California High-Speed Rail Ridership and Revenue Model

Business Plan Model-Version 3 Model Documentation

final

report

prepared for

California High-Speed Rail Authority

prepared by

Cambridge Systematics, Inc.

February 17, 2016

www.camsys.com

final report

California High-Speed Rail Ridership and Revenue Model

Business Plan Model-Version 3 Model Documentation

prepared for

California High-Speed Rail Authority

prepared by

Cambridge Systematics, Inc.
555 12th Street, Suite 1600
Oakland, CA 94607

date

February 17, 2016

Table of Contents

List of Tables

List of Figures

Abbreviations

ACE	Altamont Corridor Express
ACV	Arcata/Eureka Airport
ACS	American Community Survey
ASC	Alternative Specific Constant
ASC-LLC	Airport Systems Consulting, LLC
AP	Attraction-Production
ATS	1995 American Traveler Survey
BFL	Meadows Field Airport (Bakersfield)
BLS	Bureau of Labor Statistics
BPM-V3	Business Planning Model – Version 3
BRT	Bus Rapid Transit
BUR	Bob Hope Airport (Burbank)
BTS	Bureau of Transportation Statistics
CHSRA	California High Speed Rail Authority
CS	Cambridge Systematics, Inc.
CSHTS	California Statewide Household Travel Survey
CSTDM	California Statewide Travel Demand Model
CTPP	Census Transportation Planning Package
CVR	Conventional Rail
EDD	California Employment Development Department
EEO	Equal Employment Opportunity
FAA	Federal Aviation Administration
FAT	Fresno Yosemite International Airport
FIML	Full Information Maximum Likelihood

HBO	Home-Based Other
HBSC	Home-Based School
HBSH	Home-Based Shopping
HBSP	Home-Based Serve Passenger
HBSR	Home-Based Social/Recreational
HBW	Home-Based Work
HSR	High Speed Rail
LAX	Los Angeles International Airport
LGB	Long Beach Airport
LEHD	Longitudinal Employment and Household Dynamics
LMI	Labor Market Information Division of EDD
LRT	Light Rail Transit
MOD	Modesto City-County Airport
MPO	Metropolitan Planning Organization
MRY	Monterey Regional Airport
MTC	San Francisco Metropolitan Transportation Commission
NAICS	North American Industrial Classification System
NHBW	Nonhome-Based Work
NHBNW	Nonhome-Based Non-Work
NEC	Northeast Corridor (Amtrak)
NHTS	National Household Travel Survey
NPTS	National Passenger Transportation Survey
OAK	Oakland International Airport
OD	Origin-Destination
ONT	Ontario International Airport

OTM	On the Map (mapping service for LEHD)
OXR	Oxnard Airport
QCEW	Quarterly Census of Employment and Wages
PA	Production-Attraction
PRG	CHSRA Peer Review Group
PSP	Palm Springs International Airport
PUMA	U.S. Census Bureau's Public Use Microsample Area
PUMS	U.S. Census Bureau's Public Use Microdata Sample
RP	Revealed Preference
RP/SP	Revealed Preference/Stated Preference
RTAP	CHSRA's Ridership Technical Advisory Panel
SACOG	Sacramento Area Council of Governments
SAN	San Diego International Airport
SANDAG	San Diego Association of Governments
SBA	Santa Barbara Airport
SESA	State Employment Security Agencies
SFO	San Francisco International Airport
SJC	Mineta San Jose International Airport
SMF	Sacramento International Airport
SNA	John Wayne Airport (Orange County)
SP	Stated Preference
TAZ	Traffic Analysis Zone
UCFE	Unemployment Compensation for Federal Employees
UI	Unemployment Insurance
URBR	Urban Rail

1.0 Introduction and Model System Overview

1.1 Introduction

Since 2007, Cambridge Systematics (CS) has been supporting the California High-Speed Rail Authority (CHSRA) by producing ridership and revenue forecasts for different high-speed rail (HSR) service options. CS developed the "Version 1" model, which was estimated and calibrated using data from the 2000-2001 California Household Travel Survey (CSHTS) and stated-preference (SP) survey data from a revealed preference/stated preference (RP/SP) survey conducted in 2005 for the express purpose of HSR ridership and revenue forecasting.[1] The Version 1 model was used to support alternatives analyses and project-level environmental work.

In preparation for the 2012 Business Plan, CS updated the Version 1 model based on a new trip frequency survey of long-distance travel made by California residents and recalibrated it to 2008 conditions. The enhancements culminated in ridership and revenue model runs used to support the California High-Speed Rail 2012 Business Plan.[2]

In 2012 and 2013, CS made additional enhancements to the ridership and revenue model to accommodate the evolving forecasting needs of the Authority, including the 2014 Business Plan. The enhanced model, known as the Version 2 ridership and revenue model, represented a major overhaul of all model components and incorporated new and reanalyzed data from the 2012-2013 CSHTS and the 2005 SP and revealed preference (RP) data. The enhancements to the Version 2 model incorporated the recommendations of the Authority's Ridership Technical Advisory Panel (RTAP) and considered comments from the Authority's Peer Review Group (PRG) and the Government Accountability Office's report. In addition to the ridership and revenue model enhancements, CS developed a risk analysis approach to estimate uncertainty in the forecasts and prepare and present ridership and revenue forecasts.[3]

Since application of the Version 2 model in the 2014 Business Plan, CS has updated the model to the current Business Plan Model-Version 3 (BPM-V3). During the development of the 2014 Business Plan, CS was completing a new 2013-2014 RP/SP survey that has now been incorporated into the BPM-V3 model.[4] The BPM-V3 has been estimated using data from the 2013-2014 RP/SP survey in addition to the 2005 RP/SP survey and the 2012-2013 CSHTS data. Additionally, the model includes an adjustment to explicitly divide auto costs by an assumed average auto occupancy of 2.5 for those who travel in groups.

Finally, based on model applications using the Version 2 model, CS identified a tendency of the model to forecast trips with long access and/or egress times, coupled with relatively short trips on the main mode.

