

Table 34: Long-Term Induced Vehicle Travel Elasticity Check

	Scenario 1	Scenario 2	Scenario 3
Model Framework	2018 RTP/SCS	2018 RTP/SCS	2040 RTP/SCS
Network	2018 RTP	2018 RTP	2040 RTP/SCS
Socioeconomic	2018 RTP	2040 RTP/SCS	2040 RTP/SCS
Lane Miles	7,020	7,020	7,069
Total VMT	4,869,563	5,503,619	5,527,618
Model VMT Change			658,055
Model VMT Change due to Population and Employment		634,056	
Model VMT Change due to Roadway Capacity			23,999
Literature VMT Change [1]	34,565		

Fresno Council of Governments (FCOG): Fresno ABM

The Fresno Council of Governments (FCOG) adopted its latest regional transportation plan in 2022. For the preparation of the 2022 Regional Transportation Plan, FCOG replaced VMIP2, a four-step, trip-based model, with an activity-based model (ABM) for estimating household travel in the county (while retaining VMIP2 for freight and other components). The model was calibrated with data from the 2012 California Household Travel Survey and the 2010 National Household Travel Survey, with a base year of 2014. The model and its application are described in the Fresno Activity-Based Model Update report published in 2018 as well as Appendix C of the plan. The modeling process is split into an input processing procedure and what is called the "Fresno Model." The Fresno Model includes three main components – skims, demand, and final assignment – with feedbacks between the components (see Figure 1: Model Process Flow).

At the core of the demand model, DaySim uses land use data and synthesized population characteristics for "micro-zones" to simulate all travel by residents of the county minute-by-minute over a 24-hour period. Rather than using a Monte Carlo simulation for population synthesis, as in many other ABMs, the Fresno ABM uses a Population Sampler that is more efficient (in terms of iterations to convergence) for smaller regions (p. 16). DaySim uses a set of long-term choice models as well as short-term choice models to produce estimates of person trips (see Figure 3: DaySim Sub-Models). The long-term choices are: usual work location for each worker, usual school location for each student, work location for student workers, and household auto ownership. The short-term choices are: day pattern (number and type of tours made by each person), primary activity destination, main mode of travel for each tour, primary activity scheduling for each tour, number and purpose of intermediate stops made on each tour, and the location, mode of travel, and scheduling of each intermediate stop. The model is structured hierarchically, with long-term choices influencing or constraining the short-term choices. At the same time, logsums from tour destination and tour mode-choice models are fed into other short-term models and into long-term models. The DaySim Buffer Tool is used to estimate land use and transit access variables for areas around each micro-zone that are used in several of the submodules (see pp. 13-16).

Travel Time Sensitivity and Feedbacks

According to the Model Update document, "DaySim's forecasts in all dimensions (activity and travel generation, tours and trip-chaining, destinations, modes, and timing) are sensitive to travel times and costs that vary by mode, origin–destination path, and time of day" (p. 11). The document does not provide details on the variables included in each submodule; other DaySim models include logsum variables that reflect travel times (and other aspects of utility). Travel time is not a predictor variable for auto ownership.

The Model Update document states that the model includes feedbacks from interim assignments for two-time periods to the DaySim submodules. Skims for two time periods are used for the feedback loops, and three feedback loops to DaySim are run before the final assignment is run. The feedback loop does not include auto ownership estimates.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	No	Yes	pp. 38-39	
Trip Frequency	Yes	Yes	Yes	pp. 11-13	Within DaySim, presumably through logsum variables, though document does not provide details.
Trip Distribution					
Mode Choice					
Network Assignment	Yes	Yes	Yes	pp. 20-21	Equilibrium assignment.

* Fresno Activity-Based Model Update, 2018

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring convergence		
Auto Ownership	No	N/A	N/A		
Trip Frequency	Yes	3	Yes	pp. 4-5 & 22-23	Through logsums. Skims from two time periods used in three feedback loops. Other details not provided.
Trip Distribution					
Mode Choice					
Network Assignment	Yes	See note	Yes	pp. 22-23	50 iterations for peak 20 for off-peak

* Fresno Activity-Based Model Update, 2018

Time Periods

The Fresno ABM estimates trips on a minute-by-minute basis. Estimated trips are aggregated to four time periods for network assignment: AM peak period, Mid-day period, PM peak period, and evening period. If the feedback loops in DaySim include feedback to the scheduling submodules, the model would be able to capture the effect of changing levels of congestion on travel time departures and this could reflect the shifting of trips into shoulder periods in response to congestion.

Land Use Scenarios

Chapter 5 of the FCOG 2022 Regional Transportation Plan describes an extensive process for public engagement in the creation of three scenarios for the Sustainable Communities Strategy. The degree to which assumptions about highway capacity expansion differed across the scenarios is not readily apparent, though each scenario puts maintenance of existing streets and roads as highest priority. The Fresno ABM was used to assess the impact of each scenario on VMT and GHG emissions. Fresno COG selected Scenario B as the preferred scenario; 27% of total transportation dollars are allocated to "streets & roads capacity increasings" in this scenario, a decrease from 34% in the 2018 RTP/SCS (see Table 5-3 in Chapter 5).

Induced Travel

The 2022 Regional Transportation Plan does not discuss the possibility that increased capacity will lead to an increase in VMT. Sensitivity testing of the Fresno ABM, as described in the Model Update document, included testing for sensitivity to auto operating cost, transit fares, new transit service, and new employment center but not highway capacity (p. 83).

Documents

FCOG 2022 Regional Transportation Plan. https://www.planfresno.com/sustainable-communities-strategies-fall-outreach/

Fresno Activity-Based Model Update. https://www.fresnocog.org/wp-content/uploads/2017/06/Fresno-COG-ABM-Report.pdf

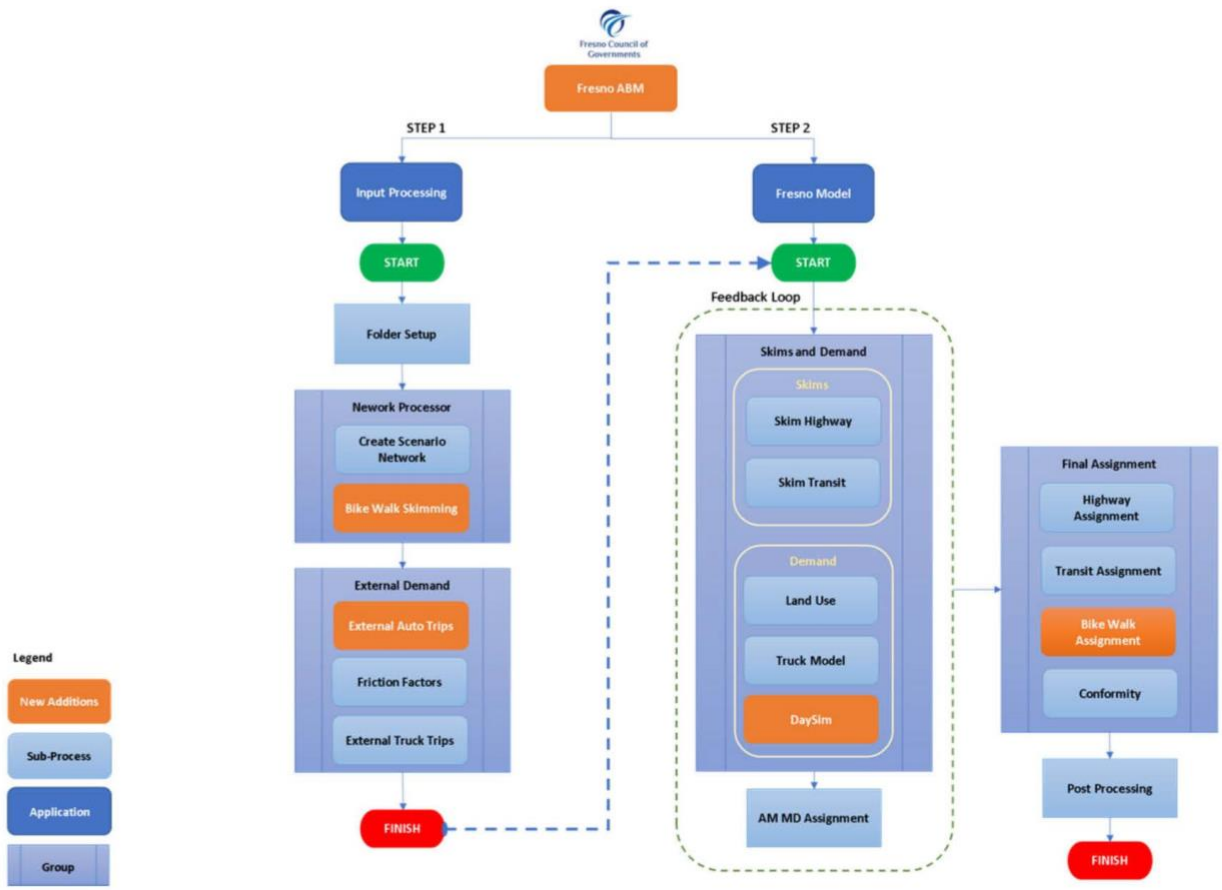


FIGURE 1: MODEL PROCESS FLOW

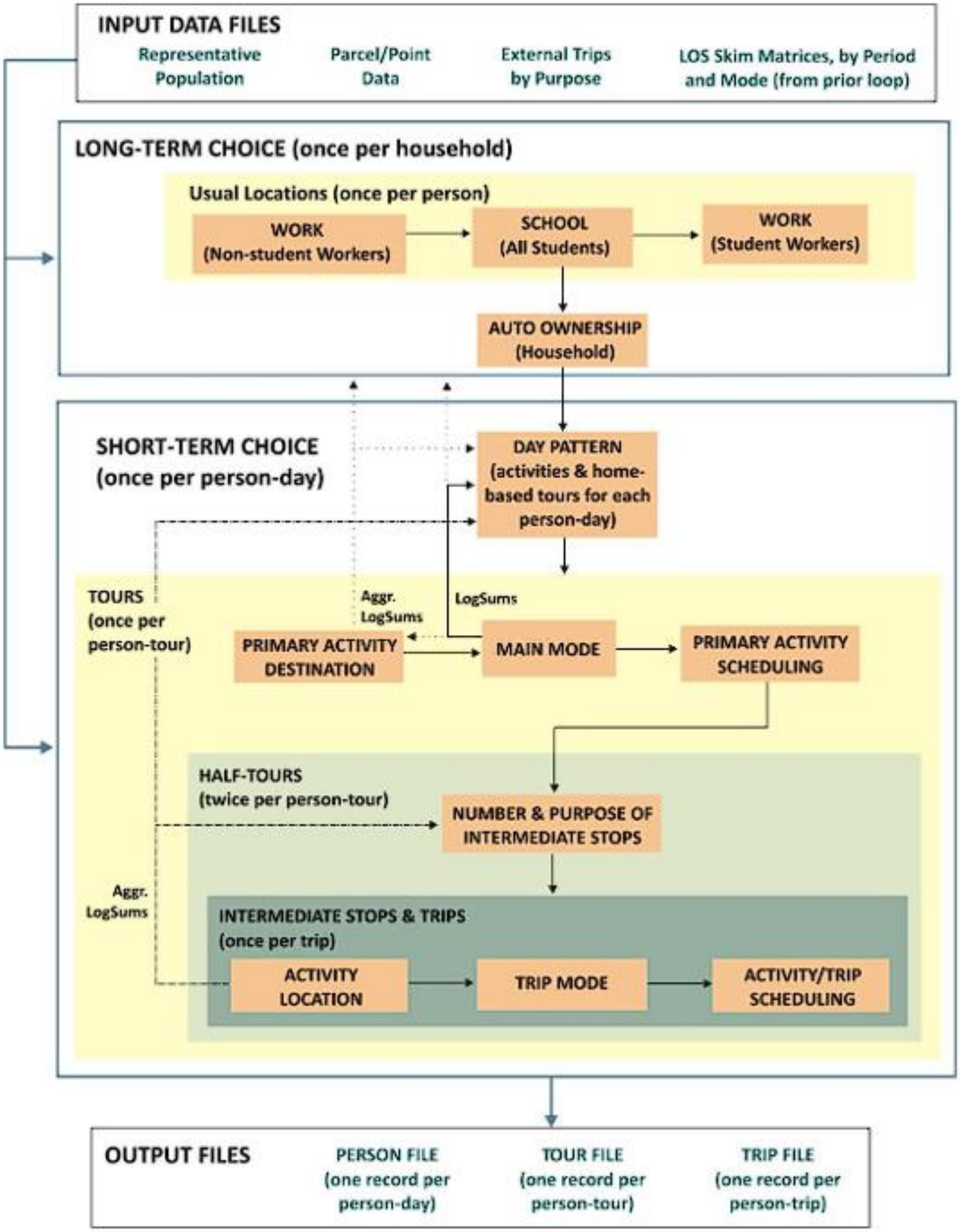


FIGURE 3: DAYSIM SUB-MODELS

Kern Council of Governments (KCOG): VMIP-2

The most recent KCOG Regional Transportation Plan was adopted in 2022. The agency employed the VMIP-2 model in preparing this plan. This model is an update to the 2010 VMPI-1 model reflecting more recent census and travel survey data as well as several model improvements. The model is documented in the Model Development Report, published in 2017 and prepared by Fehr & Peers. The VMIP-3 model updates, described in a memo from DKS Associates dated February 2022, include recalibration of the model to reflect more recent data.

Travel Time Sensitivity and Feedbacks

The trip distribution, mode choice, and trip assignment submodules are sensitive to travel time, but the auto ownership and trip generation submodules are not. The model includes a feedback loop in which estimated congested travel times are fed back into the trip generation and mode choice submodules (note that the diagram for the model shows a feedback look to the auto ownership model). The report does not provide details on the number of iterations or criteria for convergence.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	Yes	Yes	pp. 30-31	Multinomial logit model. Reflects commute cost relative to income.
Trip Generation	No	No	Yes	pp. 32-42	Daily person trip rates by income levels, place types, household size, and housing type for seven trip purposes.
Trip Distribution	Yes	No	No	pp. 42-43	Gravity model
Mode Choice	Yes	Yes	No	pp. 43-53	Multinomial logit with segmentation by trip purpose and auto ownership.
Trip Assignment	Yes	Yes	No	pp. 54-55	

* KCOG VMIP2 Model Development Report

Iterative Feedbacks

Submodule	Sensitivity of Submodules			Document Page(s)	Notes
	Feed-back	Max. Iterations	Ensuring convergence		
Auto Ownership	No	N/A	N/A		
Trip Generation	No	N/A	N/A		
Trip Distribution	Yes	Not specified	Not specified	p.55	
Mode Choice	Yes	Not specified	Not specified	p.55	
Trip Assignment	Yes	Not specified	Yes		

* KCOG VMIP2 Model Development Report

Time Periods

The Model Development Report does not clearly define the time periods used in the model. The report does not explain how trips are assigned to time periods and makes no mention of the trips being pushed from one period into another one due to congestion and its resulting impact on travel times.

Land Use Scenarios

KCOG uses the UPlan scenario tool to create land use scenarios. UPlan accounts for proximity to highway facilities in determining where new development is likely to locate, though it does not directly account for travel times. As described in the Kern SB 375 Land Use Modeling Methodology, the agency's modeling process includes a manual feedback loop between the travel model and the land use model (p. 5; see also Kern COG SB 375 Modeling Flowchart). The feedback is of the location and nature of transportation infrastructure rather than travel times (p. 11).

The scenarios analyzed include "business as usual" or "no change" scenarios, which assume historical growth patterns and trends, as well as alternative scenarios that explore the impact of different transportation investments. These scenarios vary in the degree to which they prioritize different types of infrastructure, such as transit versus highways, allowing for comparisons of different growth patterns and their impact on travel behavior.

