MTI Report 02-03

Verifying the Accuracy of Regional Models Used in Transportation and Air Quality Planning

M T I

Mineta Transportation Institute

Created by Congress in 1991

MINETA TRANSPORTATION INSTITUTE

The Norman Y. Mineta International Institute for Surface Transportation Policy Studies (MTI) was created by Congress through the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and established in the California State University system at the San José State University College of Business. MTI continues as a University Transportation Center (UTC), reauthorized in 1998 by the Transportation Equity Act for the 21st Century (TEA-21).

MTI is unique among UTC's in two areas. It is the only center with an outside, internationally respected Board of Trustees, and it is the only center located in a College of Business. The Board provides policy direction, assists with needs assessment, and connects the Institute and its programs with the international transportation community. The Institute's focus on policy and management resulted from a Board assessment of the industry's unmet needs and led directly to the choice of the San José State University College of Business as the Institute's home. MTI applies the focus on international surface transportation policy and management issues in three primary areas:

Research

The Institute aims to provide policy-oriented research for all levels of government and the private sector, to foster the development of optimum surface transportation systems. Research areas include: security of transportation systems; planning and policy development; interrelationships among transportation, land use, the environment, and the economy; financing of transportation improvements; and collaborative labor-management relations. Certified Research Associates conduct the research. Certification requires an advanced degree, generally a Ph.D., a record of academic publications, and professional references. Research projects culminate in publication available both in hardcopy and on the Institute's website.

Education

The educational goal of the Institute is to provide graduate-level education to students seeking a career in the development and operation of surface transportation programs. MTI, through the College of Business at San José State University, offers an AACSB accredited California State University Master of Science in Transportation Management and a Graduate Certificate in Transportation Management that will prepare the nation's transportation managers for the 21st century. The masters degree is the highest conferred by the California State University system. With the active assistance of the California Department of Transportation, MTI delivers its classes over a state-of-the-art broadcast videoconferencing network throughout the State of California and via webcasting beyond, allowing working transportation professionals to pursue an advanced degree regardless of their location. To meet the needs of employers seeking a diverse workforce, MTI's education program promotes enrollment to under-represented groups.

Information and Technology Transfer

MTI's third responsibility is to develop and maintain electronic information systems to store, retrieve, and disseminate information relating to surface transportation policy studies. The Institute's website, *TransWeb,* enables transportation professionals, students and individuals worldwide to access information relating to surface transportation research and policy. *TransWeb* is found at http://transweb.sjsu.edu and delivers regional, state, national, and international transportation information. The Institute also maintains a library of periodicals and other unique publications for transportation research in cooperation with the San José State University Library system. MTI is funded by Congress through the United States Department of Transportation Research and Special Programs Administration (RSPA), the California Legislature through the Department of Transportation (Caltrans), and by private grants and donations.

MTI REPORT 02-03

Verifying the Accuracy of Regional Models Used in Transportation and Air Quality Planning

June 2003

Caroline Rodier, Ph.D.

a publication of the

Mineta Transportation Institute
College of Business
San José State University
San Jose, CA 95192-0219

Created by Congress in 1991

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
FHWA/CA/OR-2002-28			
4. Title and Subtitle Verifying the Accuracy of Regional Models Used in Transportation and Air Quality Planning		5. Report Date June 2003	
		6. Performing Organization Code	
7. Authors Caroline Rodier, Ph.D.		8. Performing Organization Report No. MTI 02-03	
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San Jose, CA 95192-0219		10. Work Unit No.	
		11. Contract or Grant No. 65W136	
12. Sponsoring Agency Name and Address California Department of Transportation Sacramento, CA 95819	U.S. Department of Transportation Research and Special Programs Administration 400 7th Street, SW Washington, DC 20590-0001	13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes			

16. Abstract

Communities with air quality problems in California and across the nation are proposing major beltway and highway projects to address roadway congestion problems. However, the travel and emissions models used in conformity analyses and environmental impact statements have low accuracy. Travel demand models are typically estimated on and calibrated to observed data, but rarely validated against observed data not used in their estimation and calibration. Validation of a model is critical to determining the degree of precision to which it can be reasonably applied. In this historical forecasting case study in the Sacramento, California region, the original version of the Sacramento regional travel demand model (estimated with 1991 data) is used with Year 2000 observed data to validate the model over a nine-year period. Three simulations are performed to test, respectively, model accuracy, the effect of errors in socioeconomic/land use projections, and induced travel.

The results of the study suggest that the travel demand model (that is, its functional forms and parameters) overestimates vehicle miles traveled, vehicle hours traveled, and vehicle hours of delay (5.7, 4.2, and 17.1 percent, respectively). The errors in the socioeconomic/land use projections made in 1991 and used in the model approximately double the errors in vehicle travel. The model also underestimates induced travel (elasticity of 0.14) compared to the estimate of actual induced travel (elasticity of 0.22) in this study, but the upward bias in the model error swamps this underestimation. If the model were used for conformity analyses in this region, its overestimation of daily vehicle travel should provide a relatively generous margin of error with respect to meeting air quality emissions budgets. (Note that the version of the model used in this study is no longer used by the region.) On the other hand, in the analysis of travel effects of proposed highway investment projections in environmental impact statements, the overestimation of the daily travel results would tend to overestimate no-build travel demand and congestion and thus the need for new highway projects in the region. Compared to that in the no-build alternative, the magnitude of change for the highway alternative would have to be greater than the model error to be considered significantly different. This may be a difficult standard for the typical new highway project to meet.

17. Key Words	18. Distribution Statement		
Travel demand; Land use predictions; Regional analysis; Regional planning; Regional travel model.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 38	22. Price $15.00

Form DOT F 1700.7 (8-72)

Library of Congress # 20021141182

To order this publication, please contact the following:

Mineta Transportation Institute
College of Business
San José State University
San Jose, CA 95192-0219
Tel (408) 924-7560
Fax (408) 924-7565
e-mail: mti@mti.sjsu.edu
http://transweb.sjsu.edu

ACKNOWLEDGEMENTS

Dr. Rodier wishes to thank Gordon Garry at the Sacramento Regional Council of Governments for his invaluable assistance with the modeling in the study. She would also like to thank Dr. J. Michael Pogodzinski, Professor of Economics at San José State University, for his comments on the final draft of the report and Bill Cowart of ICF Consulting for his comments on early drafts of the project design. She would also like to thank the U.S. Environmental Protection Agency for their support of this work.

Thanks also to MTI staff, including Research Director Trixie Johnson; Research and Publications Assistant Sonya Cardenas; Graphic Artists Shun Nelson, Emily Kruger, and Tseggai Debretsion; Webmaster Barney Murray; and Editorial Associates Irene Rush and Catherine Frazier for their assistance in the publication of this report.

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

In this historical forecasting case study in the Sacramento, California region, the original version of the Sacramento regional travel demand model (SACMET94 estimated with 1991 data) is used with Year 2000 observed data to validate the model over a nine-year period. Three simulations are performed in order to test, respectively, model accuracy, the effect of errors in socioeconomic/ land use projections, and induced travel. The first simulation tests the predictive accuracy of the model. The second simulation tests how errors in the socioeconomic/land use projections made in 1991 for the year 2000 affect model travel forecasts. The third simulation tests how well induced travel is represented in the model and provides an estimate of actual induced travel.