[1] Cambridge Systematics, Inc., *Bay Area/California High-Speed Rail Ridership and Revenue Forecasting Study: Interregional Model System Development*, prepared for Metropolitan Transportation Commission and the California High-Speed Rail Authority, August 2006.

[2] Cambridge Systematics, Inc., *California High-Speed Rail 2012 Business Plan, Ridership, and Revenue Forecasting, Final Technical Memorandum*, prepared for Parsons Brinckerhoff for the California High-Speed Rail Authority, April 12, 2012.

[3] Cambridge Systematics, Inc., *2016 Business Plan Risk Analysis Methodology Summary*, prepared for the California High-Speed Rail Authority, January 29, 2016.

[4] Cambridge Systematics, Inc., Corey, Canapary and Galanis Research, and Kevin F. Tierney, *California High-Speed Rail 2013-2014 Traveler Survey – Survey Documentation*, prepared for the California High-Speed Rail Authority, February 2015.

This tendency did not show up in the model calibration or validation since most observed trips on conventional rail (CVR) were relatively short and, conversely, most trips by air were relatively long. Since HSR provided competitive service for the full range of distances, trips by HSR were more likely affected by the long access-egress/short main mode issue and, thus, the issue was not identified until model application.

In response, CS made enhancements to the BPM-V3 by including four new variables in the mode choice utility functions: auto access time, non-auto access time, auto egress time, and non-auto egress time with each being divided by total auto distance. These variables appear in the access and egress utility components of the mode choice model. The BPM-V3 model is being used to produce forecasts of total ridership and revenue primarily for business planning purposes.

1.2 Overview of BPM-V3

In many ways, the structure of the BPM-V3 is very similar to the structure of the Version 2 model. Like the Version 2 model, the BPM-V3 includes the following components:

- **Long-Distance Travel –** Trips within California that are to or from locations 50 or more miles from a traveler's home, measured by straight-line distance length; and
- **Short-Distance Travel within the Southern California Association of Governments (SCAG) and San Francisco Metropolitan Transportation Commission (MTC) Regions**[5] – Trips that are less than 50 miles from a traveler's home, measured by straight-line distance, that are made totally within the SCAG and MTC regions.

Figure 1-1 shows the components in the BPM-V3. The long-distance model estimates trip frequency, destination choice, and access/egress and main mode choice stratified by trip purpose (business, commute, recreation, and other). The long-distance trip frequency models account for induced travel based on improved accessibilities due to high-speed rail options. Likewise, the destination choice models account for induced high speed rail corridor travel resulting from improved accessibilities causing diversion from other corridors.

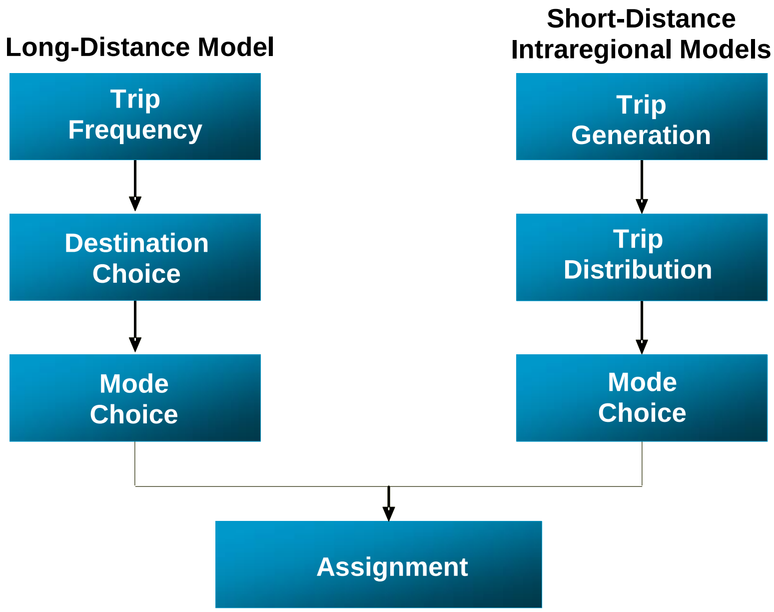
The short-distance model uses static trip tables that are summarized from the SCAG and MTC Metropolitan Planning Organization (MPO) models for particular horizon years to estimate mode choices for those urban area trips. The Trip Generation and Trip Distribution steps for the short-distance model have been performed by each MPO using their current travel models, local urban area highway and transit systems, and demographic forecasts. The resulting trip tables obtained from the MPOs are processed for input to the short distance mode choice model. For consistency within the BPM-V3, the short-distance mode choice model for each region is based on the MTC Baycast[6] model, updated to include consideration of high-speed rail. The updated mode choice model is calibrated to reproduce base year transit ridership by mode in each region. Thus, the resulting short-distance mode choice model reflects local demographics, urban area highway and transit systems, trip generation, and trip distribution for each MPO as well as using consistent procedures for forecasting short-distance high-speed rail ridership within each region.

5 The SCAG region encompasses six counties: Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The MTC region encompasses nine counties in the San Francisco Bay Area: San Francisco, Alameda, Santa Clara, Contra Costa, San Mateo, Marin, Sonoma, Solano, and Napa.

6 Metropolitan Transportation Commission, *Travel Demand Models for the San Francisco Bay Area (BAYCAST-90) Technical Summary*, June 1997.

The transit assignments from the long-distance model and the two intraregional models of short-distance travel are merged to produce total ridership and revenue on the HSR and other public modes.

Figure 1-1 BPM-V3 Components



1.3 Long-Distance Model

Long-distance trips are defined as any trip made to a Traffic Analysis Zone (TAZ) 50 miles or more from the respondent's home TAZ with one end of the trip at home and the other a location within California. All distances are calculated as straight line distances between TAZ centroids. This means that the following travel is not included (in addition to all short-distance trips, less than 50 miles in length):

- Nonhome-based travel occurring more than 50 miles from home;
- Trips by visitors to California; and
- Trips with one end outside of California.