Induced VMT

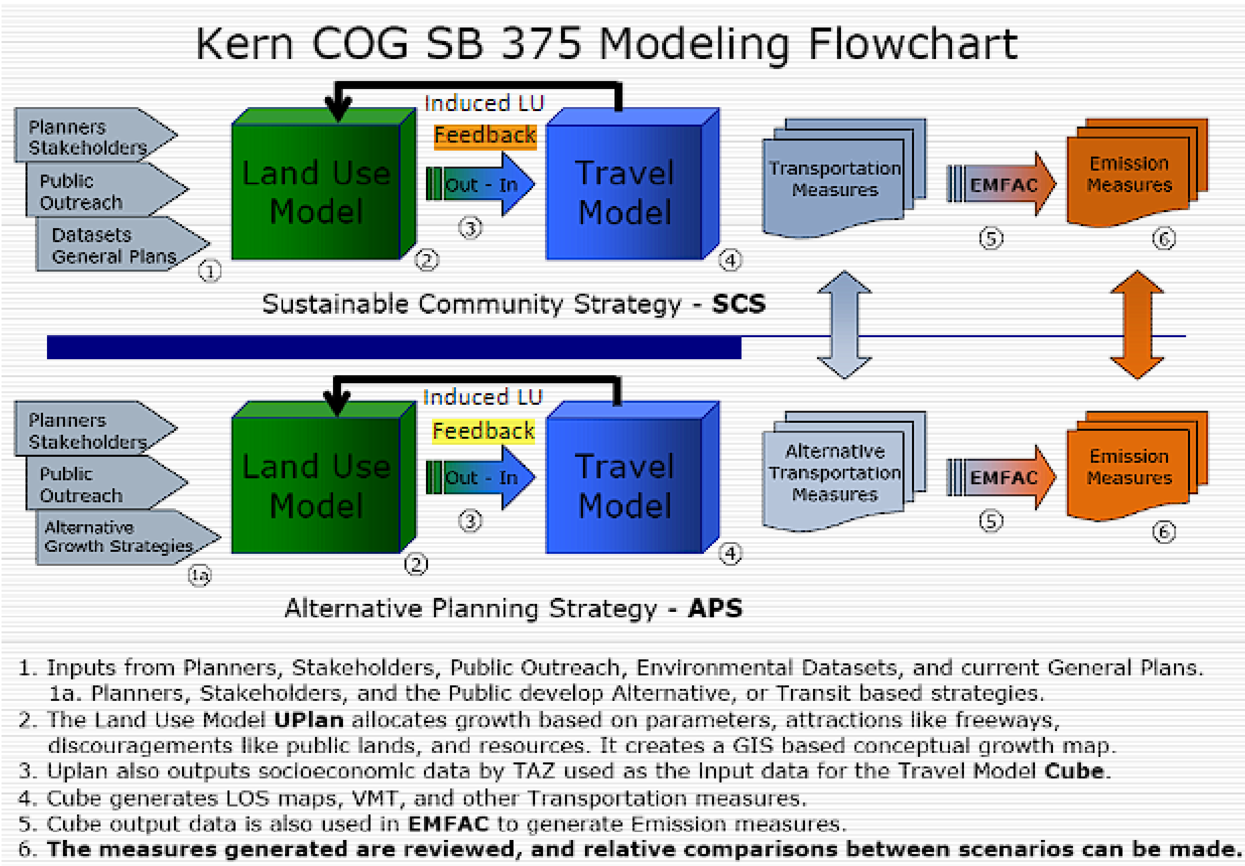
The documentation does not specifically mention induced VMT directly tied to highway expansions, though it does discuss induced development from infrastructure investments. The effects of land use strategies and transit investments on VMT are estimated using the travel demand model (in conjunction with the land use model); the effects of other strategies are estimated "off model" using methods outlined in the RTP/SCS.

Documents

2022 Regional Transportation Plan/Sustainable Communities Strategy. https://www.kerncog.org/wp-content/uploads/2022/12/2022_RTP.pdf

KCOG VMIP-2 Model Development Report. https://www.kerncog.org/wp-content/uploads/2017/11/VMIP-2-Model-Development-Report-KernCOG.pdf

Summary of updates to the Kern COG VMIP-3 travel demand model. https://www.kerncog.org/wp-content/uploads/2022/03/VMIP-3_Model_Updates.pdf



Kings County Association of Governments: MIP-1

KCAG released its most recent Regional Transportation Plan/Sustainable Communities Strategy in 2022. KCAG documents adjustments to their travel model in Chapter 13 and Appendix XV of the plan. The 2022 RTP/SCS was prepared by DKS Associates and can be accessed from KCAG's webpage for the 2022 Plan. KCAG produced a comprehensive technical overview of the MIP-1 Travel Model in 2008, which goes into much greater detail than any more recent documentation of the model. As of 2022, KCAG still uses the MIP-1 travel model, a trip-based, four-step model, as noted in Chapter 13 of the 2022 RTP (p. 40). As a result, most information regarding the model's functionality was sourced from the 2008 Model Update, written by Dowling Associates.

Travel Time Sensitivity and Feedbacks

The model accounts for travel time in the trip distribution and route assignment submodules but not the trip generation submodule; it does not have auto ownership or mode choice submodules. The model includes a feedback loop from the estimated congested travel times to trip distribution (see Figure 1: KCAG Travel Demand Process). The feedback loop is iterated using a method of successive averages until congested speeds and traffic volumes do not differ significantly between iterations (p. 27).

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	N/A	N/A	N/A	pp. 33-35	
Trip Generation	No	No	No	pp. 16-19	Daily person-trip rates for four trip purposes and by auto ownership category.
Trip Distribution	Yes	No	No	pp. 20-21	Gravity model. Uncongested speeds used in the initial run; congested speeds used in iterations.
Mode Choice	No	No	No	p. 22	Auto share assumed to be 100%. Person trips converted to vehicle trips based on average vehicle occupancy.
Route Assignment	Yes	No	No	pp. 23-24	

*KCAG 2008 Model Update: Model Documentation and Validation Report

Iterative Feedbacks

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	N/A	N/A	N/A	pp. 33-35	
Trip Generation	No	N/A	N/A	pp. 16-19	
Trip Distribution	Yes	Not specified	Yes	pp. 20-21	
Mode Choice	No	N/A	N/A	p. 22	
Route Assignment	Yes	20	Yes	pp. 23-24	

*KCAG 2008 Model Update: Model Documentation and Validation Report

Time Periods

In addition to daily travel demand, KCAG's model also estimates travel demand for a single hour in the AM peak period and again in the PM peak period (p. 5). The model documentation does not explain how trips are assigned to time periods and makes no mention of the trips being pushed from one period into another one due to congestion and its impact on travel times.

Land Use Scenarios

KCAG, in the "Scenario Development Process" section of the 2022 SCS, reports its intent to integrate both transportation and land use scenario planning, in accordance with SB 375 (p. 29). KCAG developed two land use scenarios, both independent of travel times and any assumptions regarding transportation network investment.

Induced VMT

Induced travel is discussed in the "Efficient and Equitable Development" Section of the 2022 SCS. Here, KCAG reports that its roadway expansion plans are meant to "provide necessary access to approved/planned residential parcels" rather than to alleviate existing traffic congestion (p. 25). KCAG asserts that their network currently has a "lack of congestion" and thus their road expansion plans will not meaningfully alter current travel times. Sensitivity analysis shows that mode splits are not greatly affected by assumptions about transportation investments.

Documents

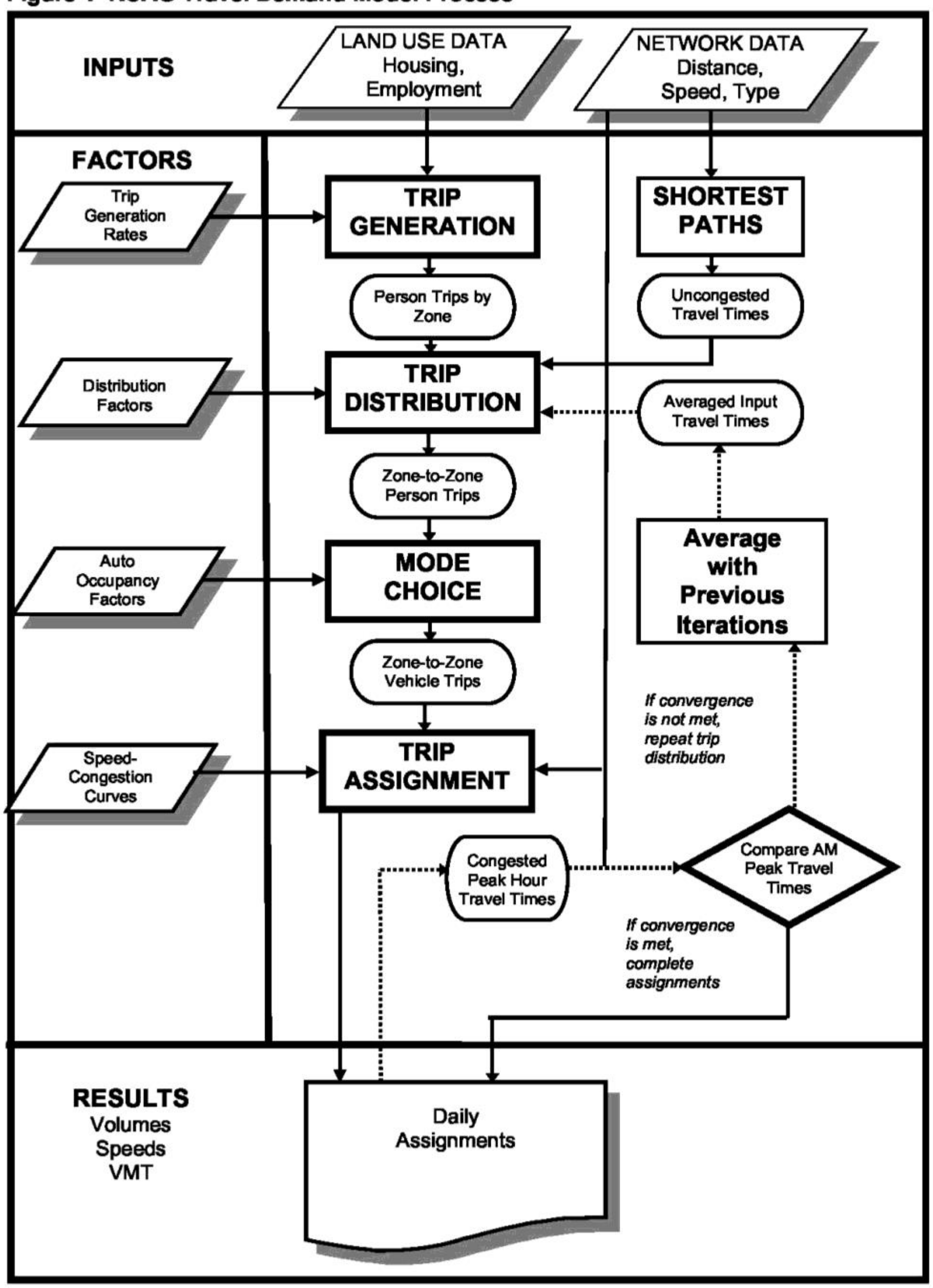
2022 Regional Transportation Plan (RTP) Adopted. https://www.kingscog.org/2022rtp_adopted

2022 RTP Chapter 13. https://www.kingscog.org/vertical/Sites/%7BC427AE30-9936-4733-B9D4-140709AD3BBF%7D/uploads/2022_KCAG_RTPSCS_Chapter_13.pdf

2022 RTP Appendix XV. https://www.kingscog.org/vertical/Sites/%7BC427AE30-9936-4733-B9D4-140709AD3BBF%7D/uploads/Appendix_XV_-_Modeling_Adjustments_and_Technical_Memo.pdf

Dowling Associates
Transportation Engineering • Planning • Research • Education

Figure 1 KCAG Travel Demand Model Process



Kings County Association of Governments 2008 Travel Demand Model Update **Page 4**

Merced Council of Governments (MCAG): Single-County Model v. 1.0

The Merced County Association of Governments (MCAG) is the Metropolitan Planning Organization for Merced County. MCAG released its most recent Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) in 2022. This plan had a time horizon of 24 years, forecasting as far as the year 2046. MCAG's travel demand model (TDM), referred to as the Single-County Model in supporting documentation, is a traditional four-step model. The model is described in the 2022 RTP Model Development Report released in April 2023 and a user guide released in August 2023. Both reports were prepared by Fehr & Peers and can be accessed from the "Transportation Modeling" page on MCAG's website.

Travel Time Sensitivity and Feedbacks

The auto ownership, trip distribution, and route assignment models are sensitive to travel time, but the trip generation model is not. The mode choice model is not explained in detail but appears to be based on fixed percentages of each mode depending on trip purpose and trip distance, with different assumptions for trips with and without transit access (measured at the zone level) at both trip ends.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	Yes	Yes	No	p. 21	
Trip Generation	No	No	No	pp. 23-27	Daily person trip rates by land use categories with percentages for five purposes.
Trip Distribution	Yes	Yes	No	p. 28	Gravity model
Mode Choice	No	No	No	p. 29	Model appears to assume fixed percentages by mode, depending on transit access.
Route Assignment	Yes	Yes	No	pp. 29-30	

* 2022 RTP Model Development Report.

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	No	N/A	N/A	p. 21	
Trip Generation	No	N/A	N/A	pp. 23-27	
Trip Distribution	No	N/A	N/A	p. 28	
Mode Choice	No	N/A	N/A	p. 29	
Route Assignment	Yes	Not specified	Yes	pp. 29-30	

* 2022 RTP Model Development Report.

Time Periods

The model estimates total daily travel for the average weekday. The model development report does not specify what periods of time are used for route assignment or the method by which trips are assigned to time periods. The report makes no mention of the trips being pushed from one period into another one due to congestion and its impact on travel times.

Land Use Scenarios

In the RTP/SCA, MCAG presents three scenarios, each assuming a different distribution of land uses and transportation network investments. The first is baseline scenario, in which past patterns of development and transit service levels are continued. The second scenario, “Conserve Merced County,” assumes greater infill development, particularly of multi-family homes as well as greater investment in bicycle and pedestrian improvements but not public transit service. The third scenario, “Conserve and Connect Merced County,” assumes even greater-density development, combined with expansions to the county’s bus and microtransit network. This is considered the “Preferred Scenario” by the MPO’s board. The three scenarios appear to assume the same investments in highways, streets, and roads.

Induced VMT

MCAG’s development report closes with a discussion of induced travel, or increases in vehicle miles traveled (VMT) that result from an increase in lane-miles for the regional road network. Induced travel was estimated under four possible scenarios. Two scenarios were “no-build scenarios” in which the RTP’s proposed projects are not built. A comparison of the “build” and “no-build” scenarios with no change to socioeconomic characteristics was used to estimate a short-term induced VMT elasticity, as shown in Table 13 of the model development report. According to the RTP/SCS, roadway projects in the plan “emphasize congestion relief, connections to accommodate growth, and support for alternative transportation, transit, and rail access” (pg. 96).

Documents

2022 Regional Transportation Plan. https://www.mcagov.org/364/2022-RTP

Transportation Modeling webpage. https://www.mcagov.org/386/Transportation-Modeling

MCAG 2022 RTP Travel Demand Model: Single-County Model Version 1.0 Development Report. https://www.mcagov.org/DocumentCenter/View/4172/MCAG-Single-County-Model-v1-Development-Report?bidId=

Table 13: Short-Term Induced Vehicle Travel Elasticity Check

	Unconstrained	Constrained	Change
Lane Miles	2,814	2,958	5.12%
Total VMT	7,828,430	7,840,109	0.15%
Model VMT Change	11,679		
Literature VMT Change [1]	3,356 to 20,135		

Note:

1. The change in VMT is based on CARB research for short-term elasticity ranging from 0.1 to 0.6.

Source: Fehr & Peers, 2023.

Madera County Transportation Commission (MCTC): Madera County Travel Model (MIP)

The Madera County Transportation Commission (MCTC) released its most recent Regional Transportation Plan in 2022, with a time horizon to 2046. In anticipation of this RTP, MCTC initiated a project to update their regional travel demand model in 2019. The revisions made to the TDM are detailed in a report released in September 2020. This report was prepared by Elite Transportation Group, Inc., and is available from the MCTC website as an appendix to the 2022 RTP.

Travel Time Sensitivity and Feedbacks

The trip distribution, mode choice, and route assignment submodules are sensitive to travel time, by the trip generation submodule is not. The model includes a feedback loop in which the estimated congested travel times are fed back into the trip distribution and mode choice submodules. The model does not use convergence criteria but rather uses one feedback loop, meaning that the model is run once with free-flow times and once with congested times.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	Yes	Yes	Yes	p. 11	
Trip Generation	No	No	Yes	pp. 41-46	Daily person trip rates by land use category for 11 trip purposes; 75 categories of households.
Trip Distribution	Yes	Yes	No	pp. 47-50	Gravity model by trip purpose, using logsum from mode choice model.
Mode Choice	Yes	Yes	No	pp. 50-53	Multinomial logit model with seven modes for 8 trip purposes, 3 household categories, and 2 time periods.
Route Assignment	Yes	Yes	No	pp. 55-56	Equilibrium assignment.

*Madera County Travel Demand Model: 2019 Model Update

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	No	N/A	N/A	pp. 33-35	
Trip Generation	No	N/A	N/A	pp. 24-32	
Trip Distribution	Yes	2 iterations	Not guaranteed	pp. 56-57	
Mode Choice	Yes	2 iterations	Not guaranteed	pp. 56-57	
Route Assignment	Yes	50 on-peak, 20 off-peak	Yes	pp. 55-56	

* Madera County Travel Demand Model: 2019 Model Update

Time Periods

After the mode choice model and before the traffic assignment model, vehicle trips are classified and aggregated for six time periods over a typical weekday (AM and PM peak hours, AM and PM peak periods, midday period, night period) assuming fixed percentages depending on trip purpose. The report makes no mention of the trips being pushed from one period into another one due to congestion and its resulting impact on travel times.