Several conclusions are drawn from this case study. First, the results suggest that the model (that is, its functional forms and parameters) modestly overestimates vehicle miles traveled (VMT) and vehicle hours traveled (VHT) (5.7 percent and 4.2 percent, respectively) but more significantly overestimates vehicle hours of delay (VHD) (17.1 percent). Second, the errors in the 1991 socioeconomic/land use projections approximately double the model's errors in vehicle travel (11.8 percent for VMT, 12.8 percent for VHT, and 38.4 percent for VHD). Third, it appears that the model underestimates induced travel compared to the estimate of actual induced travel in this study. However, the upward bias in the model error swamps this underestimation. Fourth, the elasticity of VMT, with respect to lane miles estimates for the model and actual travel over the nine-year period, are low compared to those found in the literature (0.14 and 0.22, respectively). This may be explained by the fact that this study could not isolate the effect of new transit service or high-occupancy vehicle lanes on reducing the increase in VMT resulting from new roadway construction.

The 1994 Sacramento regional travel demand model has been replaced by the 2001 Sacramento regional travel demand model. The new model has been recalibrated to 2000 survey data, and some structural changes have been made to the model. However, the results of this study indicate that if the 1994 model were used for conformity analyses in this region, its overestimation of daily vehicle travel would provide a relatively generous margin of error with respect to meeting air quality emissions budgets. On the other hand, in the analysis of travel effects of proposed highway investment projections in environmental impact statements, the overestimation of the daily travel results would tend to overestimate no-build travel demand and congestion and, thus, the need for new highway projects in the region. Compared to the no-build alternative, the magnitude of change for the highway alternative would have to be greater than the model error to be considered significantly different. This may be a difficult standard for the typical new highway project to meet.

INTRODUCTION

Communities with air quality problems, both in California and throughout the nation, are proposing major beltway and highway projects to address roadway congestion problems. It is widely acknowledged, however, that the travel and emissions models used in conformity analyses and environmental impact statements have low accuracy. The conformity requirements of the 1990 Clean Air Act Amendments assume the ability of travel models to estimate key travel inputs to emission models accurately enough to forecast within a few percentage points. Moreover, recent evidence for the induced travel hypothesis (Goodwin 1996; Hansen and Huang 1997; Noland and Cowart 2000; Chu 2000; Fulton et al. 2000; Noland 2001) has increased concerns over the limited ability of most regional travel demand models to represent how an increase in roadway supply reduces the time cost of travel and, to the extent that demand is elastic, increases the quantity of travel demanded. Most travel demand models' representation of travel time throughout model hierarchy is limited, and models are not operated in an iterative fashion; thus, faster travel times do not affect the demand for travel. Therefore, the failure to represent induced travel will lead to an underestimation of vehicle miles traveled and congestion for roadway projects.

In this historical forecasting case study in the Sacramento, California region, the original version of the Sacramento regional travel demand model (SACMET94 estimated with 1991 data) is used with Year 2000 observed data to validate the model over a nine-year period. Three simulations are performed in order to test, respectively, model accuracy, the effect of errors in socioeconomic/ land use projections, and induced travel. The first simulation tests the predictive accuracy of the model (that is, its functional forms and parameter estimates). The second simulation tests how errors in the socioeconomic/land use projections made in 1991 for the year 2000 affect model travel forecasts. The third simulation tests how well induced travel is represented in the model and provides an estimate of actual induced travel.

BACKGROUND

The transportation-related air quality problems that travel and emissions models address are critical. Approximately 133 million Americans live in metropolitan areas with air pollution levels above the National Ambient Air Quality Standard (NAAQS) (EPA 2001). The U.S. Environmental Protection Agency (EPA) has adopted more stringent NAAQS and stricter tailpipe emissions standards. However, the emissions standards may not be stringent enough to overcome increased driving, and the new NAAQS may still not be met in many metropolitan areas.

The 1990 Clean Air Act Amendments and the resulting conformity regulations rely on travel and emissions models to be accurate enough to demonstrate that regional transportation plans, which have 20-year time horizons, conform to the emissions budgets set out in the approved state implementation plans. Nonconformity results in the automatic implementation of contingency measures, in the possible loss of federal funding for highway projects, and, most important, in the public's further exposure to harmful air pollutants. Three regions—Charlotte, North Carolina; Atlanta, Georgia; and New Jersey—have already experienced significant highway project delays due to conformity lapses.

It is widely acknowledged, however, that forecasts produced by travel and emission models are typically inaccurate; it is not uncommon to find large differences between predicted and actual outcomes. Some transportation professionals believe that current state-of-the-art methods can forecast emissions with an accuracy of plus or minus 15 percent to 30 percent (Chatterjee et al. 1995). The transportation plans examined by regional governments across the United States typically differ from the base case and/or emissions budgets by less than 1 percent. Locally, the Sacramento region is an example of such a case; it barely passed the conformity test for NOx emissions (by 0.04 tons out of 77.87 tons per day) for the year 1999.

Regional travel demand models used by metropolitan planning agencies typically do a poor job of representing induced travel. Most travel demand models account for mode and route shifts associated with induced travel, but many do not account for other induced travel effects such as changes in land use, trip generation (or number of trips), and trip distribution (or destination choice). All these behaviors can change the travel models' estimates of vehicle miles traveled (VMT) and congestion.

Recent research has provided persuasive evidence for induced travel (Goodwin 1996; Hansen and Huang 1997; Noland and Cowart 2000; Chu 2000; Fulton et al. 2000; Noland 2001), and the principle has been acknowledged by leading transportation researchers (Transportation Research Board 1995; Transportation Research Circular 1998) and by the EPA (2000). This research indicates that about 25 percent of total long-run VMT growth in metropolitan areas can be attributed to induced travel.

The representation of induced travel effects in travel demand modeling is critical to the accurate evaluation of highway and transit plans. If induced travel effects are not represented in the analysis of new highway capacity, then estimates of VMT and congestion will be underestimated. If these induced travel effects are not represented in the analysis of transit alternatives, then estimates of VMT and congestion will be overestimated. Communities with air quality problems, both in California and throughout the nation, are proposing major beltway and highway projects to address roadway congestion. A few of these projects are Route 710 in California, the Grand Parkway in Houston, Texas, and the Legacy Highway in the Salt Lake region of Utah.

The critical transportation-related air quality problems facing the United States help explain the increased demands placed on travel and emissions models by legislation and regulations within the last decade. Despite their uncertainty, it is likely that there will continue to be a demand for their forecasts because the models address important economic and environmental problems. As evidence of such problems grows, so will the pressures placed on these models.

The important issue, then, is how to use uncertain models responsibly. Models can be abused if their limitations and uncertainties are not known, acknowledged, and made explicit. Unfortunately, uncertainty in models has traditionally been ignored, not only in the transportation profession but also in policy analysis in general (Stopher and Meyberg 1975; Hartgen 1995; Morgan and Henrion 1990). Morgan and Henrion (1990) lament that “despite, or perhaps because of, the vast uncertainties inherent in most policy models, it is still not standard practice to treat uncertainties in an explicit probabilistic fashion, outside the relatively small fraternity of decision analysts.”