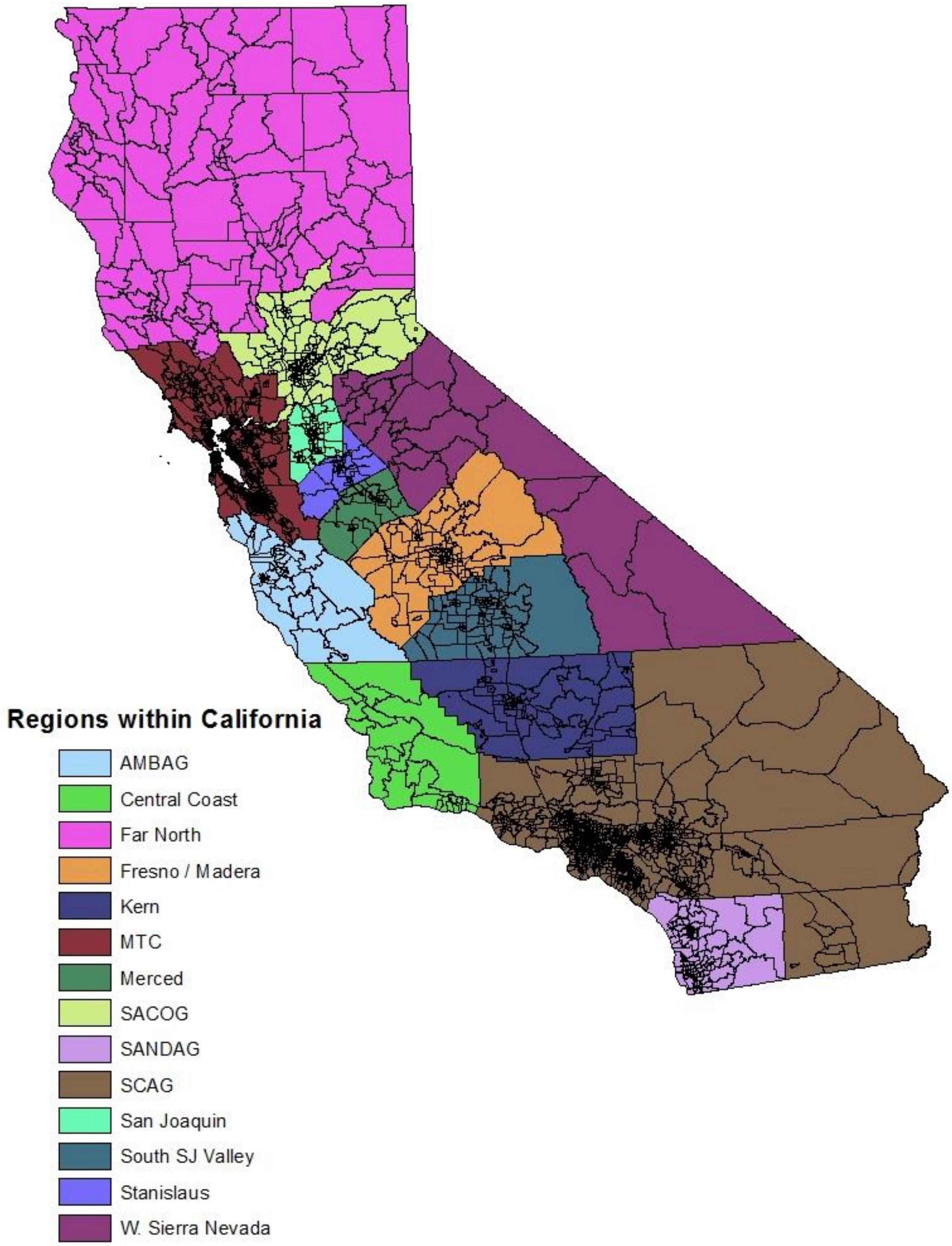
Ignoring these trips tends to reduce the expected ridership and revenue for high-speed rail, making the forecasts conservatively low. While not inconsequential, these trips are expected to make up only a small fraction of overall high-speed rail ridership. Future enhancements to the BPM-V3 may consider trips for the above three purposes as more reliable data are collected to forecast the trips. Nevertheless, the net effect of forecasting trips for the above three purposes would be an increase in high-speed rail ridership and revenue.

Figure 1-2 shows the TAZ system (outlined in black) and the 14 regions within the State (indicated by colors). The long-distance model uses the TAZ system made up of 4,683 zones as the primary unit of geography within the model, but the regions are used during calibration of the destination choice and trip frequency model and to summarize model output.

The long-distance model is stratified by four trip purposes:

- **Business –** Includes all business travel to locations other than a traveler's normal place of work.
- **Commute –** Includes all travel to a person's regular place of work. Note that a person might work from home three or more days per week but travel to an assigned office more than 50 miles from their home one or two days per week. Such travel is included in the commute category.
- **Recreation –** Includes all trips made for recreation, vacations, leisure, or entertainment.
- **Other –** Includes all trips made for other purposes, such as school, visiting friends or relatives, medical, personal business, weddings, and funerals.

Figure 1-2 Long-Distance Model TAZs and Regions



The overall structure of the long-distance model is illustrated in Figure 1-3. The primary components are the following submodels:

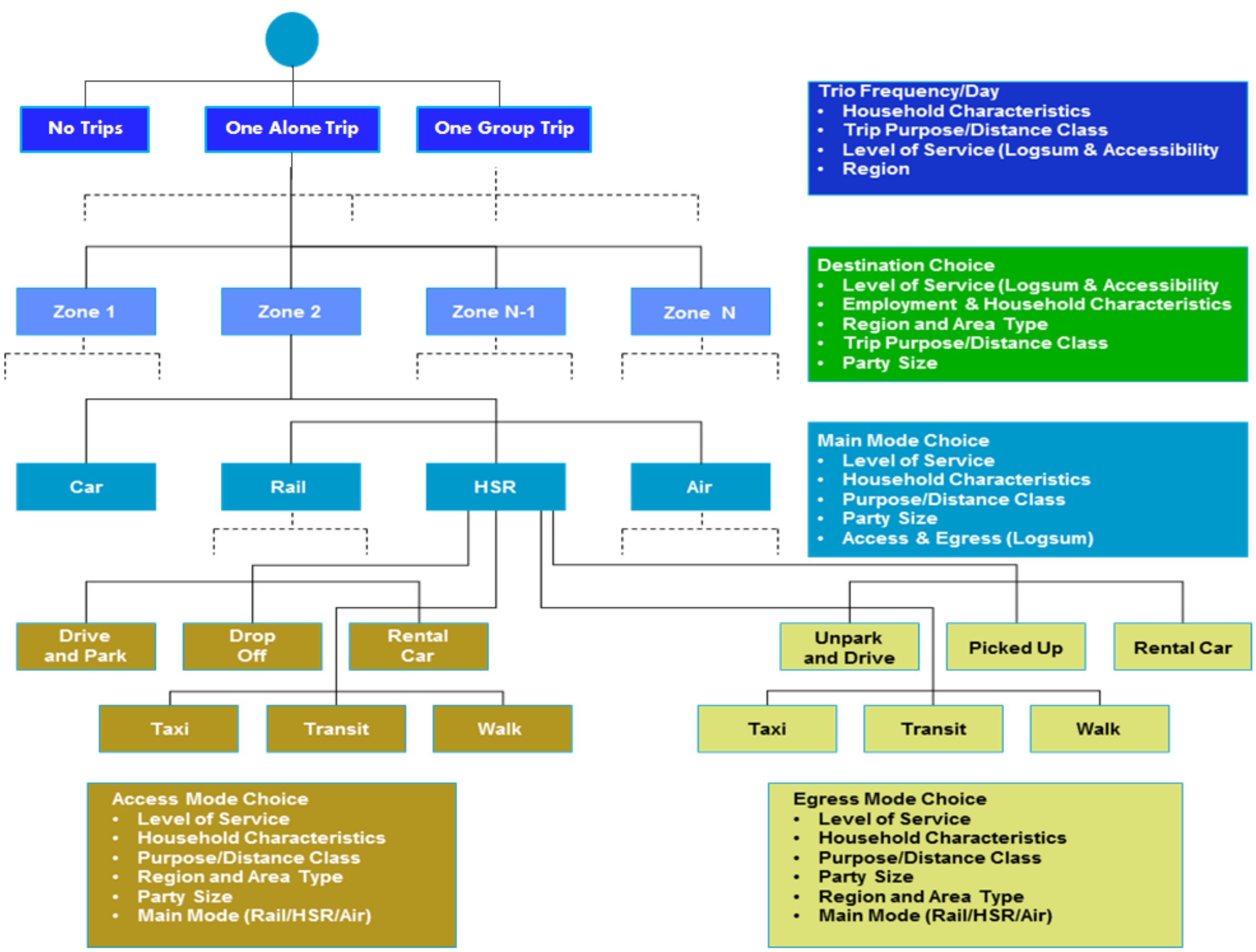
- **Trip frequency model**, which estimates the number of trips taken by a household on an average day, in the following categories:
  - Zero;
  - One alone; or
  - One in a group.

  The model uses household and zonal characteristics, and destination choice logsums.

- **Destination choice model**, which estimates the destinations of home-based trips based on distance from the origin zone, destination zonal characteristics, and main mode choice logsums.

- **Mode choice model**, which estimates the choice of main mode (e.g., auto, air, conventional rail, or high-speed rail) as well as access/egress mode. The mode choice model uses transportation level-of-service information, zonal characteristics of access and egress airports and rail stations, and household characteristics.

Figure 1-3 Long-Distance Model Structure



1.4 Short-Distance Intraregional Models

Short-distance trips (less than 50 miles in length) that take place within the SCAG or MTC region are modeled with separate intraregional mode choice models. Both the SCAG and MTC intraregional mode choice models use the structure shown in Figure 1-4, which is based on the MTC Baycast model. The models use static trip tables adopted from SCAG and MTC's regional models.[7] In addition, the models use transportation level-of-service characteristics and household characteristics developed specifically for the high-speed rail model system. The models are stratified by trip purpose:

- Home-based work;
- Home-based shop;
- Home-based recreation/other;
- Nonhome-based work; and
- Nonhome-based other.

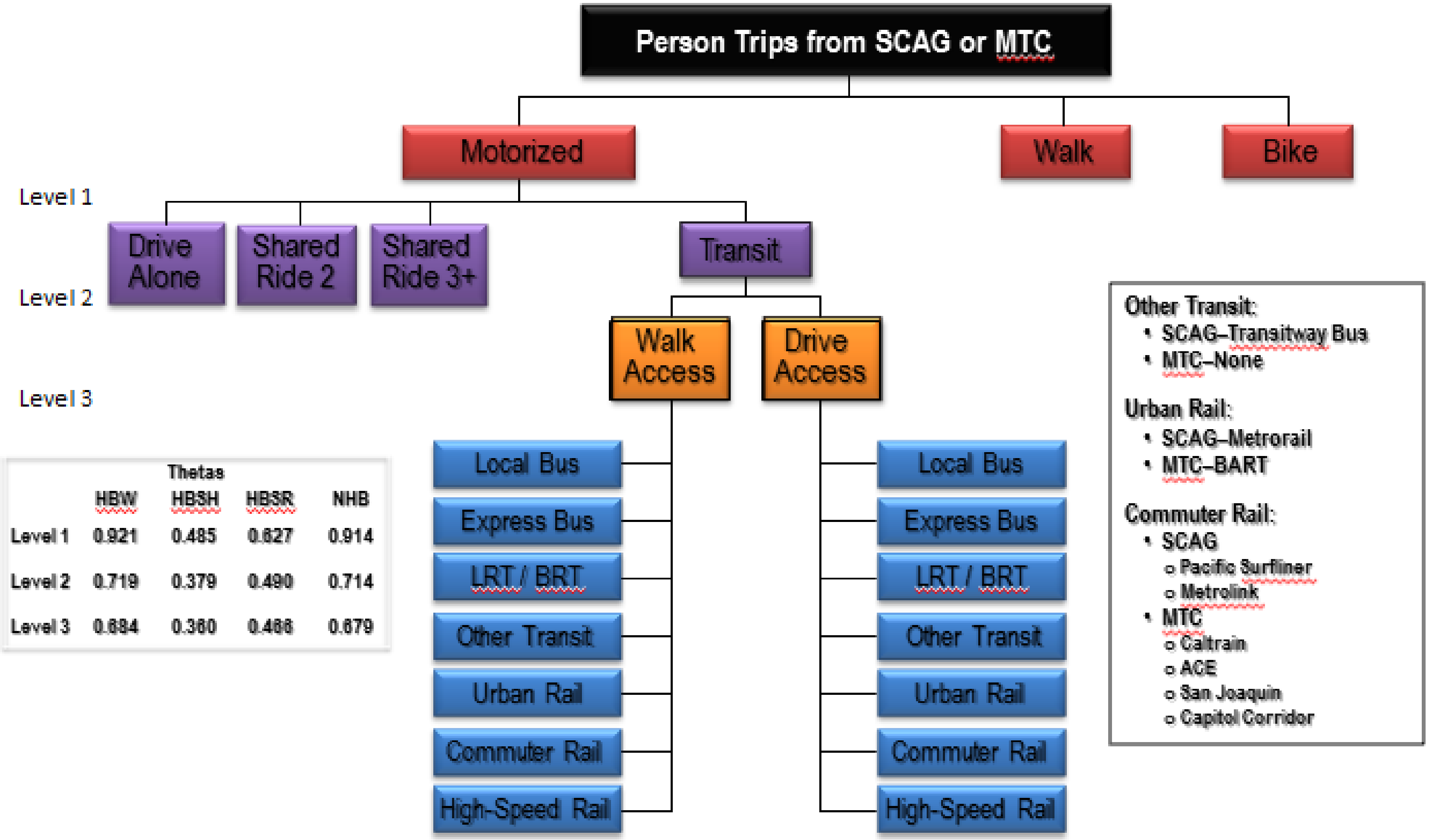
The mode choice model considers the following modes:

- **Auto Modes:**
  - Drive Alone;
  - Shared Ride 2; and
  - Shared Ride 3.
- **Nonmotorized Modes:**
  - Walk; and
  - Bike.
- **Transit Modes:**
  - Local bus;
  - Express bus;
  - Light Rail, Bus Rapid Transit, and Ferry;
  - Other Transit (i.e. Transitway Bus for SCAG, none for MTC);
  - Urban Rail (e.g. BART, Metrorail);
  - Commuter Rail (e.g. Caltrain, Metrolink); and
  - High-Speed Rail.

[7] Southern California Association of Governments. *SCAG Regional Travel Demand Model and 2008 Model Validation*. June 2012.

Metropolitan Transportation Commission. *Travel Model Development: Calibration and Validation*. May 2012.

Figure 1-4 Intraregional Model Overview



Thetas

	HBW	HBSH	HBSR	NHB
Level 1	0.921	0.485	0.627	0.914
Level 2	0.719	0.379	0.490	0.714
Level 3	0.684	0.360	0.466	0.679

1.5 BPM-V3 and Previous Model Version Differences

The Version 2 model represented a major overhaul of all model components, incorporated new and reanalyzed data, and reflected the most current thinking about California's future. The overall BPM-V3 structure is unchanged from Version 2, and thus, has these same attributes. Table 1-1 outlines the differences between the Version 1 and the Version 2/BPM-V3 long-distance models. Any differences between the BPM-V3 and the Version 2 model are shown in italics under the Version 2/BPM-V3 column. Table 1-2 and Table 1-3 outline the differences between the Version 1 and Version 2/BPM-V3 intraregional SCAG and MTC short-distance models. The Version 2 intraregional short-distance models for SCAG and MTC have been used without modification for the BPM-V3.

Table 1-1 Long-Distance Models

Item	Version 1	Version 2/BPM-V3
Model Structure	• Separate "interregional" models for short-distance (less than 100 miles) and long-distance (100 miles or more) • Conventional rail limited to lines that crossed regional boundaries	• Combined model that includes all long-distance trips 50 miles or more from home • Intraregional trips less than 50 miles are modeled using SCAG and MTC intraregional models • All conventional rail lines included
Model Estimation Data	• 2005 stated-preference data • 2001-2002 California Household Travel Survey data (without a true long-distance travel component) • Interregional trips from 2000 Urban household travel surveys performed for SCAG, MTC, and SACOG regions	• 2012-2013 California Household Travel Survey data from long-distance travel component • 2005 stated-preference and revealed-preference data • 2013-2014 RP/SP data (BPM-V3 only)
Model Calibration and Validation Data	• 2001-2002 California Statewide Household Travel Survey data (without a true long-distance travel component) • 1995 American Traveler Survey (ATS) data • 2000 Census Transportation Planning Package (CTPP) data • U.S. DOT Federal Aviation Administration (FAA) origin-destination (OD) 10-percent ticket sample for 2000-2005 • Rail passengers in 2000 by operator and route • Year 2000 traffic count data	• 2012-2013 California Household Travel Survey data weighted to Year 2010 • FAA OD 10-percent ticket sample for 2009 • Rail passengers in 2010 by operator and route
Socioeconomic Data	• 2005 data compiled from Caltrans and Metropolitan Planning Organizations • 99 market segmentation categories for household characteristics • Three employment categories	• Compiled from 2010 population synthesis data developed for California Statewide Travel Demand Model • 99 market segmentation categories for household characteristics • Nine employment categories