Land Use

MCTC used UPlan, a land use allocation tool, to develop three scenarios for the 2022 RTP/SCS based on extensive public input. The scenarios differ with respect to their assumptions about land use density and about investments in low-emission forms of transportation. It is not clear whether assumptions about highway investments differ in the three scenarios. The modeling of the three scenarios shows that the preferred scenario, which focuses on infill development and low-emissions travel, produces a somewhat greater reduction in VMT than the more conservative scenarios.

Induced Travel

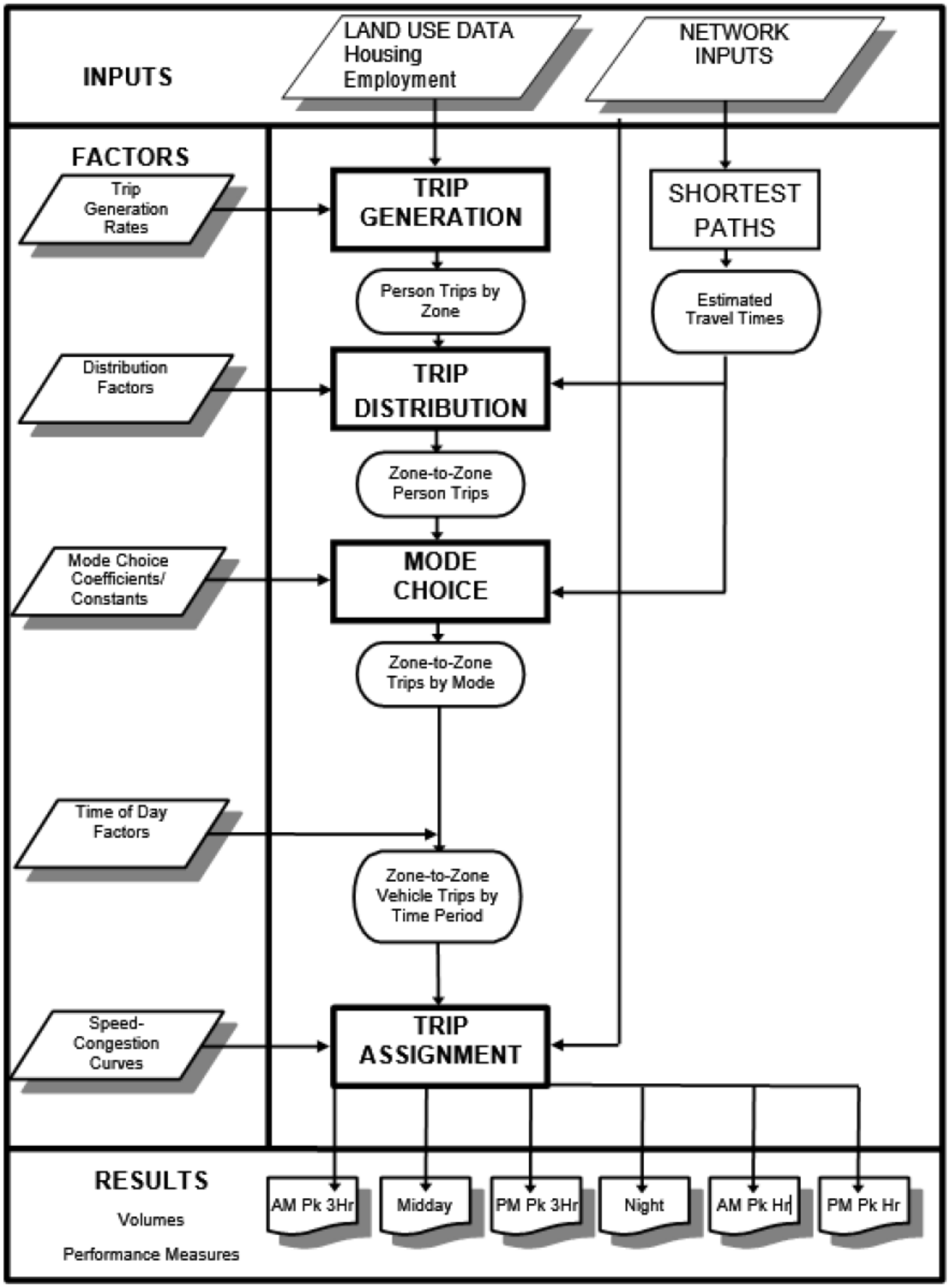
The analysis of induced travel in the RTP/SCS employs the California Induced Travel Calculator to estimate the increase in VMT attributable to proposed roadway capacity expansion. The county has no Class 1 facilities and so employs an elasticity of 0.75, noting that “the elasticity in Madera would not necessarily be this high based on the rural, low population and congestion nature of much of the region” (p. 3-12).

Documents

Madera County 2022 Regional Transportation Plan and Sustainable Communities Strategy. https://www.maderactc.org/transportation/page/your-madera-2046-rtpscs

Madera County Travel Demand Model: 2019 Model Update. https://www.maderactc.org/sites/default/files/fileattachments/transportation/page/5641/appendix_f_-_model_documentation_r.pdf

Figure 2: Travel Model Process



Metropolitan Transportation Commission: Travel Model 1.5

The Metropolitan Transportation Commission (MTC) and its sister agency the Association of Bay Area Governments (ABAG) adopted its latest regional transportation plan, *Plan Bay Area 2050*, in 2021. MTC uses an integrated transportation-land use model in developing the plan and analyzing its performance. Land use is modeling using Bay Area UrbanSim 2 (BAUS2), a custom variant of the UrbanSim model. The travel demand forecasting model, Travel Model 2.5, is an activity-based model. In the integrated modeling framework, outputs from the Travel Model are fed back into the Land Use Model, and, in the latest version of the framework, the outputs from the Land Use Model are also fed back into the regional growth forecasting process (see Figure 1. Integrated model flow Plan Bay Area 2040 vs. Plan Bay Area 2050).

The Forecasting and Modeling Report, published in October 2021, describes the Travel Model and provides an overview of the modeling process; more detail is provided in various documents on a github site. Travel Model 2.5 simulates person-level travel behavior for a typical weekday. It is considered a “partial agent-based simulation” in that it does not include the simulation of the behavior of individual vehicles on the roadway network (p. 65). The program PopulationSim is used to create a synthetic population for the region. The model then simulates a sequence of choices: usual workplace and school location, household auto ownership, daily activity pattern, tour frequency and scheduling, tour travel mode, stop frequency and location, trip travel mode, and route assignment (see Model Schematic).

The model report provides a detailed explanation of how each strategy in the plan is represented in the modeling framework (pp. 99-100) or addressed through “off-model” calculations (pp. 101-122). The model includes a ride-hailing as a mode and includes submodel that accounts for occupancy and dead-heading (pp. 82-87). The model also has features that can incorporate different levels of autonomous vehicle market penetration (p.88). Telecommuting is represented through a dampening of tour generation in the Coordinated Daily Activity Pattern submodel based on percentages derived from available data on working at home (pp. 89-90); the assumed percentages were updated to reflect post-Covid patterns in 2024.

Travel Time Sensitivity and Feedbacks

The modeling report provides a general outline of Travel Model 2.5 as well as detail about inputs to the model and improvements to the model over previous versions of the model. Detailed explanations of the submodels are not provided in the report or in other readily available documents. The model appears to be similar to the SANDAG model, in which case the key components of the resident travel model (auto ownership, trip frequencies, destination choices, mode choices) are sensitive to travel times through the inclusion of accessibility measures and/or mode choice logsums that reflect travel times. The model schematic does not show a feedback loop from estimated congested times back to the beginning of the model, though such loops are typical in activity-based models.

Sensitivity of Submodels

Submodule	Sensitivity of Submodels			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	Yes?	Yes?	Yes?		Details not available.
Trip Frequency	Yes?	Yes?	Yes?		
Destinations	Yes?	Yes?	Yes?		
Mode Choice	Yes?	Yes?	Yes?		
Route Assignment	Yes?	No?	No?		

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	Yes	Not specified	Not specified		Details not available.
Trip Frequency	Yes				
Destinations	Yes				
Mode Choice	Yes				
Route Assignment	Yes	Not specified	Not specified		Details not available.

Time Periods

Travel Model 2.5 simulates person-level travel behavior for a typical weekday. The scheduling components of the tour models determine the departure time for the start of the tour. The modeling report does not discuss the temporal scale of the simulation or the aggregation of trips into time periods for route assignment. The inclusion of scheduling submodels coupled with a feedback look for congested travel times should ensure that, in the model, trips will shift timing depending on congestion levels.

Land Use Scenarios

Land use scenarios are developed using the Bay Area UrbanSim 2 (BAUS2) model. This model allocates the forecasted growth in population and employment to locations around the region based on land use strategies as well as transportation investments (p. 3). The estimated congested zone-to-zone travel times from the Travel Model are an input to BAUS2. Transportation network and land use scenario within a plan scenario should be consistent. Two scenarios analyzed, "No Project" (expected trajectory of region without the plan), and "Plan." Based on priority development areas, priority production areas, transit-rich areas, transit-rich and high-resource areas, and high-resource area with basic bus service.

Induced VMT

Although the plan does not used the term "induced" VMT, the agency does consider the phenomenon in developing its strategies. One of the plan's main transportation strategies is to "maintain and optimize the existing system" (p. 61). Near-term priorities include addressing highway bottlenecks and improving interchanges "through a limited selection of widenings or road extensions to serve new developments" (p. 62). The plan notes, "These projects may help reduce congestion temporarily, though they will likely increase vehicle miles traveled in the long term, with congestion relief benefits disappearing by the year 2050." As solutions to congestion in the long-term, the plan includes road pricing, transit-supportive land use, and transit improvements. Planned investments include some new general-purpose lanes and carpool lanes but mostly an expansion of the express lane network, include conversions of existing lanes to tolled express lanes (see Map 4-1 on p. 63). The plan proposes "implementing per-mile tolling on select congested freeways where parallel transit options exist" (p. 64).

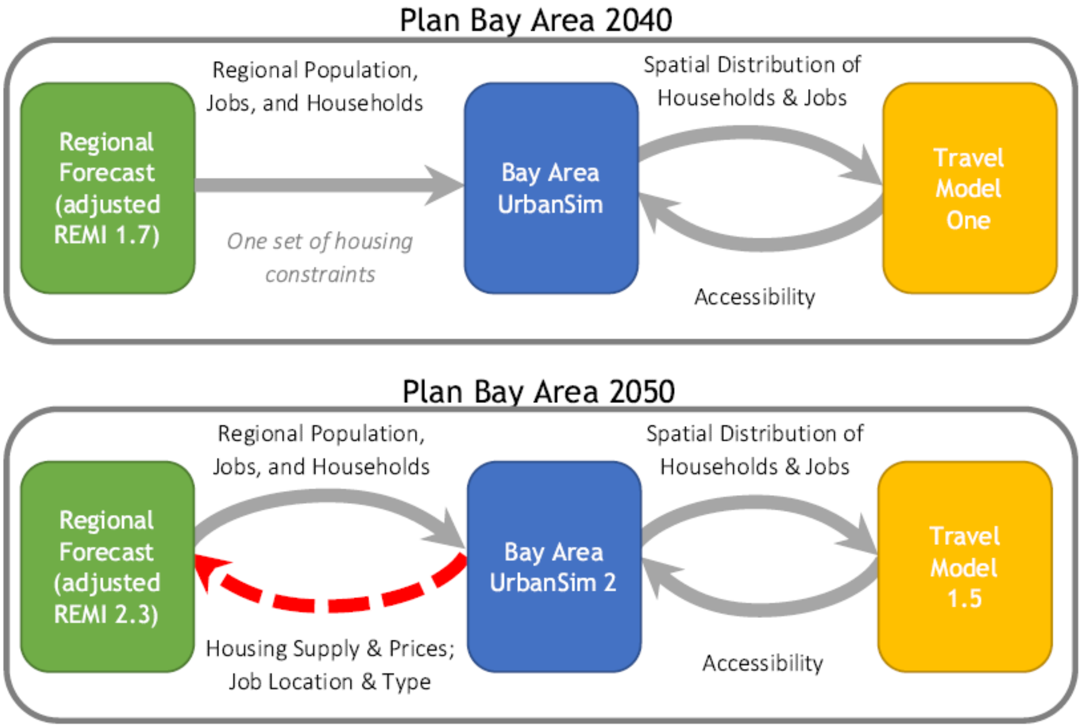
Documents

Plan Bay Area 2050: A Vision for the Future
https://mtc.ca.gov/sites/default/files/documents/2021-11/Plan_Bay_Area_2050_October_2021.pdf

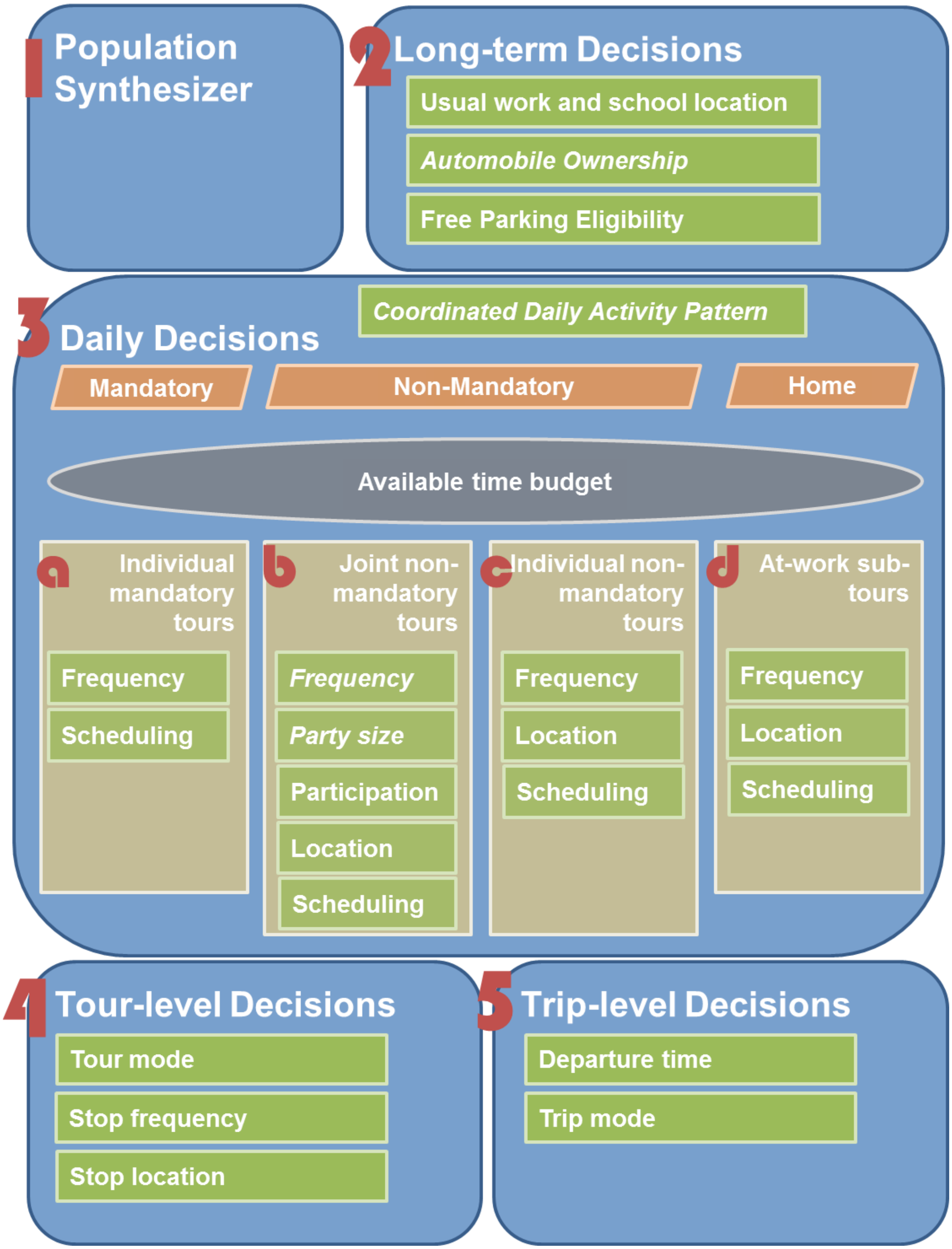
Plan Bay Area 2050 Forecasting and Modeling Report
https://planbayarea.org/sites/default/files/documents/Plan_Bay_Area_2050_Forecasting_Modeling_Report_October_2021.pdf

Travel Model github https://github.com/BayAreaMetro/modeling-website/wiki/TravelModel

Figure 1. Integrated model flow Plan Bay Area 2040 vs. Plan Bay Area 2050



Model Schematic (https://github.com/BayAreaMetro/modeling-website/wiki/ModelSchematic)



Sacramento Area Council of Governments: SACSIM19

The Sacramento Area Council of Governments (SACOG) adopted its latest regional transportation plan, called the Metropolitan Transportation Plan/Sustainable Communities Strategy (MTP/SCS) in 2020. The agency uses the activity-based model SACSIM19 to develop and evaluate its plan. The model is documented in the User Guide and Model Documentation for SacSim19, published in 2020. The document was written by SACOG staff based on material prepared by consultants who contributed to model development. SACSIM19 reflects several refinements to the previous model, SACSIM15. SACSIM19 is the third version of the SACSIM model.