THE SACRAMENTO REGIONAL TRAVEL DEMAND MODEL

The Urban Transportation Planning (UTP) model or travel demand model was developed in the late 1960s and early 1970s to determine the need for additional roadway lanes or segments to relieve traffic congestion. These models typically are developed with travel behavior surveys, socioeconomic data, and the characteristics of the transportation system for a base year. Travel demand models generally include four steps—trip generation, trip distribution, mode choice, and traffic assignment—and forecast future travel conditions.

The Sacramento regional travel demand model (SACMET94) is typical of a UTP model or travel demand model that has been improved to better meet the current demands of air quality conformity analysis and transportation planning. This is accomplished by enhancing the representation of travel time and cost variables throughout the hierarchy of the model; expanding the range of modal options, including land use variables; and improving the detail of zone and network structures. The model was developed with a 1991 regional travel behavior survey and 1991 observed socioeconomic/land use data. The discussion of the model here highlights key features of the model. Complete documentation of the SACMET94 model is provided in the *Model Development and User Reference Report* (DKS Associates 1994).

The SACMET94 model's representation of geographic detail is relatively fine. It includes a detailed transportation network comprising more than 10,000 links and 1,061 travel analysis zones (TAZ). TAZs are the geographic units used by travel demand models. Zones contain area-specific information (for example, number of households and employment) and are the location at which trips begin and end in a model. The network of a travel demand model represents the roadways and transit lines of a region with a series of links connected by nodes. All the links in the models are described in terms of key variables (for example, type of road, speed, and number of lanes).

The SACMET94 model differs from the traditional four-step UTP model in that it includes an auto ownership step that precedes the trip generation step. The auto ownership step is a logit model that predicts the probability of owning zero, one, two, or three or more autos. The variables in this model include retail employment within one mile, total employment within 30 minutes by transit, a pedestrian environmental factor, and household size, workers, and income.

The trip generation step in the SACMET94 model estimates the number of person-trips that begin or end in a zone based on the number and type of households (number of persons and workers), employment (retail and non-retail), and school enrollment (college and K through 12th grade). A measure of retail accessibility is also included in the trip generation models for some trip purposes.

The SACMET94 model represents six trip purposes: home-work, home-shop, home-school, home-other, work-other, and other-other. The first part of the trip purpose title (home, work, and other) refers to the activity location at which the trip begins, and the second part refers to the activity location at which the trip ends.

The trip distribution step in the SACMET94 model links the trips from trip generation in an origin-destination pattern using travel times that reflect street traffic as opposed to free-flow travel times. This is accomplished by the feedback of travel times from the traffic assignment step to the trip distribution step until convergence is achieved. The home-based work trip purpose is a joint destination and mode choice logit model and includes travel time and cost variables (or composite utility). The other trip purposes use the traditional gravity model formulation and include only the travel time variable.

The mode choice step predicts the probability that a traveler will choose a particular mode from a range of available modes. The modes included in the SACMET94 model are drive-alone, shared-ride, transit (walk and drive access), walk, and bike. Modes are chosen as a function of modal attributes (time and cost), household characteristics (auto ownership, income, size, workers), and land use variables (pedestrian amenities and employment distance).

In the traffic assignment step, vehicle trips are assigned to routes, with preference given to the fastest routes. The well-known user-equilibrium traffic assignment algorithm is used to assign vehicle trips by separate a.m. and p.m. peak (both 3-hour and 1-hour peaks) and off-peak periods. The outputs from traffic assignment are link volumes, link speed, VMT, and vehicle hours of delay. These outputs play an important role in the evaluation of travel effects of transportation alternatives and are key inputs to emissions analyses.

VALIDATION TESTS

In the process of developing a travel demand model, the model is estimated on local data, and then the model is calibrated or adjusted to closely match observed data. However, the observed data is the same data that was used to develop and calibrate the model. Thus, calibration results are not a good measure of model accuracy. Validation tests show how well the model predicts observed data, which was not used to estimate or calibrate the model, and will indicate with what degree of precision models can be applied. Whole-model validation is the gold standard academic test of model validity. For example, if the results of model validation tests indicate that the model's predictions differ from actual data by 5 percent, then the model can only be applied validly in studies where the magnitude of change is greater than 5 percent.

Two approaches to the validation of the model in this study were considered, historical forecasting and "backcasting." In general, the historical forecasting approach would use an older version of a model to forecast the most recent observed travel with observed input data. The backcasting approach would use the most recent version of a model to forecast past observed travel with past observed input data.

The SACMET model has been updated several times since it was originally developed in 1994. These updates consist of some structural changes to the model and changes in the zone structure of the model (that is, dividing and adding transportation analysis zones). The historical forecasting approach was used in this study rather than the backcasting approach because the structural changes in the latest version of the SACMET model (SACMET01) required some data that were not available in 1991.

In this study, the original version of the SACMET model (SACMET94 estimated with 1991 data) is used with Year 2000 observed data to test the accuracy of the model over a nine-year period. See Appendix A for a detailed description of the modifications made to the 2000 input data for the SACMET94 model historical forecasting study. The following are detailed descriptions of the validation tests implemented in the study and their analytical results (see also Table 1 on page 11).

TEST OF ACCURACY

Travel for the Year 2000 is simulated with the SACMET94 model, the Year 2000 roadway and transit network, and the Year 2000 socioeconomic/land use data. The network and socioeconomic/land use data used in this test are estimated from observed conditions in the year 2000. The travel results from this simulation are compared to available observed 2000 travel to assess the accuracy of the SACMET94 model (that is, functional form and parameters), which is represented by the estimate of model error described in Table 1. This is the percentage change from the travel forecast in this test to the observed travel.

TEST OF SOCIOECONOMIC/LAND USE PROJECTION ACCURACY

Travel for the Year 2000 is simulated with the SACMET94 model, the Year 2000 roadway and transit network, and the socioeconomic/land use projections made in 1991 for the Year 2000. The difference between this simulation and the above test of model accuracy is the use of socioeconomic/land use projections made in 1991 for the year 2000 rather than observed Year 2000 socioeconomic/land use data.

The travel results from this simulation are compared to 2000 observed travel results to assess the accuracy of the SACMET94 model and the effect of errors in socioeconomic/land use projections on travel forecasts, which is represented by the estimate of model and projection error described in Table 1. This estimate is the percentage change from the travel forecast in this test to the observed travel.

The travel results are also compared to the test of model accuracy results to isolate the contribution of the errors in socioeconomic/land use projections, which is represented by the estimate of projection error described in Table 1. This estimate is percentage change yielded from the difference between the estimates described above of model and projection error and model error.

TEST OF INDUCED TRAVEL

Travel for the Year 2000 is simulated with the SACMET94 model, the Year 1991 roadway and transit network, and the Year 2000 socioeconomic/land use data. The network is estimated from observed conditions in 1991. The only difference between this simulation and the above test of model accuracy is the use of the Year 1991 roadway and transit network rather than the Year 2000 network.