Item	Version 1	Version 2/BPM-V3
Highway Network and Skims	• 2005 network and skim data compiled from Caltrans network and MPO networks • Separate peak and off-peak skims used for auto • Peak-period skims are the average of AM and PM peak periods • Off-peak skims are the average of midday and night periods	• 2010 network and skim data compiled from the University of California at Davis for the Caltrans Statewide Travel Demand Model network • Peak period is represented by the AM peak • All models use an average of peak and off-peak congested speeds from CA Statewide Travel Demand Model
Station-to-Station Skims	• Slightly different processes and assumptions for HSR and CVR skims • Reliability matrix was developed external to model	• Identical processes and assumptions for HSR and CVR skims • Generalized cost assumptions are coordinated between skims and based on model coefficients • Skims use a reliability look-up table and determine reliability based on number of transfers
Station Assignment Skims	• Path-building includes all mode options • Uses post-skimming scripts to check for and then eliminate unreasonable paths to stations • All-or-nothing assignment from each TAZ to a single station that is insensitive to fares • Path-building weights differ between skims do not match mode choice model coefficients	• Path-building assumes drive-access to main mode only • Need for post skimming scripts to eliminate unreasonable paths was obviated by other network coding and modeling changes • All-or-nothing assignment that is insensitive to fares (same as Version 1) • Path-building weights are consistent across skims and mode choice model coefficients
Access/Egress Skims	• Constrained drive access distance to no more than 50 miles to CVR stations and 100 miles to airports and HSR stations • Conventional rail access to Air and High-Speed Rail was not included • Transit skims based on all-or-nothing assignments that were insensitive to fares • One set of transit skims for Air, CVR, and HSR • Separate walk access and drive access skims • Skims developed for closest TAZ centroids to stations or airports • Parking costs at stations added into toll costs • Path-building weights differ between skims do not match mode choice model coefficients	• No limits on drive access distance to airports, CVR stations or HSR stations • Conventional rail access to Air and High-Speed Rail is included • Transit skims based on multipath assignments that are sensitive to fares • Separate skims for airports and CVR and HSR stations to allow for mode-specific transit access modes • Combined walk and drive access skims for consistency • “Dummy” TAZ centroids added at locations of airports and CVR and HSR stations • Parking costs, parking availability, and rental car availability included as separate input variables • Path-building weights are consistent across skims and mode choice model coefficients

Item	Version 1	Version 2/BPM-V3
Access/Egress Mode Choice Model	• Estimated with 2005 RP and SP data and 2005 skims • Model estimated independently of Main Mode Choice Model • No restrictions on mode availability • Access/Egress mode shares from the model were not used and instead were developed using a post-processer	• Estimated with 2005 RP data, 2012-2013 CSHTS Data and 2010 skims • Estimated data included 2013/2014 RP data (BPM-V3 only) • Model estimated jointly with Main Mode Choice Model • Revised restrictions on modal availability • Access/Egress Mode share results used directly • Added 4 new variables to help explain and control long auto or public mode access / egress with short distance on the main public mode (air, CVR, or HSR) • Divided auto costs (access, egress, or main mode) for trips made in groups by an average group size of 2.5
Main Mode Choice Model	• Estimated with 2005 SP data and original 2005 skims • Coefficients on level-of-service variables were developed independently of Access/Egress Mode Choice Model • Short-distance (<100 miles) interregional and long-distance (≥ 100 miles) interregional models were estimated separately	• Estimated with 2005 RP/SP data, 2012-2013 CSHTS Data, and 2010 skims • Estimated data included 2013/2014 RP/SP data (BPM-V3 only) • Model estimated jointly with Main Mode Choice Model • Single long-distance travel (≥ 50 miles) model • Refined specification of reliability variable • Divided auto costs (access, egress, or main mode) for trips made in groups by an average group size of 2.5
Destination Choice Model	• Estimated with 2005 RP and SP data and original 2005 skims	• Estimated with 2012-2013 CSHTS Data • Fewer constrained variables • More disaggregate employment categories used • Added Impact of Disneyland and Yosemite on recreation travel • Less reliance on district-district constants during calibration
Trip Frequency Model	• Estimated with 2005 RP and SP data and original 2005 skims • Separate estimation of trip frequency and alone/group travel	• Estimated with 2012-2013 CSHTS Data • Combined estimation of trip frequency and travel alone-group travel • Less reliance on district constants during calibration
Calibration, Validation, and Sensitivity Testing	• Calibration to Year 2000 survey data • Validation to Year 2000 observed data	• Calibration to 2012-13 CSHTS survey data • Validation to Year 2010 observed data • Validation by backcasting to 2000 • Multiple model runs to determine sensitivity to different variables and elasticities • Sensitivity testing using characteristics similar to the Amtrak's Northeast Corridor (NEC)

Table 1-2 SCAG Intraregional Model

Item	Version 1	Version 2/BPM-V3
Skims	• Only allowed modification of HSR skims; All other skims were borrowed from SCAG's model • Path-building and mode choice parameters were not consistent	• All transit skims were developed as part of intra-SCAG model system • Auto skims are borrowed from SCAG's model • Transit skims were modified to ensure consistency with intra-MTC and Long-distance Model skimming process • Consistent path-building and mode choice parameters (using the approach favored by the Federal Transit Administration)
Person Trip Tables	• From SCAG's 4,000+ zone model • Trip purposes included Home-based work, home-based shop, home-based recreation/other, and nonhome-based • Forecast year trip tables were static and could not be easily modified for different socio-economic forecasts	• Aggregated from SCAG's 12,000+ zone model into SCAG's 4000+ zone system • Trip purposes included Home-based work, home-based shop, home-based recreation/other, nonhome-based work, and nonhome-based other • Forecast year trip tables are updated based on SCAG's trip generation model and forecast year socio-economic data
Market Segments for Home-Based Work Trip purpose	• 3 Income Groups	• Segmentation as follows: – 0 vehicle households – Households with fewer vehicles than workers – 3 income groups for households with vehicles >= workers
Zonal Socioeconomic Data File	• From SCAG's 4,000+ zone model • Forecast Year socio-economic data was inconsistent with Inter-regional Model	• Socioeconomic data file modified so that there would be consistent categories between the SCAG and MTC regions. • Socio-economic data, for each model year, is consistent with long-distance socio-economic data
Mode Choice	• MTC region Baycast model modified in certain ways for SCAG application	• MTC's Baycast model modified for use in the SCAG and MTC intraregional models (i.e. model structure is identical for SCAG and MTC)
Transit Assignment and Summarizing Procedure	• Unique to Intra-SCAG model	• Generic Intraregional model process