SACSIM19 simulates individual travel patterns for a typical weekday as a series of "trip-legs" over a 24-hour period. At the core of the model, DAYSIM uses parcel-level land use data and synthesized population characteristics to simulate all travel by residents of the region. It uses a set of long-term choice models as well as short-term choice models to produce estimates of person trips (see Figure 3-3 DAYSIM Structure and Flow). The long-term choices are: household automobile availability, usual work location for each worker, usual school location for each student. The short-term choices are: number and type of tours made by each person, main destination of each tour, main mode of travel for each tour, arrival and departure times for each activity on each tour, number and purpose of intermediate stops made on each tour, location of each intermediate stop, mode of travel for each trip segment on each tour, and arrival and departure time for each intermediate activity. The models within DAYSIM are organized hierarchically, with the outputs of long-term choice models feeding into short-term choice models, as shown in the diagram. The person trips are combined with estimates of commercial vehicle trips and trips originating outside of the county and then assigned to the transportation network (see Figure 2-1 SACSIM Model System).

Travel Time Sensitivity and Feedbacks

In DAYSIM, auto ownership, trip generation, destination choice, and mode choice are all sensitive to travel times and travel costs through the inclusion of logsum variables from the path choice models, in which utility is based on travel times and costs. SACSIM uses free-flow travel times in the initial model run but then feeds estimated congested times back into the model for a sufficient number of iterations as determined by the process described in model documentation (pp. 10-1 to 10-3). The version of DAYSIM used in SACSIM19 includes a transit pass ownership model (pg. 3-13). This model is not sensitive to travel times.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	Yes	Yes	Yes	pp. 3-8 to 3-10, 3-19	In DAYSIM through logsum variables from path choice model
Trip Frequency	Yes	Yes	Yes	pp. 3-8 to 3-10, 3-16	In DAYSIM based on tours and stops, for 8 tour purposes; through logsum variables from path choice model
Destinations	Yes	Yes	Yes	pp. 3-8 to 3-10, 3-16	In DAYSIM for main destination and each intermediate stop; through logsum variables from path choice model
Mode Choice	Yes	Yes	Yes	pp. 3-8 to 3-10, 3-15	In DAYSIM for each tour segment; through logsum variables from path choice model
Route Assignment	Yes	No	Yes	pp. 3-51 to	Equilibrium assignment, with multiple routing classifications based on value-of-time, vehicle type, and vehicle occupancy

* User Guide and Model Documentation for SacSim19

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	Yes	Not specified	Not specified	pp. 10-1 to 10-3	Method of convex combinations; documentation does not specify the number of iterations.
Trip Frequency	Yes				
Destinations	Yes				
Mode Choice	Yes				
Route Assignment	Yes	300		p. 3-52	Up to 300 iterations

* User Guide and Model Documentation for SacSim19

Time Periods

The timing of trips is estimated using the time-of-day model. This model is sensitive to travel times through the inclusion of the logsum variable from the path-type models, in which utility is based on time and cost (p. 3-13). In this way, trips will shift timing depending on congestion levels. For route assignment, person trips are aggregated into zone-to-zone flows and segmented into nine time periods.

Land Use Scenarios

In the 2020 MTP/SCS, SACOG defines five community types: center and corridor communities, established communities, developing communities, rural residential communities, and lands not identified for development. The agency used an iterative process to develop three scenarios differentiated by the allocation of projected growth into these community types. Infrastructure availability is one of the considerations in this process, and transportation investments in each scenario are adjusted to match the land use allocations. These scenarios are translated into estimates of dwelling units at a parcel level as inputs to SACSIM. Based on these land use estimates, the PopGen model, maintained and hosted by the Mobility Analysis Research Group, generates synthetic populations as inputs to SACSIM. Levels of congestion as estimated by SACSIM are not formally used to adjust the land use scenarios or transportation investments, though the model analysis for the scenarios in the previous MTP/SCS provided a starting point for the development of land use scenarios for the 2020 MTP/SCS (Appendix D, p. 9).

Induced Travel

According to Appendix E, the 2020 MTP/SCS “includes policies focused on limiting the potential impact of indued travel” (p. 59). The transportation investments listed in the plan are intended to implement Policy 18 of the plan: “system expansion investments that are not directly paid for by new development should be focused on fixing major bottlenecks that exist today, and/or incentivize development opportunities in infill areas” (p. 59).

Of the $35 billion in transportation investments in the plan, $6.8 billion is slated for road and highway expansion projects, with 2/3 of this amount for existing rather than new streets and roads. A total of $12 billion in highway and roadway expansion projects were “nominated” for the plan. As one input to the decision-making process, the nominated projects were screened based on evidence of significant congestion, consistency of the proposed increase in capacity to the expected growth in that area, and whether the roadway would be well utilized in peak periods in the planning horizon year.

The ability of SACSIM to capture short-term induced travel effects was assesses through simple sensitivity tests in which roadway capacity was added (or removed) from the base model, holding land use patterns constant. The tests produced estimated elasticities (the ratio of the percentage increase in VMT over the percentage increase in capacity) of 0.06 to 0.16. The Appendix discusses strengths and limitations of using travel demand forecasting models to estimate induced travel elasticities in comparison to historical (or empirical) research and presents an approach to comparing the two approaches. This analysis produces a long-run elasticities from 0.21 to 0.47. The Appendix concludes, “The SACSIM19 forecasts fall in the middle of the range of expected changes based on the elasticity calculations" (pg. 62). This analysis was conduced before the availability of the California Induced Travel Calculator.

Documents

User Guide and Model Documentation for SacSim19
https://www.sacog.org/home/showpublisheddocument/1452/638336759814030000

MTP/SCS https://www.sacog.org/planning/blueprint/2020-mtp-scs

MTP/SCS Appendix D
https://www.sacog.org/home/showpublisheddocument/40/638212803209100000

MTP/SCS Appendix E
https://www.sacog.org/home/showpublisheddocument/42/638212803212370000

Figure 3-3 DAYSIM Structure and Flow

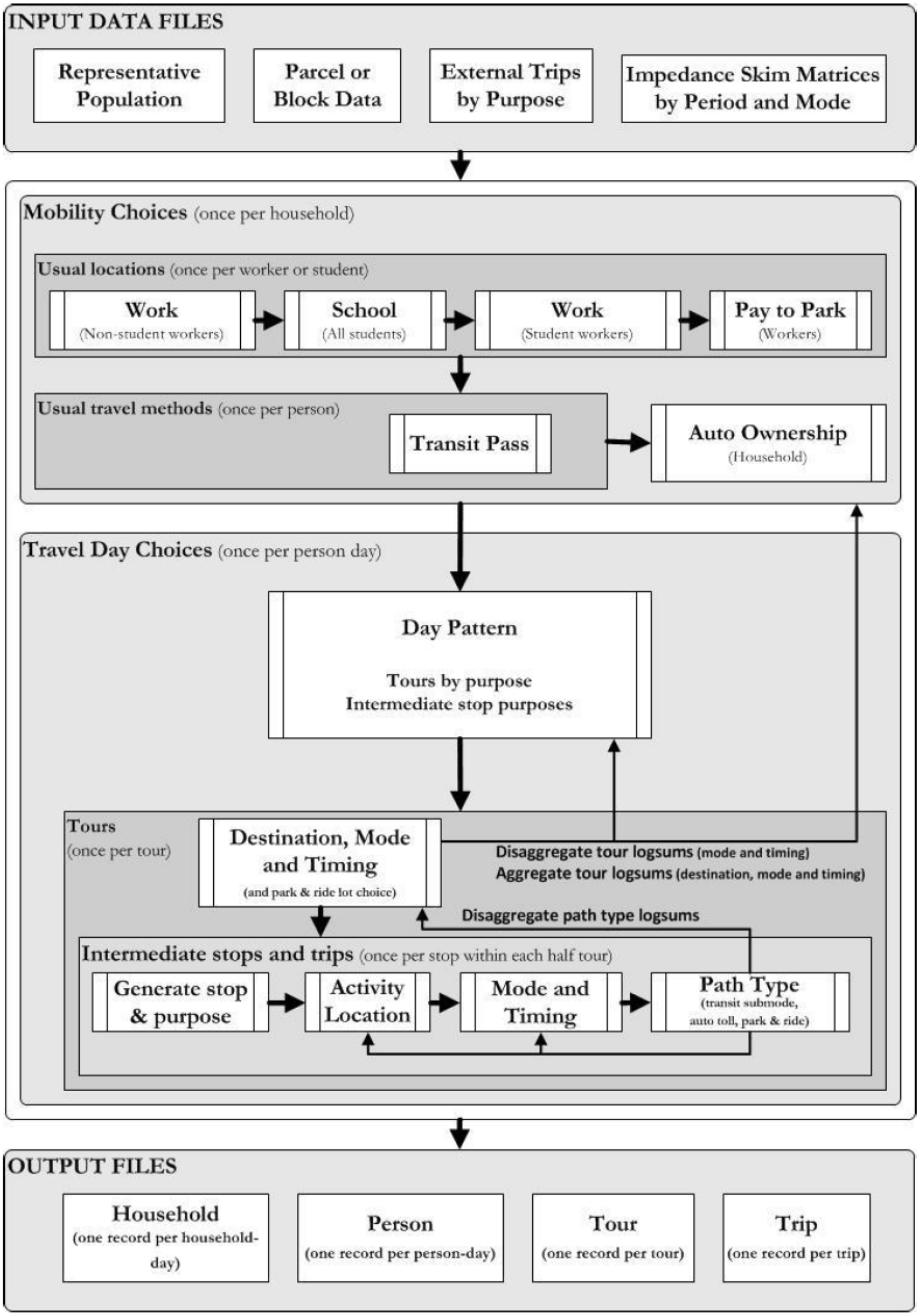


Figure 2-1 SACSIM Model System

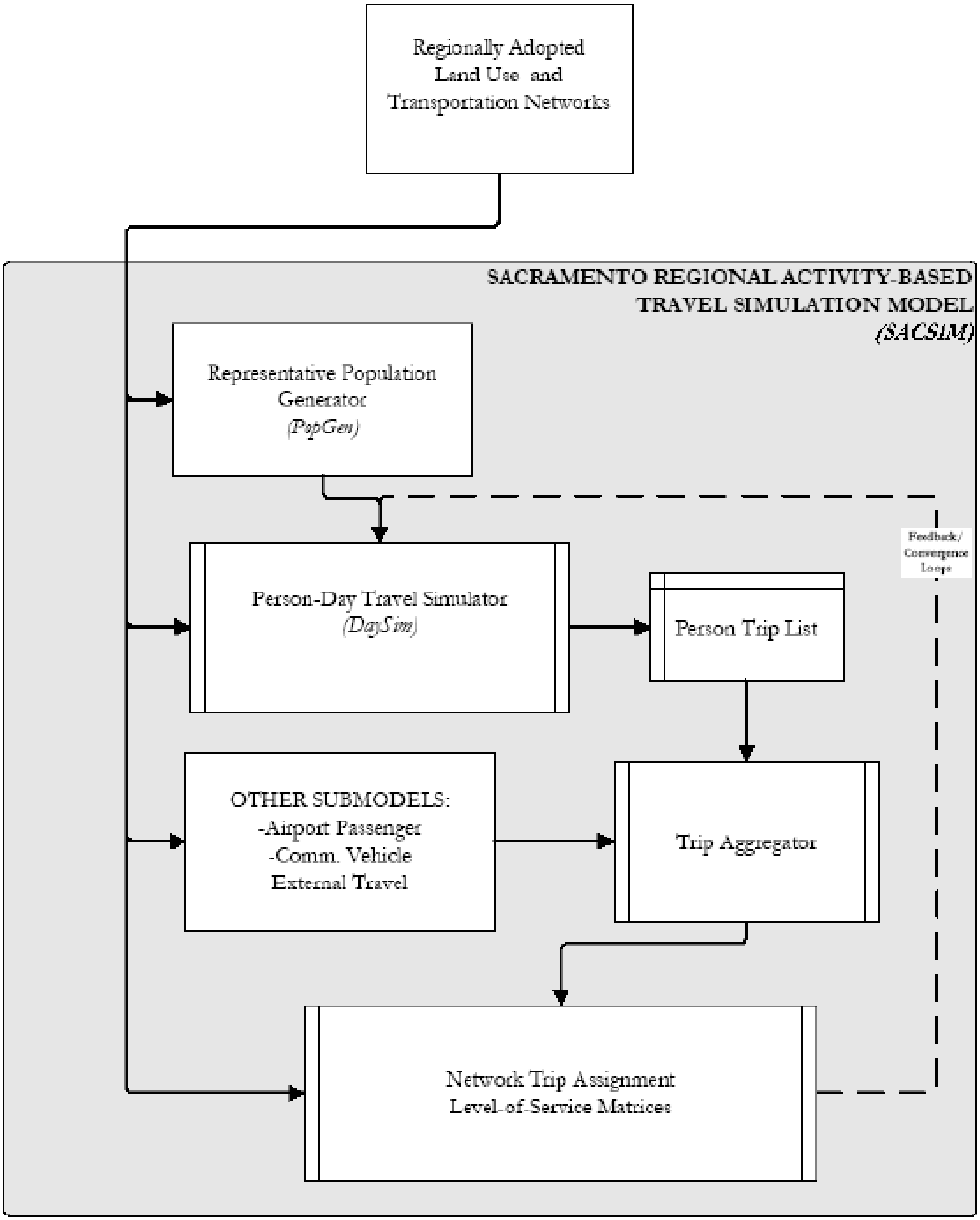
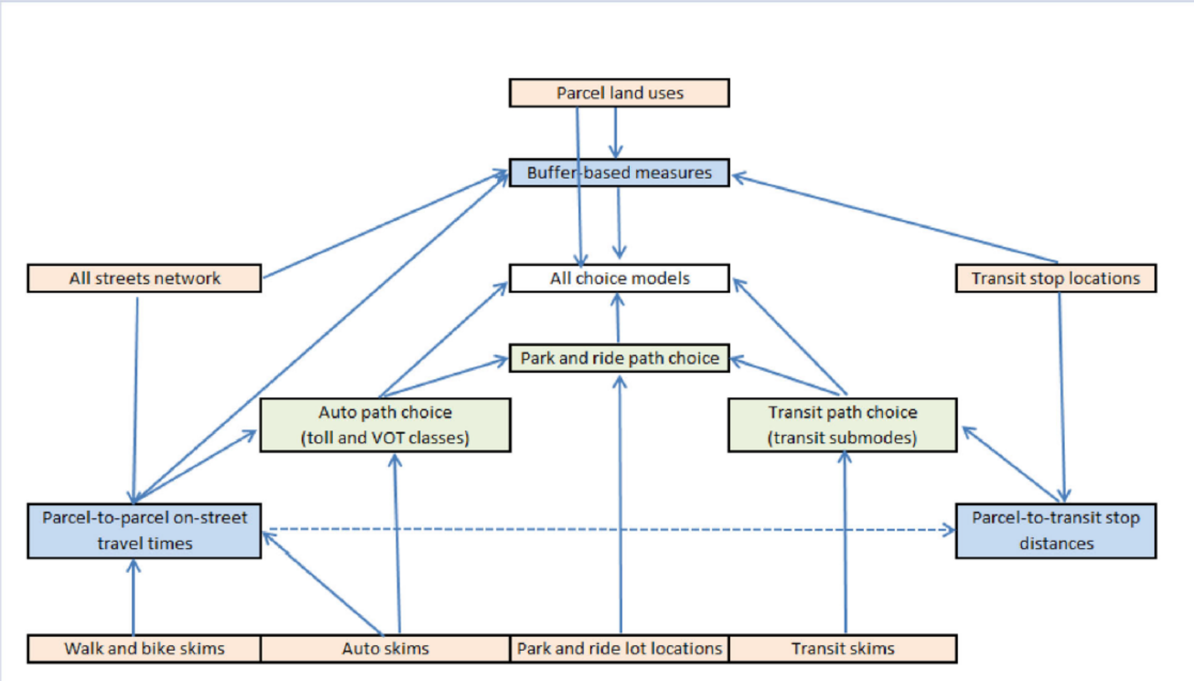


Figure 3-6 Schematic of the use of path choice models to support other DAYSIM choice models



Source: SACOG 2020.