The travel results from this simulation are compared to the travel results from the above test of model accuracy to assess the SACMET94 model's representation of induced travel, which is represented by the estimate of model induced travel described in Table 1. This estimate is the percentage change from the travel forecast in the test of model accuracy to the travel forecast in this test.

In addition, the results of this test are compared to observed 2000 data, which is represented by the estimate of induced travel described in Table 1. This estimate is the percentage change from observed 2000 travel to the travel forecast in this test. The adjusted induced travel estimate, described in Table 1, is the estimate of induced travel, except that the travel forecast in this test is subtracted by the estimate of model error to correct for model error in the forecast travel. This is an estimate of actual induced demand in the region over a nine-year period. It is important to note that the correction is approximate because the use of the 1991 network may increase or reduce the error in the simulation results; however, because the change is relatively small, it is believed that these biases may be relatively small.

Table 1: Description of Validation Tests and Analytical Results

Validation Test Forecasts	Input Network: Year Observed	Input Socio-economic/ Land Use Data	Analytic Results
1. Model Accuracy	2000	2000 observed	Model Error = $\left[\frac{(Forecast\ (1) - Observed\ 2000)}{Observed\ 2000}\right] \times 100$
2. Projection Accuracy	2000	2000 projected in 1991	Model & Projection Error = $\left[\frac{(Forecast\ (2) - Observed\ 2000)}{Observed\ 2000}\right] \times 100$ Projection Error = Model & Projection Error – Model Error
3. Induced Travel	1991	2000 observed	Model Induced Travel = $\left[\frac{(Forecast\ (1) - Forecast\ (3))}{Forecast\ (3)}\right] \times 100$ Induced Travel = $\left[\frac{(Observed\ 2000 - Forecast\ (3))}{Forecast\ (3)}\right] \times 100$ Adjusted Induced Travel = $\left[\frac{Observed\ 2000 - (Forecast\ (3)(1 - Model\ Error \times 0.01))}{Forecast\ (3)\ (1 - Model\ Error \times 0.01)}\right] \times 100$

OBSERVED DATA

The Year 2000 socioeconomic/land use data and travel data used in this study were the best available data of observed conditions for the region. These data are estimates, rather than counts; thus, there is potential for error. It is not possible to quantify the magnitude or direction of the potential error.

The Year 2000 socioeconomic/land use data used in the simulation studies are developed by the Sacramento regional transportation agency (SACOG) by conducting annual housing and triannual employment inventories and by estimating population from the housing inventory, census data, and current population estimates from the California State Department of Finance Demographic Research Unit (SACOG 2001).

The Year 2000 observed travel is obtained from two sources in this study: the 2000 SACOG Household Travel Survey and the SACMET01 model. The survey included 9,130 people and 3,941 households in the Sacramento region. Estimates of trips by purpose and mode share were obtained from the survey. Weighing factors were developed to expand the survey sample to the population of the entire region and correct for survey response bias. “For example, proportionately more small households, and especially households with retired adults, participated and provided complete responses to the survey. Proportionally fewer larger families and families with children responded” (SACOG 2001, pg. 1). The best estimates of 2000 VMT, vehicle hours of travel (VHT), and vehicle hours of delay (VHD) were available from the SACMET01 model, which was calibrated with the 2000 survey data and simulated with 2000 input data.

RESULTS

In this section, travel forecasts from the three validation tests are compared to the best available observed travel data for the Year 2000, as described above. The travel forecasts generated from the model include number of trips (or trip generation), the mode share for those trips (or mode choice), and vehicle travel including VMT, VHT, and VHD. It is not always possible to identify the cause of the errors in the analysis below, because the validation tests in the study are designed to assess the accuracy of key model forecasts and not the accuracy of specific model parameters and structures.

The trip generation results of the validation tests are presented in Table 2 and Table 3. Table 2 compares the trip generation results to the survey trips; Table 3 compares the trip generation results to the SACMET01 2000 trips. These two tables were considered necessary because of their respective advantages and disadvantages: Table 2 allows for the comparison of only some trips to the survey data, and Table 3 allows for the comparison of all trips to the SACMET01 2000 data. The SACMET model's forecast of total trip generation includes external trips and other adjustments, which would not be represented in the trip generation data from the survey. As a result, in Table 3, total trip generation forecasts for the validation tests are compared to the forecasts of the SACMET01 model. The SACMET model, however, produces trip generation results for some trip purposes that do not include external trips and other adjustments that are comparable to survey data. These are the raw calculations of trip ends from an initial trip generation program in the model. Thus, in Table 2, the raw calculations of trip ends for four of the six trip purposes represented in the model are compared to the 2000 survey data.

When the raw trip end results for the validation tests are compared to survey trips in Table 2, the percentage change for the model accuracy forecast of total trips is 6.3 percent and for the projection accuracy forecast is 14.7 percent. The lowest error for the model accuracy forecast is 0.3 percent for home-work trips, and the highest is 35.9 percent for home-shop trips. The lowest error for the projection accuracy forecast is 7.2 percent for home-school trips, and the highest is 46.6 percent for home-shop trips. The errors in the projection accuracy forecast are significantly higher than the errors in the model accuracy forecast because the total households and employment were overestimated in the 1991 projection. (See Table 4 for a comparison of total regional estimated 2000 household and employment to projected [1991] 2000 household and employment.)

In Table 3, when the trip generation results from the validation tests are compared to the SACMET01 2000 results, the percentage change for the model accuracy forecast of total trip generation is -6.1 percent and for the projection accuracy forecast is 2.0 percent. The lowest absolute error for the model accuracy forecast is 0.6 percent for home-work trips, and the highest is 25.3 percent for home-shop trips. The lowest absolute error for the projection accuracy forecast is 0.8 percent for home-other trips, and the highest is 36.9 percent for home-shop trips. The overestimation of total households and employment in the projection error forecast offsets the underestimation of trip generation for a number of trip purposes in the model accuracy forecast; thus, the total absolute error is smaller in the projection accuracy forecast compared to the model accuracy forecast.

The difference between the induced travel forecasts and the model accuracy forecasts is too small to be considered significant in both Table 2 and Table 3. The travel time and cost variables, which would be affected by new transportation facilities, have limited representation in trip generation (see the description of the trip generation model on page 7).

Table 2: Comparison of Raw Calculations of Trip Ends[a] for the Validation Tests to the 2000 Travel Survey[b]

Trip purpose[c]	Survey Trips	1. Model Accuracy	2. Projection Accuracy	3. Induced Travel
Home-Work	1,100,000	1,103,730 (0.3%)[d]	1,182,982 (7.5%)	1,103,736 (0.3%)
Home-Shop	600,500	815,909 (35.9%)	880,286 (46.6%)	815,924 (35.9%)
Home-Other	2,130,100	2,191,071 (2.9%)	2,368,481 (11.2%)	2,191,086 (2.9%)
Home-School	495,700	489,237 (-1.3%)	531,230 (7.2%)	489,229 (-1.3%)
Total	4,326,300	4,599,947 (6.3%)	4962979 (14.7%)	4,599,975 (6.3%)

a. Raw calculations of trip ends are most comparable to the weighted trips from the 2000 survey; they do not include external trips and other adjustments.
b. Survey trips are weighted to reduce sampling error in the survey results (SACOG 2002).
c. Raw calculation of trip ends were not available from the SACMET model for the Work-Other and Other-Other trip purposes.
d. Figures in parentheses are percentage change from the validation tests to the survey trips.