Table 1-3 MTC Intraregional Model

Item	Version 1	Version 2/BPM-V3
Skims	• All transit skims developed as part of intra-MTC model system • Auto skims are from MTC's Baycast model • Path-building and mode choice parameters are not consistent	• All transit skims developed as part of intra-MTC model system • Transit skims were modified to ensure consistency with intra-SCAG and Long-distance Model skimming process • Auto and Nonmotorized skims are borrowed from MTC's activity-based model • Consistent path-building and mode choice parameters (using the approach favored by the Federal Transit Administration)
Person Trip Tables	• Taken directly from MTC's Baycast model • Forecast year trip tables were static and could not be easily modified for different socio-economic forecasts	• Aggregated from MTC's activity-based model trip rosters • Forecast year trip tables are updated based on MTC's activity-based model and forecast year socio-economic data
Market Segments for HBW	• 4 Income Groups	• Segmentation as follows: – 0 vehicle households – Households with fewer vehicles than workers – 3 income groups for households with vehicles >= workers
Zonal SE File	• Structure based on MTC's Baycast model • Forecast Year socio-economic data was inconsistent with Inter-regional Model	• Socioeconomic data file modified so that there would be consistent categories between the SCAG and MTC regions • Socioeconomic data for each model year is consistent with long-distance socioeconomic data
Mode Choice	• MTC-specific translation of Transbay model for MTC region	• MTC's Baycast model modified for use in the SCAG and MTC intraregional models (i.e., model structure is identical for SCAG and MTC)
Transit Assignment and Summarizing Procedure	• Unique to Intra-MTC model	• Generic Intraregional model process

1.6 Contents of Report

This report documents the BPM-V3. Applications of the model will be documented elsewhere, such as for the 2016 Business Plan when it is released. Section 2.0 describes the travel survey datasets used for model estimation and calibration. The next sections document the long-distance model:

- Section 3.0 – Long-distance model input data;
- Section 4.0 – Long-distance model skims;
- Section 5.0 – Long-distance model estimation; and
- Section 6.0 – Long-distance model calibration.

Section 7.0 describes how the short-distance intraregional models were developed and calibrated. Section 8.0 documents the validation of the model and describes the sensitivity analysis.

2.0 Travel Survey Datasets Used for Model Estimation and Calibration

2.1 Introduction

Three travel survey datasets were used for model estimation and calibration. The first dataset was from a 2005 combined revealed and stated-preference (RP/SP) survey. The 2005 RP/SP survey was the primary survey used in estimation of the Version 1 Ridership and Revenue model. Early in the development of the Version 2 model, the 2012-2013 California Household Travel Survey (CSHTS)[8] data became available. This survey was a typical household travel survey, but covered the entire State of California and included a long-distance travel recall component. For the BPM-V3, data from a second RP/SP survey conducted in 2013 and early 2014 were also used.

Each of the datasets has specific strengths and weaknesses for a variety of reasons, including data collection methods and purpose of data collection, among others. For instance, the coverage of the 2012-2013 CSHTS is quite good, making it appropriate for expansion to the State and use in calibration. However, due to the relatively low incidence of long-distance trips observed with the one-day diary, an optional long-distance recall survey was also included. While the recall survey succeeded in significantly increasing observations of long-distance trips, it still collected relatively few non-auto mode long-distance trips in the observed dataset. On the other hand, the 2005 and 2013-2014 RP/SP surveys were specifically directed at capturing respondents using different mode options and, therefore, the modal data is more diverse.

Table 2-1 shows how the datasets were used for model estimation and calibration of each individual model component. Due to the fundamental difference between revealed- and stated-preference data, the RP and SP portions of the 2005 and 2013-2014 surveys are split in Table 2-1. The SP data were used solely in the main mode choice model estimation since they were the only data with any information about HSR preferences. The 2013-2014 RP data were also used for main mode choice model estimation. The 2005 RP data and the 2012-2013 CSHTS data were used for the estimation of the Version 2 destination choice models and the 2012-2013 CSHTS data were used for the estimation of the Version 2 trip frequency model; those models were not re-estimated for the BPM-V3 (although they were recalibrated) since the data used for their original estimation was unchanged. The 2012-2013 CSHTS survey was most important for calibration of each model component.

The following sections describe each of the datasets in more detail.

[8] http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/chts.html.

Table 2-1 Survey Use in Model Estimation/Calibration

	2005 RP Data	2005 SP Data	2012-2013 CSHTS Data	2013-2014 RP Data	2013-2014 SP Data
Estimation					
Access/Egress Mode Choice	Yes	No	No	Yes	No
Main Mode Choice	Yes	Yes	Yes	Yes	Yes
Destination Choice[a]	Yes	No	Yes	No	No
Trip Frequency[a]	No	No	Yes	No	No
Calibration					
Access/Egress Mode Choice	Yes	No	Yes	No	No
Main Mode Choice	No	No	Yes	No	No
Destination Choice	No	No	Yes	No	No
Trip Frequency	No	No	Yes	No	No

[a] Version 2 models were not re-estimated for the BPM-V3.

Source: Cambridge Systematics, Inc.

2.2 2012-2013 California Household Travel Survey Data

This section describes and summarizes the data sources used to estimate existing long-distance travel within the State of California. The primary data source is the long-distance recall survey component of the CSHTS. This survey was conducted using the long-distance travel log (LDTL), an optional element of the CSHTS. However, use of the long-distance recall survey without other data sources would have severely underestimated both the total magnitude and relative characteristics of the existing long-distance travel markets. Therefore, other available data sources were used to complete this analysis, including:

- Daily Diary data from the 2012-2013 CSHTS;
- The 2011 Harris On-Line Panel Long-Distance Survey;[9]
- 2010 population synthesis of the California household population;[10] and
- The 2010 U.S. Census.

[9] Cambridge Systematics, Inc., Technical Memorandum: California High Speed Rail Ridership and Revenue Forecasting Long Distance Interregional Travel Survey Results – 3rd Draft, September 22, 2011.

[10] Cambridge Systematics, Inc. and HBA Specto, Inc., "California Statewide Travel Demand Model, Version 2.0: Population, Employment, and School Enrollment," prepared for California Department of Transportation, May 2014.