San Diego Association of Governments (SANDAG): ABM2+

The San Diego Association of Governments (SANDAG) adopted its latest regional transportation plan in 2021. In developing the *San Diego Forward: The 2021 Regional Plan*, the agency used the ABM2+ activity-based model. Documentation on the model is provided in Appendix S of the 2021 Regional Plan and through a github wiki page. The agency has recently released ABM version 14.3.0, and ABM3 is currently in development. The model is regularly reviewed by the ABM Technical Advisory Committee, “a panel of national experts in the travel demand forecasting field” (p. S-1).

ABM2+ simulates individual travel patterns across 24-hours for a typical weekday. The model uses Master Geographic Reference Areas (23,002 across the county), roughly equivalent to census blocks, for the simulation of residential travel, but larger-scale traffic analysis zones (4,996 cross the county) for traffic assignment and the estimation of zone-to-zone roadway travel times. The resident travel submodel is based on the Coordinated Travel Regional Activity-Based Modeling Platform (CT-RAMP), a family of ABMs. Inputs to the model include a population synthesis and estimates of accessibility (based on destination-choice logsums). The model then simulates a sequence of travel-related decisions (Figure S.4). The model starts with long-term decisions about car ownership, working from home, and work/school location. A second tier of decisions includes car ownership, toll transponder ownership, free parking eligibility, and telework frequency. Daily activity patterns and tours are then simulated for mandatory and non-mandatory activities, including frequency, destination, and mode. Stop-level models determine stop frequency, purpose, location, and departure time, while trip-level models determine trip mode, auto parking, and assignment. The model accounts for intra-household interactions.

Travel Time Sensitivity and Feedbacks

The key components of the resident travel model (auto ownership, trip frequencies, destination choices, mode choices) are sensitive to travel times through the inclusion of accessibility measures. The accessibility measures are calculated for MAGRAs based on travel cost and an “attraction size variable” such as employment. The model employs a series of different accessibility measures that differ with respect to the cost component and the attraction size variable (see Table S-5 in Appendix S). Depending on the model, travel cost is defined as peak or off-peak travel time, or as the mode choice logsums, which reflect travel time as well as travel cost. The attraction size variable may be defined as total employment or certain types of employment.

The model includes a feedback loop in which estimated congested travel times are fed back into the resident travel model. The documentation does not describe the number of iterations or the criteria by which convergence is assessed.

Sensitivity of Submodels

Submodule	Sensitivity of Submodels			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	Yes	Yes	Yes	pp. S-27, S-30	Nested logit with 5 categories
Trip Frequency	Yes	Yes	Yes	pp. S-28, S-32 to S-33	Activity pattern model followed by tour frequency model; through logsums, for 10 activity types
Destinations	Yes	Yes	Yes	pp. S-29, S-56 to S-57,	Discrete choice model using tour mode choice logsums
Mode Choice	Yes	Yes	Yes	pp. S-43 to S-49	Tour mode choice model (9 modes) followed by trip mode choice model (14 modes)
Route Assignment	Yes	Yes	Yes	p. S-92	Equilibrium assignment; uses generalized cost and three value-of-time bins

*2021 Regional Plan Appendix S

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	Yes	Not specified	Not specified	Figure S.1	Documentation does not describe number of iterations or convergence criteria
Trip Frequency	Yes				
Destinations	Yes				
Mode Choice	Yes				
Route Assignment	Yes	No	Yes		Criterion is $5x10^{-4}$

* 2021 Regional Plan Appendix S

Time Periods

The simulation portion of the model runs at 30-minute intervals for 24-hours (starting at 3am and ending at 3am the next day). Time of day choice models for each trip purpose determine the 30-minute departure period for each trip (pp. S-43 to S-44). The time-of-day model includes the mode choice logsum, which reflects travel times and costs. In this way, the model "considers congestion and pricing effects on travel time-of-day and peak spreading of traffic volume" (p. S-15). After the mode choice model, trip tables are combined and summed by time of day, vehicle class, value of time (p. S-4) into five aggregate time periods (early am, am, midday, pm, and evening). Route assignment is estimated for the five time periods.

Land Use Scenarios

Appendix F of the 2021 Regional Plan describes the development of the land use scenarios for the SCS. The preferred scenario reflects continued concentration of housing and jobs within the urbanized areas of the region in either "Mobility Hubs" or "Smart Growth Opportunity Areas" (p. F-8). Coordination with transportation plans? Appendix T discusses the technical and consultative processes involved in the development of the slate of transportation investments for the plan. Rather than prioritizing projects by mode, the agency developed "multimodal bundles" of projects for different areas of the county, taking travel patterns into consideration and focusing on the need to connect key origins and destinations (p. T-8). A "visual analysis" was used to assess the alignment of the bundles with travel patterns in that area. Evaluation criteria for the bundles were closely tied to the goals outlined in the 2021 Regional Plan. The bundles were incorporated into the region-wide "build" network. A "corridor capacity analysis" was used to assess whether the proposed additions to the freeway network (in the form of managed lanes) along with major investments in transit services would be sufficient to meet future demand in the corridor (Appendix T, Attachment 1, p. 17). ABM2+ was used in evaluating the proposed investments according to the agencies criteria, including the impact on VMT and GHG emissions. It appears that the analysis for the proposed network used different land use scenarios for the "build" and "no-build" transportation scenarios (Appendix S, p. S-106) though no explanation of the DS-ID 38 and DS-ID 39 land use "versions" are provided.

Induced Travel

The plan includes expansion of the network of managed lanes in the region. It emphasizes the use of technology to dynamically manage the flow of traffic as one strategy for ensuring "the efficient movement of people and goods" and to "make traffic smoother, prioritize non-solo driving, and create a safer environment for everyone" (p. 13). Neither the 2021 Regional Plan or the model documentation in Appendix S discuss the potential for highway capacity expansion to induce VMT.

Documents

2021 Regional Plan https://www.sandag.org/-/media/SANDAG/Documents/PDF/regional-plan/2021-regional-plan/final-2021-regional-plan/2021-regional-plan-chapter-2-2021-12-01.pdf

2021 Regional Plan Appendix F https://www.sandag.org/-/media/SANDAG/Documents/PDF/regional-plan/2021-regional-plan/final-2021-regional-plan/2021-regional-plan-appendix-f-2021-12-01.pdf

2021 Regional Plan Appendix S https://www.sandag.org/-/media/SANDAG/Documents/PDF/regional-plan/2021-regional-plan/final-2021-regional-plan/2021-regional-plan-appendix-s-2021-05-01.pdf

2021 Regional Plan Appendix T https://www.sandag.org/-/media/SANDAG/Documents/PDF/regional-plan/2021-regional-plan/final-2021-regional-plan/2021-regional-plan-appendix-t-2021-05-01.pdf

SANDAG Activity-Based Travel Demand Model https://github.com/SANDAG/ABM/wiki

ABM2+ Traffic Assignment https://github.com/SANDAG/ABM/wiki/files/traffic_assignment.pdf

Figure S.1: SANDAG ABM2+ Flow Chart

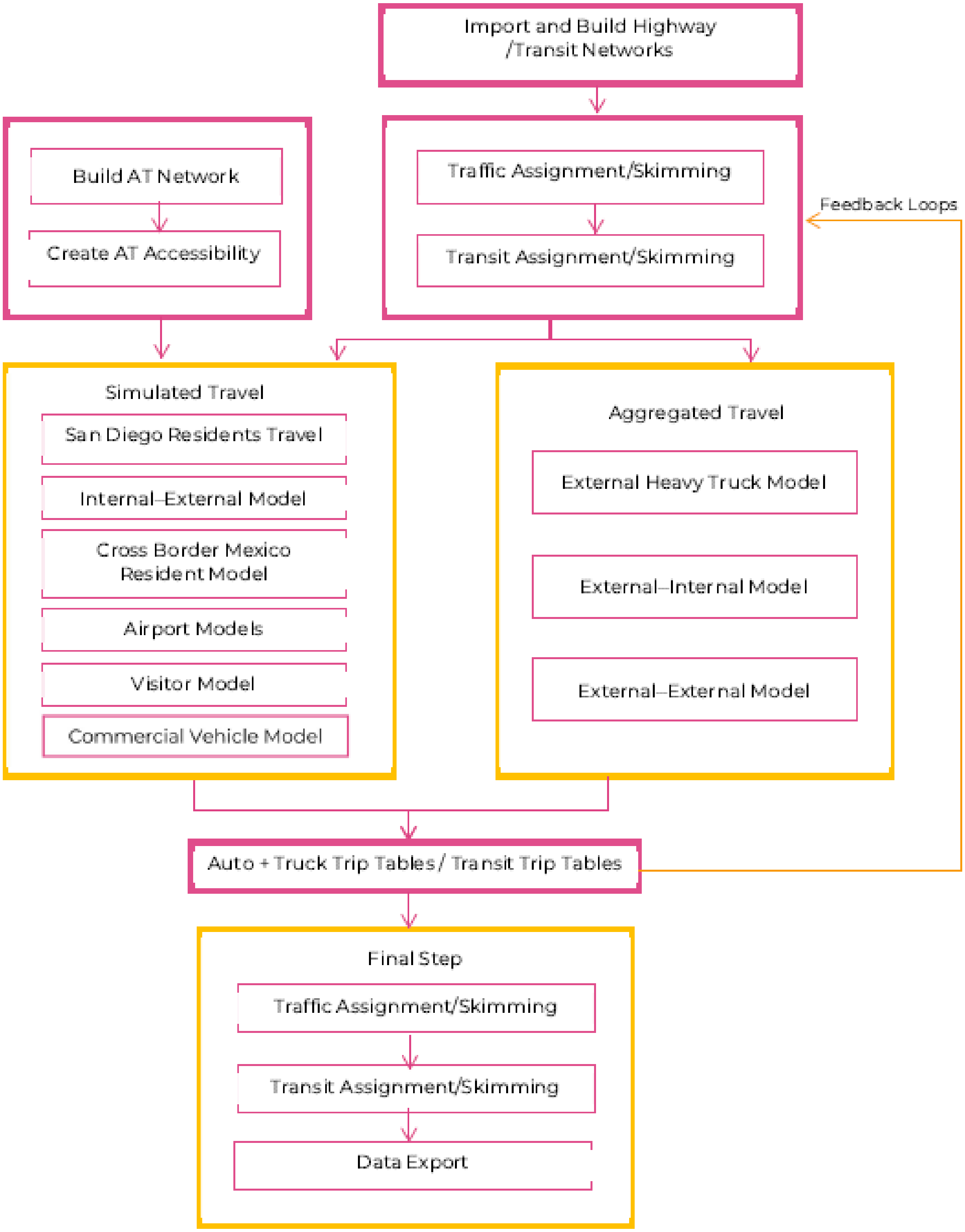
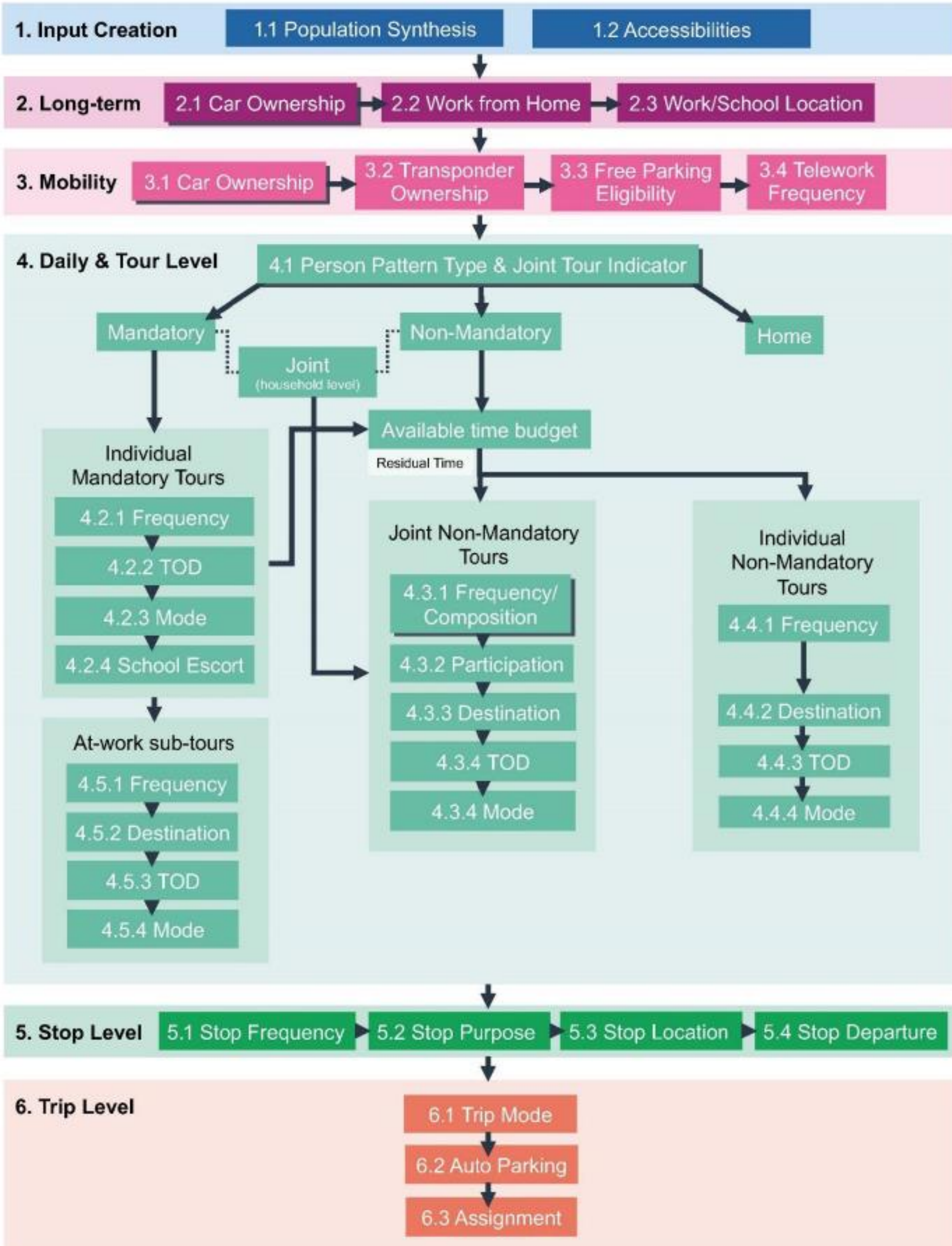


Figure S.4: Resident Travel Model Design and Linkage Between Sub-Models



San Joaquin Council of Governments (SJCOG): VMIP-2

SJCOG is a part of the San Joaquin Valley Modeling Improvement Project (VMP), a collaboration among eight MPOs in the San Joaquin Valley that began in 2010 with the aim of improving travel demand forecasting models. SJCOG's latest Regional Transportation Plan/Sustainable Community Strategies (RTP/SCS), adopted in 2022, used the updated 1-county version of VMIP2 to forecast travel demand outcomes to 2046 (i.e., 25 years from 2020 as a baseline year). An overview of the model is provided in Appendix X of the 2022 RTP/SCS.

Travel Time Sensitivity and Feedbacks

The trip distribution and mode choice submodules are sensitive to travel times but the auto ownership and trip generation submodules are not. Figure 2 in Appendix X depicts a feedback loop in which estimated travel times are fed back into the auto ownership submodule, but it appears that this submodule and the trip generation submodule do not incorporate travel time. According to Appendix X, "The feedback mechanism inputs congested travel times into the model, which helps to account for travelers who change their travel route and mode in response to congestion" (pg. 11), suggesting that the feedback is to at least the mode choice and trip assignment submodules. The number of iterations or criteria for convergence are not discussed.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	Yes	Yes	p. 10	Based on auto operating cost and accessibility.
Trip Generation	No	No	Yes	p. 11	Daily person-based trip rates by income, household size, workers, drivers, and vehicles for eleven trip purposes.
Trip Distribution	Yes	Yes	Yes	p. 11	By trip purpose, based on travel time by all modes, travel cost, congestion, and vehicle ownership. Matches income to job salaries.
Mode Choice	Yes	Yes	Yes	p. 11	Multinomial logit with 7 modes.
Trip Assignment	Yes	No	No	p. 11	

* 2022 SJCOG RTP/SCS report Appendix X

Iterative Feedback Loops

Submodule	Sensitivity of Submodules			Document Page(s)	Notes
	Feed-back	Max. Iterations	Ensuring convergence		
Auto Ownership	No	No	No		Figure 1 suggests feedback but submodule is not sensitive to travel time.
Trip Generation	No	No	No		
Trip Distribution	Yes	Not specified	Not specified	p. 11	See Figure 1. Details of iterations not provided.
Mode Choice	Yes	Not specified	Not specified		
Trip Assignment	Yes	Not specified	Not specified	p. 11	See Figure 1. Details of iterations not provided.