Table 3: Comparison of Trip Generation for the Validation Tests to the SACMET01 2000 Results[a]

Trip purpose	SACMET01 2000	1. Model Accuracy	2. Projection Accuracy	3. Induced Travel
Home-Work	1,167,556	1,174,993 (0.6%)[b]	1,260,981 (8.0%)	1,175,005 (0.6%)
Home-Shop	856,965	1,073,903 (25.3%)	1,173,119 (36.9%)	1,073,264 (25.2%)
Home-Other	2,891,571	2,646,441 (-8.5%)	2,867,630 (-0.8%)	2,645,438 (-8.5%)
Work-Other	983,115	880,372 (-10.5%)	939,209 (-4.5%)	880,373 (-10.5%)
Other-Other	1,702,267	1,377,968 (-19.1%)	1,527,460 (-10.3%)	1,378,016 (-19.0%)
Home-School	477,338	433,849 (-9.1%)	469,658 (-1.6%)	434,042 (-9.1%)
Total	8,078,812	7,587,526 (-6.1%)	8,238,057 (2.0%)	7,586,138 (-6.1%)

a. The SACMET01 2000 results include external trips and other adjustments and are the best estimate of total trip generation in the region for the year 2000.
b. Figures in parentheses are percentage change from the validation tests to the model trips.

Table 4: Comparison of Total Regional Estimated 2000 Household and Employment to Projected (1991) 2000 Household and Employment

	Estimated 2000	Projected 2000
Household	651,588	802,421 (7.7%)[a]
Employment	701,930	874,747 (9.0%)

a. Figures in parentheses are percentage change from the validation tests to the survey.

Table 5 presents the comparison of daily mode share results from the model validation tests to the survey results. In general, the results show that the SACMET94 model tends to underestimate shared-ride and transit modes and overestimate the drive-alone and walk and bike modes. The lowest absolute error for the model accuracy forecast is 2.9 percent for shared-ride, two passengers; the highest is 35.3 percent for the walk mode. The lowest absolute error for the projection accuracy forecast is 2.7 percent for shared-ride, two passengers; the highest is 38.8 percent for the walk mode.

Table 5: Comparison of Daily Mode Share from the Validation Tests to the 2000 Survey

Mode	Survey[a]	1. Model Accuracy	2. Projection Accuracy	3. Induced Travel
Drive-Alone	47.5%	51.1% (7.7%)[b]	50.7% (6.7%)	51.2% (7.7%)
Shared-Ride 2	25.1%	24.4% (-2.9%)	24.4% (-2.7%)	24.3% (-3.1%)
Shared-Ride 3+	18.5%	15.3% (-17.5%)	15.4% (-17.0%)	15.2% (-17.7%)
Transit-Walk	0.8%	0.7% (-14.8%)	0.8% (-5.9%)	0.7% (-16.7%)
Transit-Drive	0.2%	0.2% (-8.8%)	0.3% (26.2%)	0.1% (-49.3%)
Walk	5.1%	6.9% (35.3%)	7.1% (38.8%)	7.0% (37.7%)
Bicycle	1.3%	1.5% (13.0%)	1.5% (13.4%)	1.5% (14.6%)

a. Source SACOG, 2002
b. Figures in parentheses are percentage change from the validation tests to the survey.

Table 6 presents the comparison of daily travel results, VMT, VHT, and VHD to the SACMET01 2000 results. As described above, regional VMT, VHT, and VHD estimates are not available from the 2000 survey, and the best available estimates were from SACMET01 2000. These total regional estimates are important because they are key inputs to air quality models and key evaluation criteria for proposed new roadway projects (that is, reduced congestion or VHD). The model accuracy forecasts indicate an error of 5.7 percent for VMT, 4.2 percent for VHT, and 17.1 percent for VHD. The projection accuracy forecasts indicate an error of 11.8 percent for VMT, 12.8 percent for VHT, and 38.4 percent for VHD. The errors for the projection accuracy forecasts are significantly higher than the errors for the model accuracy forecasts because of the overestimation of population in the 1991 projections. Table 6 indicates that the projection overestimated total households by approximately 8 percent and total employment by about

9 percent. The induced travel forecast indicates less VMT and greater VHT and VHD compared to the model accuracy forecast because of the smaller 1991 roadway network.

Table 6: Comparison of Daily VMT, VHT, and VHD from the Validation Tests to the SACMET01 2000[a]

	SACMET01 2000	1. Model Accuracy	2. Projection Accuracy	3. Induced Travel
Vehicle Miles Traveled (VMT)	39,825,519	42,101,575 (5.7%)[b]	44,530,308 (11.8%)	41,882,150 (5.2%)
Vehicle Hours of Travel (VHT)	1,149,087	1,068,650 (4.2%)	1,295,761 (12.8%)	1,213,957 (5.6%)
Vehicle Hours of Delay (VHD)	109,707	128,482 (17.1%)	151,835 (38.4%)	143,664 (31.0%)

a. Regional VMT, VHT, and VHD estimates are not available from the 2000 survey; the best available estimates are obtained from the SACMET01 2000.

b. Figures in parentheses are percentage change from the validation tests to the model trips.

The summary of analytic results for the validation tests is presented in Table 7 on page 21. The overestimation of household and employment projection in 1991 for the year 2000 produces relatively large errors in total trip generation (8.1 percent). The error in total trip generation for both model and projection error (2.0 percent) is lower than projection error only (8.1 percent) because the overestimation that results from projection error is offset by the underestimation that results from model error. The total error for trip generation in the model accuracy forecast is -6.1 percent. The range of trip generation errors for the various trip purposes is largest for model and projection error (-10.3 to 36.9 percent), followed by model error (-19.1 to 25.3 percent), and finally projection error (6.0 to 11.6 percent).

The model's representation of induced travel for trip generation was not significant; all the results showed no change, with the exception of 0.1 percent for the home-shop purpose. As described above, the trip generation step in the model is relatively insensitive to change in travel time and cost. The induced travel results that compare the induced travel forecast to observed 2000 travel produce unreasonable outcomes for the home-work and home-shop trip purposes. The increase in the roadway and transit network in the year 2000 compared to the year 1991 should increase all nonwork trip purposes. These unreasonable outcomes appear to be the result of model error. The adjusted induced travel results, in which the induced travel forecast is adjusted to account for the model error, produce more reasonable results. There is a small total increase in trip generation (0.4 percent) and increases for all trip purposes (ranging from 0.4 to 6.9 percent), with the exception of the home-work trip purpose. This last result is the best indication of actual induced trip generation in the region over the nine-year period.