* 2022 SJCOG RTP/SCS report Appendix X

Time Periods

The model estimates travel for an average weekday, covering Monday through Friday. The model breaks down the day into key periods: AM peak, PM peak, mid-day off-peak, and evening off-peak. The documentation does not explain how trips are assigned to each time period are based on the 2001. The model does not shift trips from one time period to another to account for the potential for the network to be over-capacity during peak periods.

Land Use Scenarios

SJCOG presents four land use scenarios in the 2022 RTP/SCS. These scenarios were developed using the Envision Tomorrow scenario development tool. The scenarios are based on four Priority Growth Areas (PGAs) within the San Joaquin County region: Established Neighborhoods and Centers, Urban Arterials, High-Quality Transit Areas, and New Growth Areas. Each scenario allocates growth differently across these PGAs, considering factors such as low vehicle miles traveled (VMT), jobs-housing balance, and proximity to high-quality transit areas. It is not clear whether the scenarios reflect different assumptions about highway investments.

Induced Travel

The agency used the Fehr & Peers method for determining the amount of induced VMT captured by the travel demand model. This method assumes compares the increase in VMT produced by highway capacity investments (holding all else constant) as estimated by the model to the increase as estimated by the California Induced Travel Calculator. According to the agency, “Test results showed that the SJCOG travel demand model is capable of capturing short-range induced demand from a change in lane miles. Long-range changes in the development pattern were also captured through SJCOG’s modeling framework” though the specific aspects of the framework that achieve this are not identified (Appendix X, p. 14). Appendix X goes on to note, “Although the SJCOG Model does not specifically evaluate induced travel from the perspective of longer trips, changes in mode choice, route changes or newly generated induced trips, at the regional level these effects may be negligible compared to the overall amount of travel.” The agency concludes, “additional VMT resulting specifically from induced travel demand would not be substantial, and the induced travel impact at the regional level would be less than significant.” Chapter 5 of the RTP/SCS reports that total daily VMT per capita would increase from 23.24 in 2020 (the baseline) to 25.53 in 2046 in response to the implementation of the plan. The Environmental Impact Analysis for the RTP/SCS presents results that show that VMT per capita is higher in 2046 with the plan than without the plan and lists a variety of regional VMT reduction programs as mitigations for this increase.

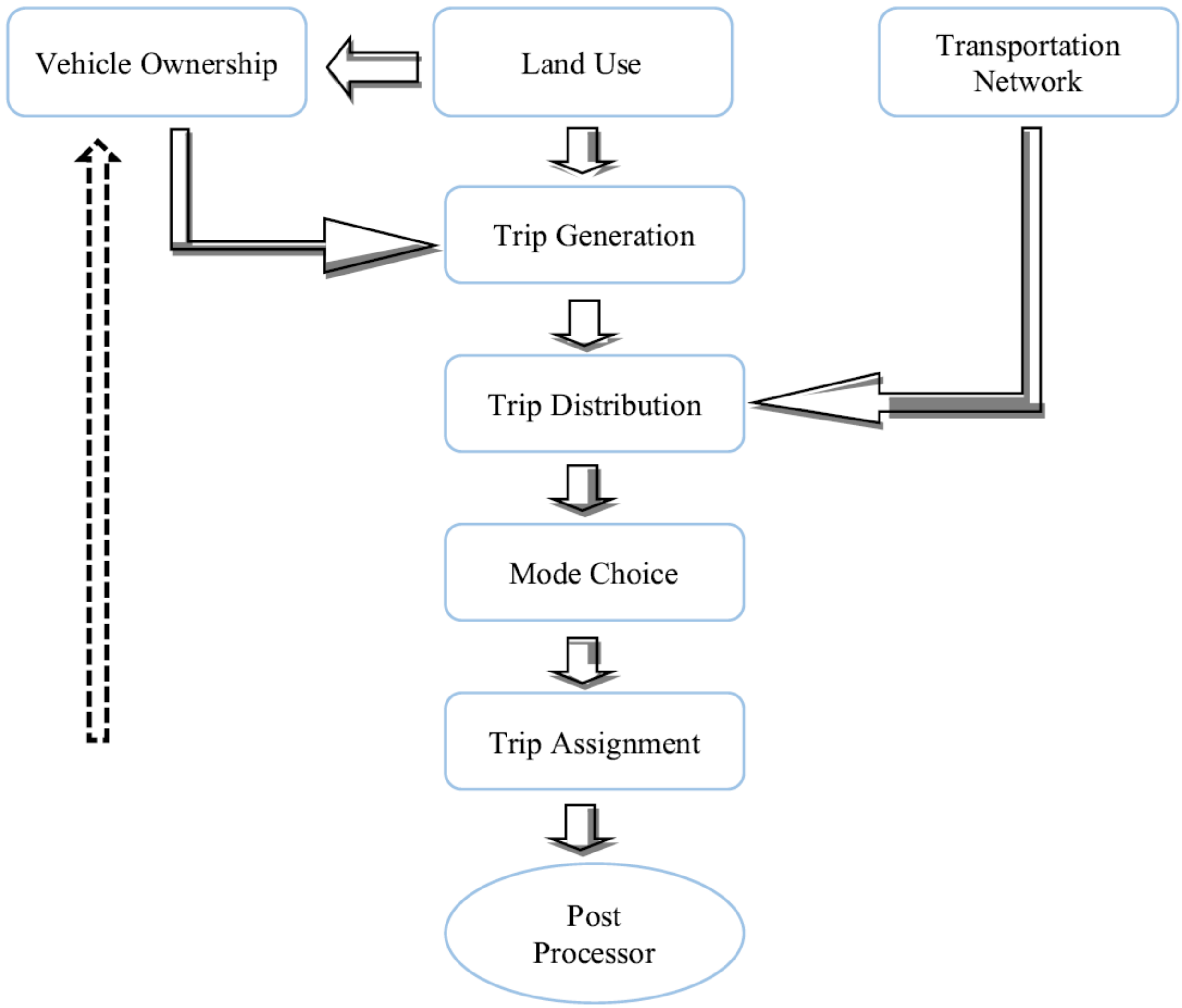
Documents

2022 RTP/SCS https://www.sjcog.org/608/Adopted-2022-RTPSCS-Plan

Appendix X https://www.sjcog.org/DocumentCenter/View/9720/Appendix-X---Technical-Methodology-Memorandum

Transportation Chapter of the RTP/SCS EIR
https://www.sjcog.org/DocumentCenter/View/7206/414-Transportation?bidId=

Figure 2 – San Joaquin Valley Model Improvement Program: Model Components



San Luis Obispo Council of Governments: Regional Travel Demand Model

The Regional Travel Demand Model (RTDM) used for the 2023 Regional Transportation Plan was developed in 2022 by Caliper Corporation using data from the 2012 California Household Travel Survey and the 2017 National Household Transportation Survey. The model is described in Appendix C: Modeling and Technical Documents; Appendix C-1 provides an overview of the entire modeling framework, while Appendix C-2 provides a detailed description of the RTDM. The RTDM is a hybrid model, combining elements of trip-based, four-step model with elements of an activity-based model, similar to the models used by AMBAG and SBCAG. A population synthesis submodule provides input to the trip generation model, including auto ownership. The model includes a transit network.

Time Sensitivity and Iterations

The trip distribution, mode choice, and trip assignment submodules are sensitive to travel times, but the auto ownership and trip generation submodules are not. The initial trip distribution and mode choice estimations use estimates of congested travel times (taken from previous model runs). After the initial model run, the newly estimated congested travel times are fed back into the trip distribution, mode choice, and trip assignment submodules (see figure of SLOCOG Planning Model). A total of five feedback loops are performed (p. 62).

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	No	Yes		Estimated in population synthesis submodule in conjunction with income.
Trip Generation	No	No	Yes	pp. 19-21	Person-based trip rates by various characteristics for 7 trip purposes.
Trip Distribution	Yes	No	No	pp. 33-37	Destination choice models used for home-based work, home-based shop, and home-based other trips; gravity models used for other trip purposes.
Mode Choice	Yes	Yes			Nested logit models with five modes; structure varies by purpose.
Trip Assignment	Yes	Yes	No		Equilibrium assignment.

* SLOCOG 2023 RTP Appendix C-2

Iterative Feedback Loops

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring convergence		
Auto Ownership	No	N/A	N/A		
Trip Generation	No	N/A	N/A		
Trip Distribution	Yes	5		pp. 62-63	Completing 5 iterations ensures stability.
Mode Choice	Yes	5			
Trip Assignment	Yes	250	Yes		

* SLOCOG 2023 RTP Appendix C-2

Time Periods

The model uses four time period: AM peak period, mid-day, PM peak period, and evening/night. Trips are assigned to departure times by trip purpose based on the combined data from the 2012 CHTS and the 2017 NHTS. The model does not shift trips from one time period to another to account for the potential for the network to be over-capacity during peak periods.

Land use Scenarios

Land use scenarios are created with the Regional Land Use Model (RLUM), based on the CommunityViz Scenario 360 extension to ArcGIS. Chapter 13 of the RTP presents the Sustainable Communities Strategy, in which four scenarios for 2035 were analyzed. The preferred scenario (Scenario C) focuses on transportation efficiency by channeling new growth to areas with sufficient highway interchanges, bikeways, and transit (pg. 13-17). The inputs to the RLUM do not include the transportation network or travel times.

Induced Travel

Induced travel is not explicitly discussed in Appendix C or the 2023 SLOCOG RTP.

Documents

2023-2045 Regional Transportation Plan. https://www.slocog.org/programs/regional-planning/2023-rtp

2023-2045 Regional Transportation Plan. Appendix C: Modeling and Technical Documents. https://www.slocog.org/programs/regional-planning/2023-rtp


SLOCOG PLANNING MODEL
SAN LUIS OBISPO COUNCIL OF GOVERNMENTS
Initialize
Trip Generation
Build Networks
Transit Skims
Highway Skims
Trip Distribution
Mode Choice
Time of Day
Feedback Assignments
Feedback Check
Final Assignments
Reports

Santa Barbara County Association of Governments (SBCAG): SBCAG Travel Demand Model

The Santa Barbara County Association of Governments (SBCAG) adopted the Connection 2050 Regional Transportation Plan/Sustainable Communities Strategy in 2023. The agency used a multimodal travel demand forecasting model and "an integrated land use modeling capability" (p. 3-29) in preparing the plan. The model, briefly described in Chapter 3 of the plan and in more detail in Appendix B: Technical Methodology, is a trip-based, four-step model with a base year of 2015. However, SBCAG is working with SLOCOG and AMBAG to develop an activity-based model for use in developing the next long-range transportation plan. The summaries for those agencies provide overviews of the hybrid models they are currently using as a step toward a full activity-based model.

SBCAG does not provide sufficient documentation of the four-step model to enable a review of time sensitivities, feedback loops, and time periods. However, Appendix B of the regional plan includes a short discussion of induced travel that suggests that components of the model are sensitive to travel times and that it may incorporate feedback loops (p. 10):

> Both the short-term and long-term effects of induced travel can be estimated using the SBCAG travel demand model. The short-term effects are captured directly in the model itself, since a) the impact of new capacity on vehicle travel speed is captured in the model, and b) the impact of speed of travel on roadways affects the frequency of trip-making, mode of travel, and travel routing. The long-term effects of induced travel are captured through SBCAG's iterative process of developing the land use forecast and identifying the roadway capacity projects for the region. This iterative process considers the magnitude and location of growth within the SBCAG region and then considers if the roadway widening projects are increasing capacity beyond what is needed to accommodate anticipated growth. Once the land use forecast and roadway capacity projects are finalized, as proposed in Connected 2050, the SBCAG model can be used to reasonably capture the long-term induced travel effects of the land development and transportation projects.

In the iterative process described, SBCAG uses UPlan, a scenario development tool, to develop land use scenarios for consideration in the Sustainable Communities Strategy while taking transportation investments into consideration, as described in Chapter 3. The available documentation is not sufficient to assess the accuracy of statements about the ability of the model to accurately estimate short-term or long-term induced travel.

Documents

Connected 2050 Regional Transportation Plan/Sustainable Communities Strategy. https://www.sbcag.org/wp-content/uploads/2023/09/Connected-2050-Final.pdf

Connected 2050 Appendices. https://www.sbcag.org/wp-content/uploads/2023/09/Connected-2050-Appendices-Final.pdf

Shasta Regional Transportation Agency (SRTA): ShastaSIM

The Shasta Regional Transportation Authority (SRTA) released its most recent Regional Transportation Plan in 2022. This plan had a time horizon of 20 years, forecasting as far as the year 2042. As a part of this most recent RTP, SRTA updated its activity-based travel demand model, ShastaSIM. This newly updated TDM is referred to as ShastaSIM 2.0. The revisions made to the model are detailed in the *ShastaSIM 2.0 Supplemental Documentation*, published in 2023. The *Shasta Sim 1.2 Model Development Report*, published in 2018, is largely still applicable to the 2.0 version of the model. Both documents were prepared by DKS Associates and are available on the SRTA website as Appendix 1 to the 2022 RTP. Further documentation of SRTA's travel demand modeling is available in Appendix 2, which deals with the RTP's technical methodology and off-model calculations.

ShastaSim simulates individual travel patterns as a series of "trip-legs" over a 24-hour period. At the core of the model, DaySim uses parcel-level land use data and synthesized population characteristics to simulate all travel by residents of the county. It uses a set of long-term choice models as well as short-term choice models to produce estimates of person trips (see Figure 16: DaySim Hierarch and Flow). The long-term choices are: household automobile availability, usual work location for each worker, usual school location for each student. The short-term choices are: number and type of tours made by each person, main destination of each tour, main mode of travel for each tour, arrival and departure times for each activity on each tour, number and purpose of intermediate stops made on each tour, location of each intermediate stop, model of travel foreach trip segment on each tour. The person trips are combined with estimates of commercial vehicle trips and trips originating outside of the county and then assigned to the transportation network (see Figure 1: Travel Model Process).

Travel Time Sensitivity and Feedbacks

Inputs to DaySim include ten "level of service" files with estimates of zone-to-zone travel times (also known as "skims") by different modes at different times of day. These files are used in the mode choice models for different purposes. The mode choice models generate "logsum" values that reflect travel times and are used in estimating trip frequencies and destinations. Logsums from models of these short-term choices are also fed back into models of long-term choices.

The diagram for ShastaSim shows a feedback loop from the estimated level-of-service matrices (reflecting congestion levels) to DaySim (see Figure 1: Travel Model Process). The model documentation does not explain how this feedback is implemented, but John Gibb, a consultant on the model, explained that the estimated skims are fed back into DaySim wherever travel times are an input.[2] The model is iterated as many as 6 to 8 times, until the estimated travel times come close to convergence.

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	Yes	Yes	Yes	p. 61	In DaySim, through logsum variables
Trip Frequency	Yes	Yes	Yes	p. 62	In DaySim, through logsum variables
Destinations	Yes	Yes	No	p. 60, 62	In DaySim, through logsum variables
Mode Choice	Yes	Yes	Yes	p. 64	In DaySim
Route Assignment	Yes	No	No	p. 79	Equilibrium assignment

* ShastaSIM Model Development Report

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	Yes	Yes	Yes		6-8 iterations from assignment back to DaySim, as per John Gibb
Trip Frequency	Yes	Yes	Yes		
Destinations	Yes	Yes	Yes		
Mode Choice	Yes	Yes	Yes		
Route Assignment	Yes	80	Yes	p. 79	Up to 80 iterations

* ShastaSIM Model Development Report

Time Periods

The DaySim travel model accounts for travel decisions and travel times in minute-long blocks of time (p. 2, 2018 Model Development Report). The Tour Primary Activity Scheduling Sub-Model simulates arrival time, departure time, and duration of stay for each individual's activities. Auto and transit travel times, including time spent in severe congestion, are accounted for in the model, which uses estimated zone-to-zone travel times, not the travel time on the actual route (pg. 67).

[2] Zoom conversation October 7, 2024.

Land Use Scenarios

SRTA does not currently use a land use model. As a part of the development of the 2015 Sustainable Communities Strategy, the agency defined strategic growth areas (SGAs) for the county. For the 2023 RTP/SCS, several scenarios were defined with respect to the share of all future growth going into the SGAs. ShastaSim was used to estimate the effect on VMT of the increased densities in each scenario, and adjustments were made to SGA boundaries based on this analysis. Model forecasts for the final SCS scenario with increased densities in seven SGAs show that the scenario meet state-specified targets for reducting VMT and greenhouse gas emissions. It appears that the same transportation network was assumed for both the SCS scenario and the base scenario.