As discussed above, in general, the results show that the SACMET94 model tends to underestimate shared-ride and transit modes and overestimate the drive-alone and walk and bike modes. Model error ranges from -17.5 to 35.3 percent. The projection errors tend to reduce the errors somewhat for the drive-alone, shared-ride, and transit-walk modes, but increase the errors somewhat for the transit-drive, walk, and bike modes. Model and projection errors range from -17.0 to -38.4 percent. The mode choice results for model induced travel forecasts show little change in mode choice, as discussed above.

The daily vehicle travel results for the model error suggest that the model overestimates VMT by 5.7 percent, VHT by 4.2 percent, and VHD by 17.1 percent. Projection error increases the overestimation of VMT by 6.1 percent, VHT by 8.6 percent, and VHD by 21.3 percent. The model and projection error may be considered relatively high for the nine-year period (11.8 percent for VMT and 12.8 percent for VHT). VHD, the measure of congestion, can be considered high for all the error results.

The induced travel results for VMT show a 0.5 percent increase for model induced travel and a 0.9 percent increase for adjusted induced travel (again, the best indicator of actual induced travel in this study). The induced travel result for VMT is unreasonable (-10.6 percent) because this result does not account for model error. A summary of changes in lane miles and elasticity of VMT with respect to lane miles for the induced travel results is provided in Table 8 on page 22. There is a 3.8 percent increase in roadway lane miles from 1991 to 2000. The model induced travel results produce an elasticity of VMT with respect to lane miles of 0.14 and the adjusted induced travel results produce an elasticity of 0.22. Thus, the model's representation of induced demand underestimates induced travel compared to our best estimate of actual induced travel over the nine-year period. The results are low compared to the elasticities reported in the literature for induced travel (see Table 9 on page 22), which range from 0.3 to 1.0. However, the results do not isolate the effect of expanded transit service and high-occupancy vehicle (HOV) lanes. Improved transit service would reduce the VMT and offset increases in VMT resulting from new highway construction. HOV lanes may induce less travel because of the effort required to form carpools.

The induced travel results for VHT and VHD produce a 1.4 percent reduction in VHT and an 11.8 percent reduction in VHD for model induced travel, and a 1.2 percent reduction in VHT and an 8.6 percent reduction in VHD for adjusted induced travel. Reductions are much larger for the induced travel results because of the unreasonable reduction in VMT. Compared to the adjusted induced travel result, the model induced travel appears to overestimate VHT somewhat and overestimate VHD (a measure of congestion) to a larger degree.

Table 7: Summary of Analytic Results for the Validation Tests

	Model Error	Model & Projection Error	Projection Error	Model Induced Travel	Induced Travel	Adjusted Induced Travel
Trip Generation						
Home-Work	0.6%	8.0%	7.4%	0.0%	-0.6%	0.0%
Home-Shop	25.3%	36.9%	11.6%	0.1%	-20.2%	6.9%
Home-Other	-8.5%	-0.8%	7.6%	0.0%	9.3%	0.8%
Work-Other	-10.5%	-4.5%	6.0%	0.0%	11.7%	1.1%
Other-Other	-19.1%	-10.3%	8.8%	0.0%	23.5%	3.8%
Home-School	-9.1%	-1.6%	7.5%	0.0%	10.0%	0.8%
Total	-6.1%	2.0%	8.1%	0.0%	6.5%	0.4%
Mode Choice						
Drive-Alone	7.7%	6.7%	-1.0%	0.0%	-7.1%	0.6%
Shared-Ride 2	-2.9%	-2.9%	0.2%	0.1%	3.2%	0.2%
Shared-Ride 3+	-17.5%	-17.0%	0.5%	0.2%	21.5%	3.4%
Transit-Walk	-14.8%	-5.9%	8.8%	2.3%	20.1%	4.6%
Transit-Drive	-8.8%	26.2%	35.1%	79.8%	97.1%	81.1%
Walk	35.3%	38.8%	3.5%	-1.7%	-27.4%	12.3%
Bicycle	13.0%	13.4%	0.3%	-1.4%	-12.7%	0.3%
Daily Vehicle Travel						
VMT	5.7%	11.8%	6.1%	0.5%	-10.6%	0.9%
VHT	4.2%	12.8%	8.6%	-1.4%	-5.3%	-1.2%
VHD	17.1%	38.4%	21.3%	-10.6%	-23.6%	-7.9%

Table 8: Summary of Change in Lane Miles and Elasticity of VMT with Respect to Lane Miles for the Induced Travel Results

	2000	1991	% Change in Lane Miles	Elasticity of VMT with Respect to Lane Miles	
				Model Induced Travel	Adjusted Induced Travel
Roadway lane miles	87,421	84,224	3.8%	0.14	0.22

Table 9: Long-Term Elasticities of VMT with Respect to Lane Miles Reported in the Literature

Source	Geographic Region	Elasticity Range
Hansen and Huang 1997	County and Metropolitan area	0.3 to 0.7 (county) 0.5 to 0.9 (metropolitan)
Noland and Cowart 2000	Metropolitan area	0.8 to 1.0
Fulton et al. 2000	County	0.5 to 0.8
Noland 2001	State	0.7 to 1.0

CONCLUSIONS

A number of conclusions can be made for the historical forecasting validation study of the 1994 Sacramento travel demand model. First, the results suggest that the model (that is, its functional form and parameters) modestly overestimates VMT and VHT (5.7 and 4.2 percent, respectively) but more significantly overestimates VHD (17.1 percent). Second, the errors in the 1991 socioeconomic/land use projections approximately double the model's errors in vehicle travel (11.8 percent for VMT, 12.8 percent for VHT, and 38.4 percent for VHD). Third, it appears that the model underestimates induced travel compared to the estimate of actual induced travel in this study. However, the upward bias in the model error swamps this underestimation. Fourth, the elasticity of VMT, with respect to lane miles estimates for the model and actual travel over the nine-year period, are low compared to those in the literature (0.14 and 0.22, respectively). This may be explained by the fact that this study could not isolate the effect of new transit service or HOV lanes on reducing the increase in VMT resulting from new roadway construction.

The 1994 Sacramento regional travel demand model is no longer used in the region; it has been replaced by the 2001 Sacramento regional travel demand model. The new model has been recalibrated to 2000 survey data and some structural changes have been made to the model. However, the results of this study indicate that if the 1994 model were used for conformity analyses in this region, its overestimation of daily vehicle travel would provide a relatively generous margin of error with respect to meeting air quality emissions budgets. Daily vehicle travel results are key inputs to emissions models. On the other hand, in the analysis of travel effects of proposed highway investment projections in environmental impact statements, the overestimation of the daily travel results would tend to overestimate no-build travel demand and congestion and thus the need for new highway projects in the region. Compared to the no-build alternative, the magnitude of change for the highway alternative would have to be greater than the model error to be considered significantly different. This may be a difficult standard for the typical new highway project to meet.

The results of this study illustrate how validation tests can be used to gauge the degree of precision with which a model can be applied to policy studies. Making the uncertainty in the model explicit may alert the public and decision makers to potential problems and allow them to take steps now to avoid harmful future effects.

In the context of air quality conformity, if validation tests of a region's travel demand model indicate that there is a downward bias in the model, the region may want to ensure that their region meets emissions budgets by an appropriate margin. This may involve more aggressive implementation of emission reduction measures (for example, technology-based strategies, land use measures, transit investment, and pricing policies) and reconsideration of new highway projects. In addition, the EPA may consider specifying the level of certainty that it considers a sufficient demonstration of conformity and/or requiring contingency plans that could be implemented if a region failed to meet NAAQS.

In the context of the National Environmental Policy Act (NEPA) process and, in particular, the analyses of proposed highway investments in environmental impact statements, if the users of model results are aware of the model's uncertainty, the focus of the analysis may shift from meeting a point estimate of demand for travel in a particular corridor and toward the rank ordering of a number of alternative policy strategies. It may be far more defensible to use an uncertain model to compare competing alternatives rather than projecting and meeting a particular point estimate, as long as the model's structure is not biased toward particular modes or policies. The evaluation of a range of alternatives is more likely to address stakeholder concerns and encourage innovative thinking about the future.

It is well known that local interest groups are increasingly suspicious of the travel demand and emissions models used by metropolitan planning organizations in their conformity analyses and environmental impact statements. They are concerned that travel demand models do not adequately represent induced travel and thus underestimate emissions effects of regional transportation plans that include new roadways, or bias the analysis of alternatives in environmental impact statements in favor of roadway projects. Some are even concerned that underlying assumptions in the model are manipulated to make results meet emissions budgets or to make the proposed projects (generally roads) in environmental impact statements look beneficial.

As a result, there can be numerous technical debates and, ultimately, lawsuits over the adequacy of travel demand models that arise in both the air quality conformity and the NEPA processes. Candid representation of the uncertainty in models may address the stakeholders' concerns about the limitations of models and help refocus debates away from technical modeling issues to more careful consideration and planning for future alternative strategies to address air quality and transportation problems.

APPENDIX A: MODIFICATIONS TO THE 2000 INPUT DATA FOR THE SACMET94 MODEL

CHANGES IN TRAVEL ANALYSIS ZONES FROM 1991 TO 2000

The total number of travel analysis zones (TAZ) increased from 1061 in from the SACMET94 model to 1142 in the SACMET01 model. The SACMET94 model was completed in 1994 with 1991 data and the SACMET01 model was recalibrated in 2001 with 2000 data. The first step in the preparation of data for the validation study was to identify and document the history of these TAZ changes.

The 1996 SACMET Model (SACMET96)

The total number of TAZ increased from 1061 in the SACMET94 model to 1077 in the SACMET96 model. Five TAZs in the Southern Pacific Railyard/Richard Blvd. area, north of the Sacramento CBD (central business district), were split according to the adopted development plan. Table A-1 lists the TAZ changes from SACMET94 to SACMET96.

Table A-1: Zone Changes from SACMET94 to SACMET96

SACMET94	SACMET96
779	779,1162-1068
780	780,1069
781	781,1070-1074
782	782,1075-1076
783	783,1077

The 1999 SACMET Model (SACMET99)

The total number of TAZ was increased from 1077 in the SACMET96 model to 1141 in the SACMET99 model. The following describes the TAZ changes from SACMET96 to SACMET99 (Garry 2002):

> In preparation for the 1999 MTP and the 2000 Census, a comprehensive review was made and incorporated into SACMET99. Zone splits were made for two reasons: (1) to accommodate expected changes in Census blocks and block groups; (2) to divide zones with large numbers of future growth. When splitting zones, one of the "new" zones is given the "old" zone

number and additional number(s) are assigned to the new areas. This process increased the TAZ total from 1,077 to 1,138.

Three “pseudo” zones were also created to improve model operations. There are two large institutions that comprise single zones and cannot be split. However, they are very large and loading traffic onto a limited number of centroid connectors produces very unrealistic assignments. The two zones represent McClellan Air Force Base and the UC Davis campus. Each zone was split into two TAZs.

One additional zone was created for the park-and-ride lot at the Watt/I-80 LRT station. In the SACMET model, the drive-to-transit part of the transit trips are converted to vehicle trips and assigned to the road network. Generally the zone closest to the light rail station is designated as the proxy node to the station since vehicle trips can only be assigned to zone centroids. However, given the unique location of this park-and-ride lot (in the middle of the freeway), there is no adequate TAZ to serve as a proxy. So an additional zone (with no households or jobs) was created. Therefore, the SACMET99 model has 1,141 zones.

Table A-2 lists the zone changes from SACMET96 to SACMET99.

Table A-2: Zone Changes from SACMET96 to SACMET99

SACMET96	SACMET99
41	41, 1078
68	68, 1079
81	81, 1140
107	107, 1080
166	166, 1137
179	179, 1081
184	184, 1082-1083
186	186, 1084-1087
188	188, 1088
187	187, 1089-1090
206	206, 1091
313	313, 1139
330	330, 1141

Table A-2: Zone Changes from SACMET96 to SACMET99 (Continued)

SACMET96	SACMET99
563	563, 1138
839	839, 1092
848	848, 1093
1022	1022, 1094
1023	1023, 1095
849	849, 1096
1025	1025, 1097-1098
850	850, 1099
851	851, 1100
852	852, 1101
1030	1030, 1102
1034	1034, 1103
258	258, 1104
257	257, 1105
254	254, 1106
323	323, 1107
324	324, 1108
338	338, 1109
345	345, 1110
538	538, 1111
540	540, 1112-1113
544	544, 1114-1116
545	545, 1117
546	546, 1118
564	564, 1119-1121
585	585, 1122-1124

Table A-2: Zone Changes from SACMET96 to SACMET99 (Continued)

SACMET96	SACMET99
619	619, 1125
618	618, 1126
623	623, 1127-1129
636	636, 1130
927	927, 1131
754	754, 1132-1133
719	719, 1134
727	727, 1135
722	722, 1136

The 2001 SACMET Model (SACMET01)

The total number of TAZ was increased from 1141 in the SACMET99 model to 1142 in the SACMET01 model. The following describes the TAZ changes from SACMET99 to SACMET01 (Garry 2002):

> For the SACMET01 model and the 2002 MTP, the model was updated with the 2000 household travel survey. We wanted to keep the zone structure unchanged. However, one additional zone was necessary. This zone is for a proposed casino along US 50 that will have its own interchange and be isolated from adjoining land uses. To accommodate the change this zone was assigned number 1139 and the three "pseudo" zones were incremented by one. There are now 1,142 zones in SACMET01.