DaySim accounts for location choices with its work and school location models. The choice sets in these models are constrained by maximum travel times and otherwise account for travel times by incorporating the logsums from destination choice, mode-destination choice, and mode choice models (pg. 60). It is not clear if forecasted travel times are fed back into the model.

Induced VMT

Induced VMT is not discussed in the model documentation or in the 2023 RTP/SCS. Sensitivity testing for ShastaSim 2.0 examined the effect of the widening of all four-lane roadways to 6 lanes, while holding all else constant, and found an increase in VMT of 1.7% (2023 Supplemental Documentation, p. 29).

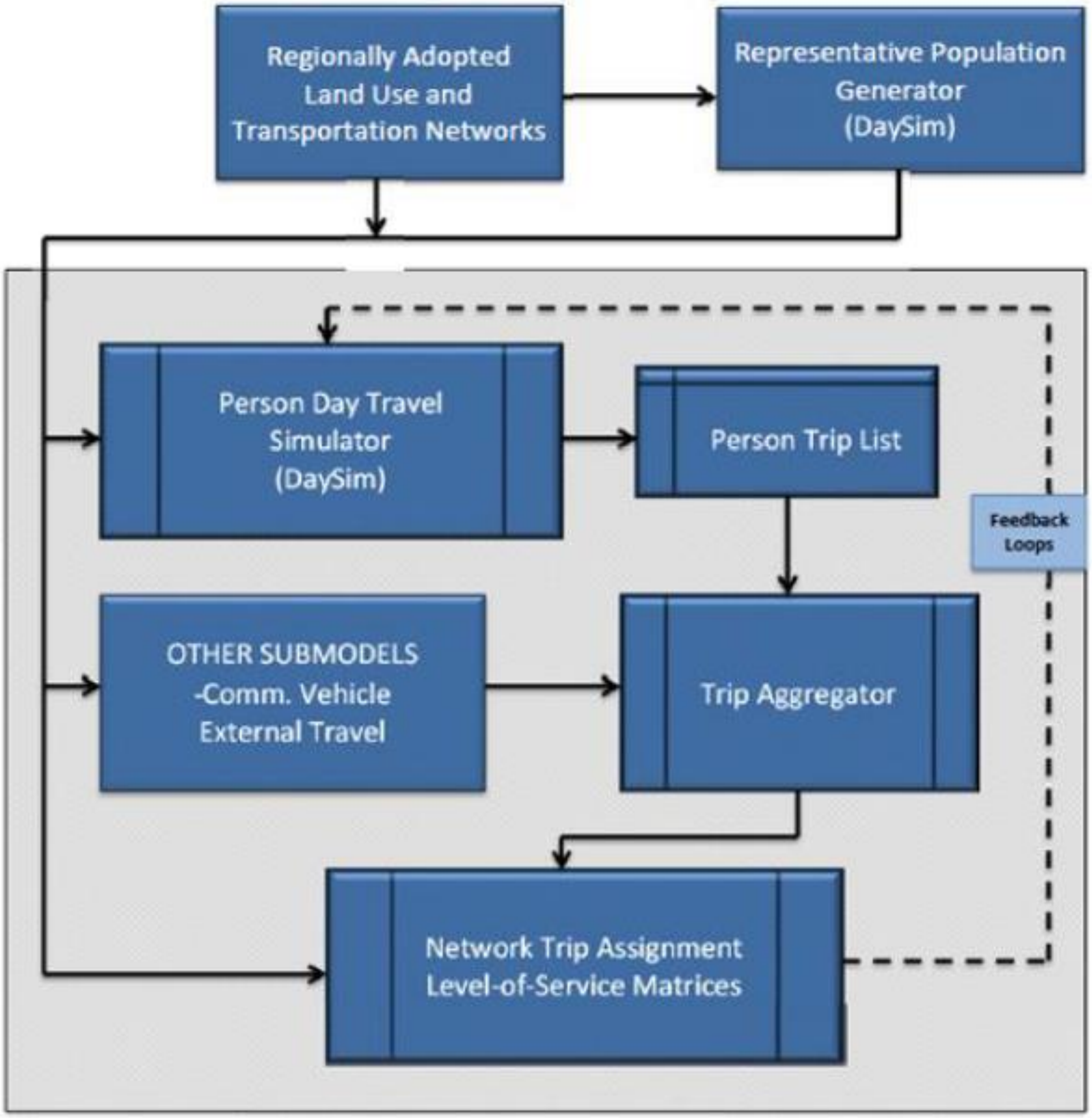
Documents

2022 Regional Transportation Plan
https://www.srta.ca.gov/DocumentCenter/View/9214/2022-Regional-Transportation-Plan--Sustainable-Communities-Strategy

ShastaSIM Model Development Report
https://www.srta.ca.gov/DocumentCenter/View/4317

ShastaSIM 2. Supplemental Documentation
https://www.srta.ca.gov/DocumentCenter/View/9108/ShastaSIM-20-Supplemental-Documentation-September-5-2023

Figure 1: Travel Model Process



Southern California Association of Governments: SCAG ABM

The Southern California Association of Governments (SCAG) has employed an activity-based model (ABM) since the development of the 2016 SCAG RTP/SCS plan. The latest version of the model, the 2024 RTP Model, is described in the *SCAG Regional Travel Demand Modal and 2019 Model Validation* report published in March 2024. This model is being used in the development of the Connect SoCal, the latest RTP/SCS adopted in April 2024. Many regional agencies as well as Caltrans were involved in the development of model enhancements. The enhancements are intended to improve the ability of the model to evaluate the effects of pricing strategies and expansion of transit services, among other strategies. The model is calibrated to 2019, to capture pre-Covid conditions. The ABM is used in conjunction with a heavy-duty truck model and external modules for airports and seaports to generate an origin-destination trip matrix that is fed into the assignment model (see Figure 1-1).

The SCAG ABM simulates the daily activities and travel patterns of all individuals in the region. The model represents individual and household decisions as well as the interactions between household members. The analysis is conducted at the zone level using 11,000 "Tier 2" traffic analysis zones (TAZs) across the region. Inputs to the model include a population synthesis, accessibility measures, and other land use characteristics (see Figure 2-1). Travel behavior is simulated through a sequence of choice submodels, flowing from long-term to short-term choices. Long-term choices include work arrangement, usual work location, usual school location, and work scheduling flexibility. Mobility choices – driver license and auto ownership – are next. Daily activity generation is the third level of choices; this includes coordinated daily activity-travel pattern (CDAP), mandatory activity generation, and non-mandatory activity generation. These models predict the frequency and start and end times for activities. The fifth layer is joint activity generation and scheduling, including frequency and participation, plus joint tour formation. The sixth layer is tour formation and scheduling, including time-of-day, trip departure time choice, and combinatorial mode choice. Trip assignment follows.

The model employs accessibility measures in many of the submodels (pp. 32-33). These origin-based accessibility measures are the "logsums" from the destination choice model, calculated over all "attractions" (reflecting employment at destinations) in the region, with attractions discounted by travel "impedance," a composite of travel times and costs to reach those destinations. Different sets of accessibility measures are used for different times of day to account for changes in travel times over the day.

Travel Time Sensitivity and Feedbacks

Auto ownership is sensitive to travel time through the inclusion of logsums (accessibility measures), as are trip generation and destination choice through the inclusion of logsums in the various activity and tour generation submodels. The mode choice model, which predicts mode choice for tours and trips in combination, so as to ensure realistic combinations of modes within a tour, presumably includes travel times in the utility function though the model documentation is not explicit about this. Estimated travel times are fed back into the demand model, affecting all submodules, for three feedback loops (p. 158).

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	Yes	Yes	Yes	pp. 67-71	Through logsums. Driver license model is similar.
Trip Generation	Yes	Yes	Yes	pp. 72-112	In activity generation and tour formation submodels, through logsums
Trip Distribution	Yes	Yes	Yes		
Mode Choice	Yes	Yes	Yes	pp. 128-132	Tour-level and trip-level modes predicted in combination. Represents 14 modes and imposes mode-switching penalties.
Route Assignment	Yes	Yes	Yes	pp. 157-161	Equilibrium assignment for 8 classes of vehicles and 5 time periods. Uses a generalized cost function.

* SCAG Regional Travel Demand Modal and 2019 Model Validation

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring convergence		
Auto Ownership Trip Generation Trip Distribution Mode Choice	Yes	3	Yes	p. 158	Estimated travel times for the AM peak, PM Peak, and midday periods are fed back into the demand model for 3 loops. Method of successive averages used to smooth volume variations across feedback loops.
Traffic Assignment	Yes	200	Yes	p. 158	Final assignment is for 5 time periods.

* SCAG Regional Travel Demand Modal and 2019 Model Validation

Time Periods

The tour scheduling model is placed after destination choice (tour formation) and before mode choice (p. 110). Tour start and end times are modeled in 15 minute intervals, while trip departure times and activity durations "are modeled in continuous time" (p. 5). This level of temporal resolution means that the model can be used with dynamic traffic assignment in the future. For now, trips are aggregated to five time periods for assignment: AM Peak, Midday, PM Peak, Evening, and Night (p. 157). The addition of a trip departure time choice model in the latest version of the model (pp. 111-112) helps to ensure that forecasts account for shifts in the timing of trips in response to congestion.

Land Use Scenarios

As described in Chapter 3 of Connect SoCal, the transportation and land use scenario for the Sustainable Communities Strategy was developed through an extensive collaborative process (pg. 79). The plan defines priority development areas (PDAs) for future growth, a necessary strategy for achieving the goals of the plan with respect to VMT and GHG reductions. The PDAs are 8.2% of the region's area but could accommodate 66% of the region's forecasted household growth and 54% of forecasted employment growth if the recommendation growth strategies are adopted (p. 100). The plan does not describe a process by which the land use scenario is coordinated or reconciled with the planned transportation investments. SCAG does not use a land use forecasting model, and neither the plan nor the model document describes a feedback from the SCAG ABM to the process of developing the land use scenario.

Induced Travel

The Connect SoCal adopts a "fix-it-first" principle to ensure that "life-cycle costs, such as maintenance and preservation expenses, are considered and planned for during the development of infrastructure projects" (p. 88). The plan also proposes transportation demand management (TDM) strategies, including congestion pricing, to "reduce the demand for roadway travel, particularly during peak times or on congested routes" and to "optimize the use of existing roadway capacity" (p. 88). Among the strategies for better managing the system includes the buildout of the regional express lanes network (p. 92). The plan for the buildout of the network includes new lanes as well as the conversion of HOV lanes to tolled express lanes (Map 3.2). The agency predicts that the plan, if implemented, will reduce both daily miles driven per capita (by 11.6%) compared to the base year and daily traffic delay per capita (by 31.8%) (p. 179). The plan does not discuss the possibility that building out the express lanes network could induce VMT. The model document does not discuss the ability of the model to capture the induced travel effects of highway capacity expansion projects.

Documents

Connect SoCal: A Plan for Navigating to a Brighter Future.
https://scag.ca.gov/sites/main/files/file-attachments/23-2987-connect-socal-2024-final-complete-040424.pdf?1714175547

SCAG Regional Travel Demand Modal and 2019 Model Validation.
https://scag.ca.gov/sites/main/files/file-attachments/scag_model_validation_report_final_rtp24.pdf?1729540664

Figure 1-1 SCAG Travel Demand Process

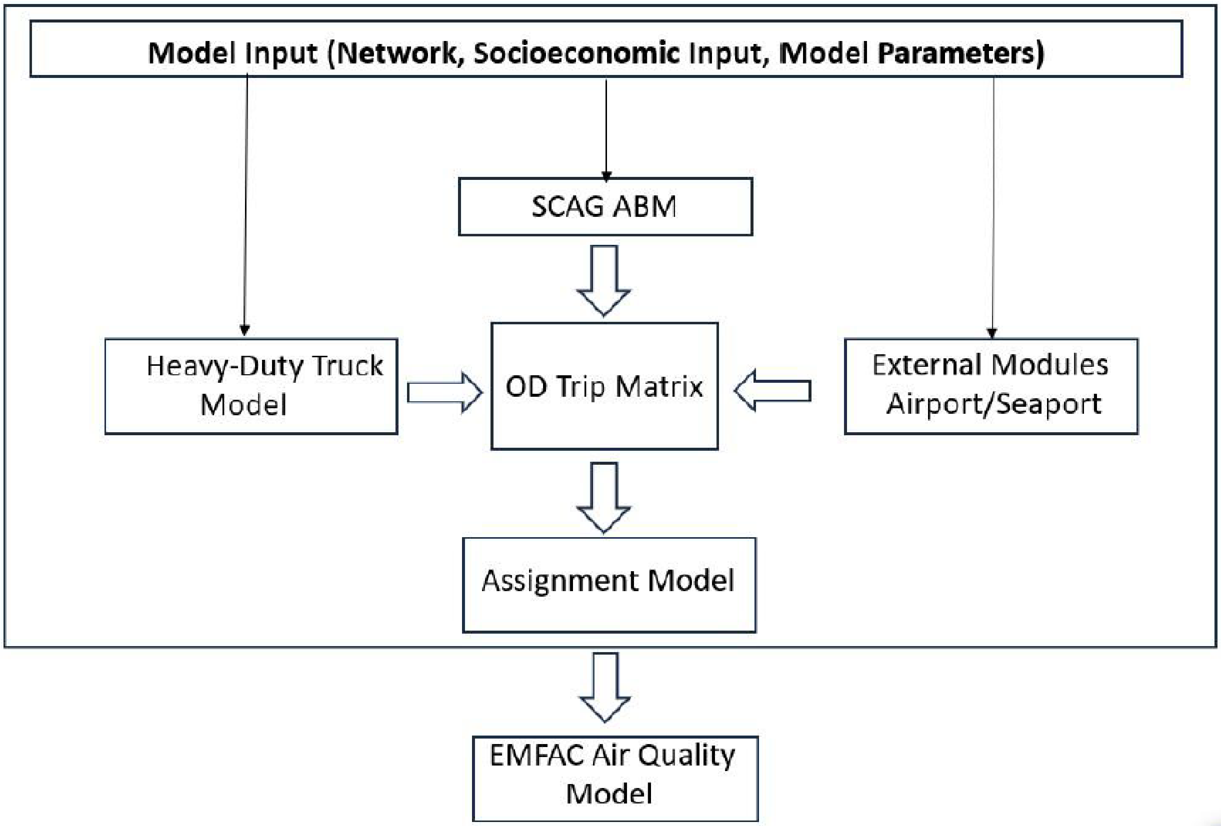
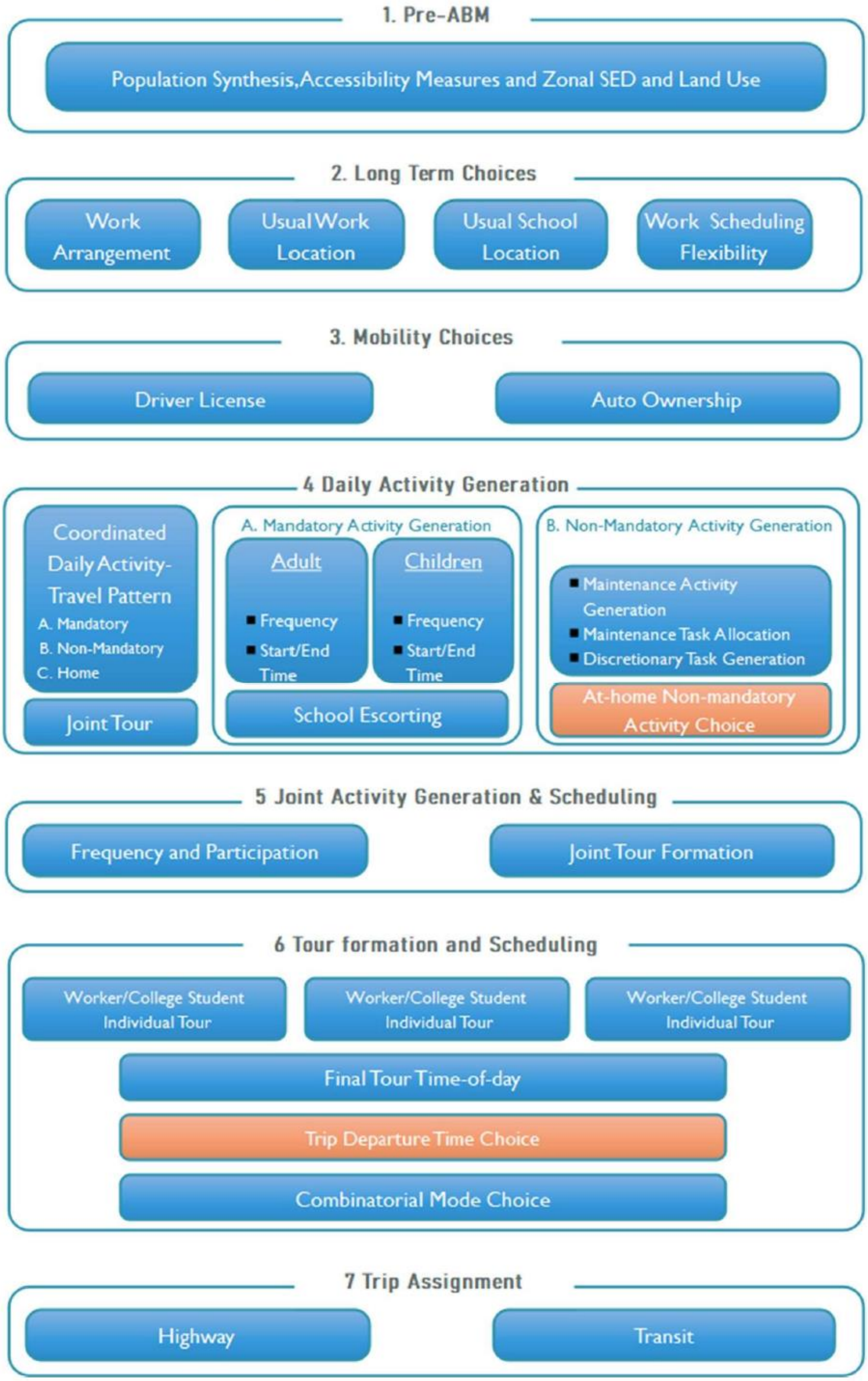


Figure 2-1: SCAG ABM System Design



Stanislaus Council of Governments: 2022 RTP Model

The Stanislaus Council of Governments (StanCOG) released the Regional Transportation Plan, with a time horizon of 2046, in 2022. The Documentation and Validation Report describing the agency's trip-based, four-step model was published in 2010. Appendix U of the 2022 RTP/SCS reports that the travel model was most recently updated in 2019, but these updates primarily involved corrections to known issues in the model and updates to socioeconomic data rather than changes to the model's overall functionality (p. 3). The StanCOG model is a sub-area version of the 3-county MIP2 travel demand model (RTP Appendix M, p. 9).