MODIFICATIONS OF YEAR 2000 INPUT DATA SETS FROM THE SACMET01 TO THE SACMET94 MODEL

To simulate the validation tests for this study, the SACMET01 input data sets were modified to be compatible with the SACMET94 model. The following data sets in the SACMET01 model were altered (see DKS 2000 for a complete description of the data files): hhmv.txt cross-classified households; zbas.txt basic zonal data; tgsp.txt gateway trips and special generators; thru.txt through-trips; tran.lin transit network; base.net roadway network.

hhmv.txt – cross-classified households

The file structure is the same in both the SACMET01 and SACMET94 model. The file was modified to aggregate the number of households by category and by zone from the divided zones back to the original zones. Note that the "pseudo" zones were added to the SACMET94 zone structure because they are necessary for proper model function with Year 2000 levels of population and employment growth, and Year 2000 network changes.

zbas.txt basic zonal data

The file structure is the same in both the SACMET01 and SACMET94 model, except that four additional columns subdividing employment types were added in the SACMET01 model. These four columns were deleted. The file was modified to aggregate the data from the divided zones back to the original zones. Some of the data in this file are averages or categories that could not be summed. However, it was found that these figures were consistent across divided zones.

tgsp.txt gateway trips and special generators

In the SACMET01 model, the Year 2000 file has two new columns that break out different categories of trucks. The new columns were collapsed back to the original SACMET94 categories. In addition, the SACMET94 model required special generator data for some zones that were not included in the SACMET01 tgsp.txt file. Because the SACMET01 model included a greater number of employment categories, it did not require this special generator data. Special generator data for the SACMET94 model for the Year 2000 was created by applying production and attraction rates for specific trip purposes and zone types from the SACMET01 model to year 2000 employment for the missing special generator zones.

thru.txt through-trips

In the SACMET01 model, the Year 2000 file has one new column that is not in the 1991 file for the SACMET94 model. This new column broke out truck trips from total vehicle trips. The new column was collapsed back into the original SACMET94 category of total vehicle trips.

transit.lin transit network

The coding of the park-and-ride lots in the 2000 transit network was revised to reflect the change from the 2000 zone structure to the 1994 zone structure. The new zones were eliminated unless they were "pseudo" zones. The nodes and links for the transit lines were manually corrected to match the changes made to the roadway network, that is, the revision from the new to the old zone structure (described below). The transit modes and fare structure in the SACMET94 model were revised to match those of the SACMET01 model.

base.net roadway network

The Year 2000 roadway network for the SACMET01 model was manually revised to be consistent with that of the SACMET94 zone system. To create the 1991 roadway network, new projects (that is, after 1991) were eliminated from the revised Year 2000 roadway networks.

ABBREVIATIONS AND ACRONYMS

CBD	Central Business District
EPA	Environmental Protection Agency
HOV	High-Occupancy Vehicle
MTP	Metropolitan Transportation Plan
NAAQS	National Ambient Air Quality Standard
NEPA	National Environmental Policy Act
SACMET	Sacramento Regional Travel Demand Model
SACOG	Sacramento Area Council of Governments
TAZ	Travel Analysis Zone
UTP	Urban Transportation Planning
VHD	Vehicle Hours of Delay
VHT	Vehicle Hours Traveled
VMT	Vehicle Miles Traveled

BIBLIOGRAPHY

Chatterjee, A., et. al. *Improving Transportation Data for Mobile-Source Emissions Estimates* (NCHRP 25-7). Washington, D.C.: National Cooperative Highway Research Program, 1995.

Chu, X. *Highway Capacity and Areawide Congestion*. Preprint for the 79th Annual Meeting of the Transportation Research Board. Washington. D.C.: National Research Council, 2000.

DKS Associates. *Model Development and User Reference Report*. Sacramento, CA.: Sacramento Area Council of Governments, October 1994.

Expanding Metropolitan Highways: Implication for Air Quality and Energy Use. Transportation Research Board Special Report 245, National Research Council. Washington, D.C.: National Academy Press, 1995.

Fulton, L.M., D.J. Meszler, R.B. Noland and J.V. Thomas. *A Statistical Analysis of Induced Effects in the U.S. Mid-Atlantic Region*. Preprint for the 79th Annual Meeting of the Transportation Research Board. Washington, D.C.: National Research Council, 2000.

Induced Travel: A Review of Recent Literature with Discussion of Policy Issues. Washington, D.C.: Office of Policy, Energy and Transportation Sectors Division, 2000.

Garry, Gordon. Sacramento Area Council of Governments. E-mail communication with author, 2002.

Goodwin, P.B. “Empirical evidence of induced traffic, a review and synthesis.” *Transportation* (1996) 23, 35-54.

Hansen, M.Y. and Y. Huang. “Road supply and traffic in California Urban Areas.” *Transportation Research A*. (1997) 31, 205-218.

Hartgen, D. “Virtual models in transportation.” *Transportation Quarterly* (1995) 49 (4): 73-80.

Highway Capacity Expansion and Induced Travel: Evidence and Implications. Transportation Research Circular, Transportation Research Board, National Research Council, February 1998.

Morgan, M. and M. Henrion. *Uncertainty*. Cambridge, MA.: Cambridge University Press, 1990.

“National Air Quality 2001 Status and Trends.” EPA website, available www.epa.gov/oar/aqtrnd01.

Noland, R.B. “Relationships between highway capacity and induced vehicle travel.” *Transportation Research A*. (2001) 35A:1, 47-72.

Noland, R.B. and W.A. Cowart. *Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel.* Preprint for the 79th Annual Meeting of the Transportation Research Board. Washington, D.C.: National Research Council, 2000.

Projections of Population, Housing, Employment, and Primary and Secondary Students. Sacramento Area Council of Governments, May 2001.

Pre-Census Travel Behavior Report Analysis of the 2000 SACOG Household Travel Survey. DKS Associates and Mark Bradley Research & Consulting, July 2001.

Sacramento Regional Travel Demand Model Version 2001 (SACMET01): Model Update Report. DKS Associates, March 2002.

Stopher, P.R. and A.H. Meyburg. *Urban Transportation Modeling and Planning*. D.C. Heath, 1975.

ABOUT THE AUTHOR

CAROLINE RODIER

Caroline Rodier is a post-doctoral researcher at the University of California PATH and a Research Associate at the Mineta Transportation Institute. She has a Ph.D. in Ecology, focusing on environmental policy analysis and transportation planning. Her research involves the use of integrated land use and transportation, regional travel demand, and emissions models to evaluate the travel, economic, equity, and air quality effects of a wide range of transportation (traditional and innovative) and land use policies. Her dissertation addresses key issues of uncertainty in travel and emissions modeling, in particular, population projections and induced travel.

Dr. Rodier has earned a variety of awards including the University of California Outstanding Transportation Student of the Year, the Federal Highway Administration's Dwight David Eisenhower Transportation Fellowship, and the Environmental Protection Agency's Science to Achieve Results Fellowship. She has authored more than 10 journal articles and 20 reports and proceedings articles.

PEER REVIEW

San José State University, of the California State University system, and the MTI Board of Trustees have agreed upon a peer review process required for all research published by MTI. The purpose of the review process is to ensure that the results presented are based upon a professionally acceptable research protocol.

Research projects begin with the approval of a scope of work by the sponsoring entities, with in-process reviews by the MTI Research Director and the project sponsor. Periodic progress reports are provided to the MTI Research Director and the Research Associates Policy Oversight Committee (RAPOC). Review of the draft research product is conducted by the Research Committee of the Board of Trustees and may include invited critiques from other professionals in the subject field. The review is based on the professional propriety of the research methodology.

Funded by
U.S. Department of Transportation and California Department of Transportation

San José State
UNIVERSITY

SAN JOSE STATE UNIVERSITY COLLEGE OF BUSINESS