Travel Time Sensitivity and Feedbacks

The trip distribution and route assignment submodules are sensitive to travel time, but auto ownership, trip generation, and mode choice are not. The model includes a feedback loop in which estimates of congested travel times are fed back into the trip distribution submodule, though this is not depicted in the diagram of the model (see Figure 1: TPPG Travel Demand Model Process).

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	No	No	pp. 25-26	Assumes static proportions
Trip Generation	No	No	No	pp. 43-48	Daily person trip rates for six trip purposes by fifty household categories.
Trip Distribution	Yes	No	No	pp. 49-50	Gravity model based on travel time.
Mode Choice	No	No	No	pp. 31-32	Person trips converted to vehicle trips based on average auto occupancy; reductions in vehicle trips to reflect transit service.
Route Assignment	Yes	No	No	pp. 50-52	Equilibrium assignment.

*2010 Documentation and Validation Report

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	No	N/A	N/A	pp. 25-26	Assumes static proportions
Trip Generation	No	N/A	N/A	pp. 43-48	
Trip Distribution	Yes	Variable	Yes	pp. 52-53	
Mode Choice	No	N/A	N/A	p. 31	
Route Assignment	Yes	8	Yes	pp. 50-52	

*2010 Documentation and Validation Report

Time Periods

StanCOG's Traffic Assignment model estimates trips for a single hour in the AM and PM peak periods, and for the remaining 22 "off peak" hours. (p. 53). The shares of trips by purpose assigned to each time period are based on the 2001 Caltrans travel survey. The model does not shift trips from one time period to another to account for the potential for the network to be over-capacity during peak periods.

Land Use Scenarios

StanCOG used Envision Tomorrow, a scenario-planning tool, to develop four land use scenarios for consideration in the 2022 RTP/SCS, according to Appendix M. Scenario A assumes no change from the 2018 RTP/SCS. Scenarios B, C, and D prioritize growth relative to the 2018 baseline, concentrated in existing downtowns, new greenfield developments, and infill in established neighborhoods, respectively. All three growth scenarios prioritize a variety of housing types and mixed uses (p. 20). The effects of infill and bus service assumptions were quantified using the RTP model, while other strategies were quantified "off-model" (Table 4). It is not clear whether assumptions about highway investments differ in the four scenarios.

Induced VMT

StanCOG reports the expected VMT that will be induced between 2022 and 2035 as a result of anticipated transportation network investments in Appendix M of the 2022 RTP/SCS. The document notes that "Although the StanCOG Model does not explicitly evaluate induced travel from the perspective of destination change from new land uses, increasing auto dependency, or newly generated induced trips previously suppressed by congestion, these effects may be negligible at the regional level compared to the overall amount of travel" (p. 10). For this reason, the analysis uses the model to estimate short-term induced VMT and the California Induced Travel Calculator to estimate total induced VMT, taking the difference between the two to estimate long-term induced VMT and adding this to the estimates from the model for the analysis of GHG emissions (p. 11). A short-term elasticity of 0.22 was estimated based on a sensitivity analysis conducted with the model in which the base model was successively modified to widen highway 99 by one lane on different segments.

The results are presented in Table 9. The document states, “Given the rural nature of Stanislaus County, the induced vehicle travel effects of roadway expansion projects are anticipated to be substantially dampened” (pg. 9) and that the analysis “should be considered a worst-case scenario” (p. 10).

Documents

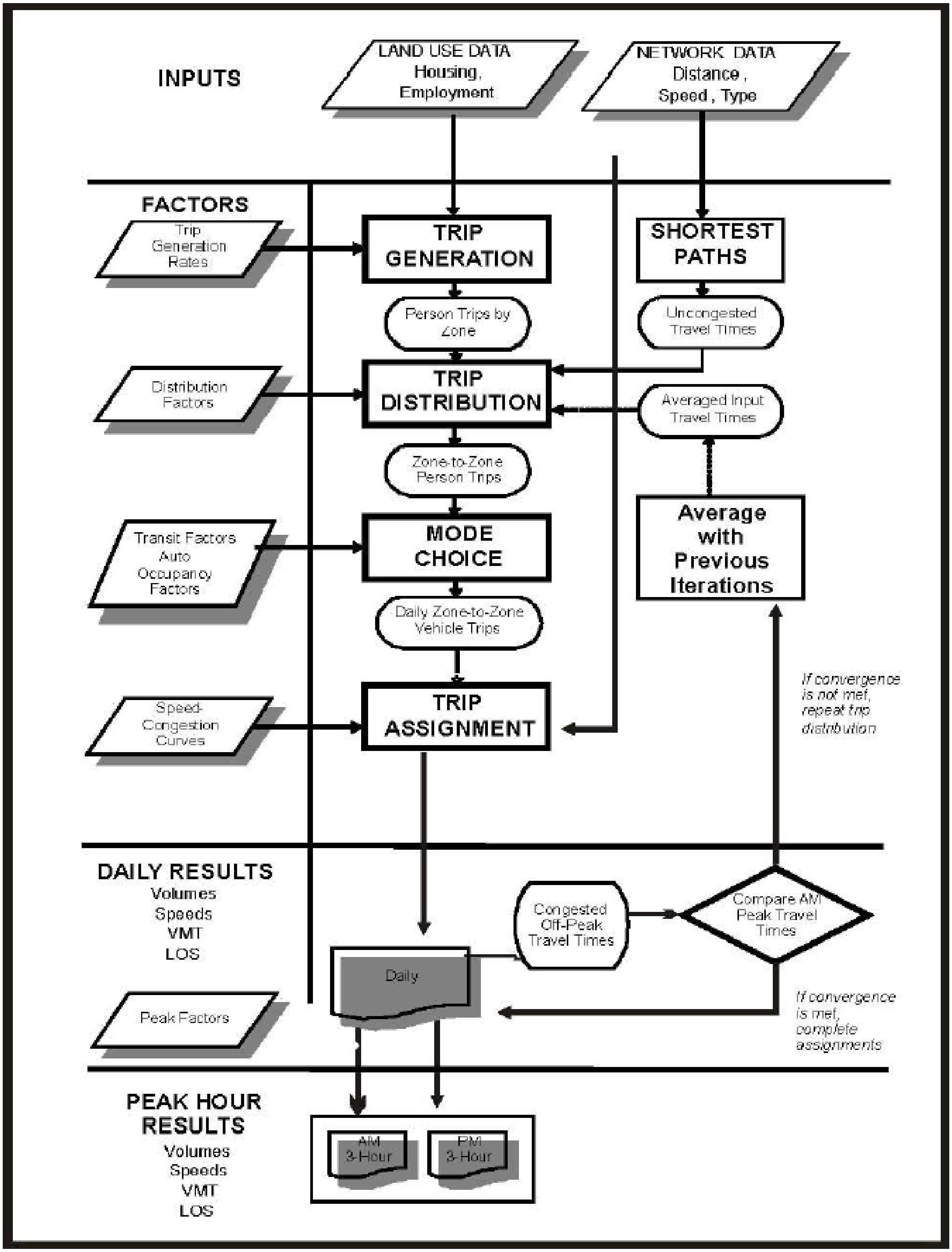
2022 Regional Transportation Plan. https://www.stancog.org/DocumentCenter/View/1473/Final-2022-Regional-Transportation-PlanSustainable-Communities-Strategy-RTPSCS

2022 RTP/SCS, Appendix M. https://www.stancog.org/DocumentCenter/View/1461/Appendix-M---CARB-SB-375-Methodology

Table 9 – 2035 SB 375 Induced Demand Analysis

Roadway Classification	2035 Total Lane Miles	2035 Lane Mile Increase	2035 Induced VMT (Long-Term Only)
Freeway (1)	337.5	25.18	100,425
Expressway & Major Arterial (2 & 3)	3,167.0	101.71	133,900
Total	***3,504.5***	***126.89***	***234,325***

Figure 1 - TPPG Travel Demand Model Process



Tulare County Association of Governments: VMIP-2

The Tulare County Association of Governments (TCAG) adopted its most recent Regional Transportation Plan/Sustainable Communities Strategy in 2022. TCAG uses a model developed as a part of the San Joaquin Valley Model Improvement Plan Phase 2 (VMP-2), an update to the VMIP-1 models developed in 2010. The model is described in the VMIP 2 Model Development Report published in July 2017 and prepared by Fehr & Peers. The current model, calibrated with data from the 2012 California Household Travel Survey (CHTS), is a trip-based, four-set model.

Travel Time Sensitivity and Feedback Loops

The trip distribution, mode choice, and route assignment models are sensitive to travel time, but the auto ownership and trip generation submodules are not. Estimated congested times are fed back into the trip distribution submodule, but the report does not say how many feedback loops are performed: "The feedback loop ensures the travel times used as input to trip distribution are consistent with the travel times on the final reported congested road network, as required for air quality conformity analysis" (p. 56)

Sensitivity of Submodules

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	Yes	Yes	p.30-32	Multinomial logit model uses ratio of commute cost to income.
Trip Generation	No	No	Yes	p.32-42	Daily person-trip rates by characteristics for 4 trip purposes; home-based work trip productions and attractions split by income.
Trip Distribution	Yes	Yes	Yes	p.42-43	Gravity model using travel times and costs by purpose; work trips segmented by income.
Mode Choice	Yes	Yes	No	p.43-53	Multinomial logit models with four modes by trip purpose. Income indirectly included through auto ownership.
Route Assignment	Yes	Yes	No	p. 54-55.	Equilibrium assignment.

* VMIP 2 Model Development Report

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring convergence		
Auto Ownership	No	N/A	N/A	N/A	
Trip Generation	No	N/A	N/A		
Trip Distribution	Yes	Not specified	Not specified	p. 56	Iteration process not described.
Mode Choice	Yes				
Trip Assignment	Yes				

* VMIP 2 Model Development Report

Time Periods

The VMIP2 model divides the day into three time periods: AM peak period, mid-day period, PM peak period, and off-peak period. The report does not explain how trips are assigned to these periods.

Land Use Scenarios

The RTP/SCS describes a consultation process for developing the preferred land use scenario. The plan does not mention the use of a scenario planning tool, though the REMI model was used to explore possible economic futures for the county. Three scenarios were prepared that different with respect to the density of new development as well as transportation investments. The preferred scenario "builds on the strategy and vision of compact and efficient growth" (p. C-1). The plan does not discuss how the proposed highway investments and/or congestion levels might influence future development patterns.

Induced Travel

Induced travel is not discussed in either the model documentation report or the RTP.

Tahoe Regional Planning Agency (TRPA): Tahoe Travel Model

The Tahoe Regional Planning Agency (TRPA) produced its most recent regional transportation plan in 2020. This plan had a time horizon of 25 years, looking ahead to 2045. TRPA maintains a Github webpage documenting the model's structure, dynamic validation, and input data for the 2018 base year. This webpage was developed with assistance from WSP USA and is much more detailed in its descriptions of the model's functionality and capabilities. The current activity-based model replaced a trip-based, three-step travel model in 2018.

Reflecting the complex transportation situation of the region, the model estimates travel for three groups separately: Tahoe Basin residents, external workers, and visitors. Each of these sub-models has its own dedicated webpage. The Resident Model is an activity-based model. The model starts with population synthesis and auto ownership estimation (see Model Flow figure). Each person's daily activity pattern is then estimated, defined by three types of activities: mandatory pattern, non-mandatory pattern, and at-home pattern. The mandatory tour model includes a destination choice sub-model; predictor variables include distance as well as the "logsum" from the mode choice model, used as an accessibility measure for destination zones. A time-of-day submodel determines the stop and start hours for the tours. The mode choice model, specifying six modes, uses travel time as well as travel costs for the modes that have them. The individual non-mandatory tour model follows a similar structure, and a joint tour model predicts patterns for shared non-mandatory activities.

As documented in Appendix G of the 2020 RTP, the travel demand model is used to estimate the impact of proposed highway projects, which for this plan includes only a revitalization project on Highway 50, and fixed-route transit projects (p. 265). The effects of other transportation improvements are estimated using the agency's spreadsheet-based Trip Reduction Impact Analysis tool (TRIA). Estimates from the TRIA tool area converted into trip reduction factors that are applied to each origin-destination pair in the travel demand model (p. 286).

Travel Time Sensitivity and Feedbacks

The trip distribution, mode choice, and route assignment sub-modules are sensitive to travel time and travel cost, but trip generation (as determined by activity and tour patterns) is not. While the equilibrium route assignment procedure includes as many as 50 iterations, the model documentation does not mention feedbacks from estimated travel times back into earlier components of the model. It is not clear what initial skims are used in the Daily Activity Pattern model.

Sensitivity of Submodules of Resident Model

Submodule	Sensitivity of Submodules			Document Page(s)*	Notes
	Travel Time	Travel Costs	Income		
Auto Ownership	No	No	Yes	See website	Uses only household and zonal characteristics.
Trip Generation	No	No	Yes	See website	Daily Activity Pattern model
Trip Distribution	Yes	Yes	Yes	See website	Destination Choice Sub-Model of the Mandatory Tour Model
Mode Choice	Yes	Yes	No	See website	Mode-Choice Sub-model of the Mandatory Tour Model
Route Assignment	Yes	Yes	No	See website	Equilibrium assignment

* https://trpa-agency.github.io/travel_demand_model/ResidentModel.html

Iterative Feedback Loops

Submodule	Iterative Feedback Loops			Document Page(s)*	Notes
	Feed-back	Max. Iterations	Ensuring Convergence		
Auto Ownership	No	N/A	N/A		
Trip Generation	No	N/A	N/A		
Trip Distribution	No	N/A	N/A		
Mode Choice	No	N/A	N/A		
Traffic Assignment	Yes	50	Yes	See website	

* https://trpa-agency.github.io/travel_demand_model/TrafficAssignment.html

Time Periods

Prior to the Traffic Assignment phase of the four-step model, TRPA's Time-of-Day Sub-Model classifies trips into one of four time periods: AM peak, midday, PM peak, and late night. The model uses a multinominal logit model but the documentation does not explain what variables are used to determine time of day. The start time and end time of trips are estimated to the nearest hour and aggregated within each period.

Land Use

The process for forecasting future land use patterns is explained in Appendix G of the 2020 Regional Transportation Plan. The plan outlines a "communities planning" approach that encourages compact, mixed-use development and focuses on meeting housing needs (p. 79).

Induced Travel

Induced travel is not discussed in the RTP or the model documentation. The plan says, "Building out the roadway system for the peak roadway demand does not make sense for the environment or for those who live, work, or visit here" (p. 14). Appendix I of the plan presents forecasts of annual average daily total VMT per capita (Table 39, p. 308).

Documents

2020 Regional Transportation Plan. https://www.trpa.gov/wp-content/uploads/documents/2020-RTP-FINAL.pdf

2020 Regional Transportation Plan Appendix G: Data and Forecasting. https://www.trpa.gov/wp-content/uploads/documents/013-2020-RTP-FINAL-AppG.pdf