The Version 2 model and BPM-V3 used the daily diary and long-distance recall data collected for the CSHTS performed for the Caltrans. The raw (unexpanded) data were used for estimation of the Version 2 model and BPM-V3 discrete choice trip frequency, destination choice, and mode choice models.

Expanded long-distance CSHTS data were used to estimate control totals for model calibration. Both the daily diary and long-distance recall survey components of the CHSTS were used to estimate daily long-distance trip-making within California.

This section describes the processes used to tabulate the survey data, to identify and rectify biases within the survey data, and to expand the survey dataset to represent the residential population of the State of California.

Summary of Findings from CHSTS Analysis

Significant findings of the analysis include:

- Work-related trip purposes (commute and business trips) account for 26 percent of long-distance trips, while recreational and other trip purposes account for the remaining 74 percent.
- Trip rates show reasonable variations by socioeconomic characteristics. For example, per capita trip rates for high-income households were observed to be more than twice as high as trip rates for low-income households.
- Residents of rural areas account for significantly higher long-distance trip rates (11 annual trips per capita) than residents of urban areas (7.6 annual trips per capita).
- Mode shares for all long-distance trips within California are dominated by the auto mode, accounting for 96 percent of all long-distance trips. Even for very long trips over 400 miles, the auto mode accounts for two-thirds of all person trips. The airplane mode, which accounts for fewer than 2 percent of all long-distance trips, accounts for 25 to 30 percent of trips over 300 miles. Bus and rail modes each account for approximately 1 percent of total long-distance trips for all trip lengths.
- Residents traveling on business trips are much more likely to use the airplane mode (6 percent) than residents traveling for other trip purposes (less than 2 percent).
- Residents traveling alone are much more likely to use non-auto modes (7 percent) than persons traveling in groups (2 percent).

Data for understanding long-distance travel in California has changed since the development of the Version 1 model in 2006-2007. The Version 1 model was calibrated to estimated long-distance travel for a 2005 base year based on a combination of 1995 American Travel Survey (ATS), 2000 Census Transportation Planning Package (CTPP), and 2001 CSHTS data. Changes in estimates of intra-California long-distance travel include:

- Commute work trips were estimated to account for approximately 40 percent of statewide long-distance travel in 2005. The expanded 2012-2013 CSHTS data indicated that long-distance commute work trips now account for about 16 percent of such travel. One possible explanation is the “dot-com” boom in the Silicon Valley was strong during the 1995 through 2001 period when the data for estimating 2005 long-distance travel was collected.

- Air travel was previously estimated to account for approximately 50 percent of long-distance travel for trips over 300 miles. The expanded 2012-2013 CSHTS data indicates that air travel now accounts for approximately 27 percent these trips. The decrease in the dot-com boom, the changes in air travel due to the terrorist attacks of 9/11/2001, and the 2008 recession would all contribute to the decrease in air travel.

- Significantly fewer very long-distance trips (more than 300 miles in length) have been estimated based on the 2012-2013 CSHTS data than were estimated for 2005 for the Version 1 model. Again, the changes in air travel due to 9/11 and the 2008 recession could contribute to the decrease.

While typical, one-day travel diaries can provide some useful information regarding long-distance travel, they are an inefficient source of information for the detailed analysis of long-distance travel. Since long-distance travel is a relatively rare occurrence for most households – the average person makes approximately nine long-distance round-trips per year – most households will not report any long-distance travel in a survey collecting travel data for a single travel day. In fact, only five percent of households participating in the CSHTS reported any long-distance trips in their daily diaries.

This next sections describe how three recent surveys performed in California have been used to provide an overall picture of long-distance travel within the State. The three surveys are the 2011 Harris On-Line Panel Long-Distance survey performed for the CHSRA and the CSHTS Daily Diary and Long-Distance Travel Recall Surveys.

Definition of ''Long-Distance Trips'' in This Analysis

Long-distance trips are defined as trips from the home region of the survey respondent to locations within California more than 50 miles from the traveler's residence. Distances are calculated using GIS to calculate the straight-line distance between geocoded origin and destination locations. Long-distance trips by California residents to other states and countries are not addressed in this analysis. Nonhome-based long-distance travel is not addressed in this analysis, although survey data suggests that nonhome-based trips account for approximately three percent of long-distance trips. Long-distance travel by nonresident visitors to California is also not included in this analysis.

Definition of ''Population'' in This Analysis

The residential population of California accounts for approximately 95 percent of the total population, which was measured at 37.34 million in the 2010 census. The remaining (nonresidential) population lives in group quarter arrangements such as prisons, long-term care facilities, college dormitories, and military barracks. The group quarter residents were not subject to independent data collection in any of the surveys, but it is reasonable to assume that this segment of the population accounts for less long-distance travel than the residential population. Therefore, the survey data were expanded to the residential population only, ignoring travel from group quarters.

To maintain consistency within this report, all per-capita trip rates refer to the residential population.

2012-2013 CSHTS Daily Diary Survey

Caltrans carried out a comprehensive household travel survey of all members of 42,431 respondent households using multiple methods of data collection, including computer-aided telephone collection, on-line data entry by respondents, and mail-back of survey forms. A stratified sampling procedure was used to ensure that the number of surveys collected from each county exceeded specified minimum quotas. CS obtained the Caltrans dataset and analyzed it to use in the Version 2 model and BPM-V3.

Data Collection and Analysis Process

Caltrans collected travel data for each member of a respondent household during the travel day appointed for the household. The travel diary was designed to collect information necessary to calibrate and validate either trip-based or activity-based travel models. The data included:

- Characteristics of each respondent household;
- The household members;
- The vehicles owned by the household;
- The places visited;
- Activities performed at those places;
- Time of travel; and
- Modes of travel between places visited.

More than 3,600 households declined to report household income and were dropped from the database used for the analysis of long-distance travel. The remaining 38,787 households with all socioeconomic data reported were used to estimate long-distance travel behavior for the diary day.

While a one-day travel diary is well suited for collecting typical travel data, it is not the ideal instrument for collecting long-distance travel data. Even with a sample the size of over 100,000 persons in the 38,787 households, a single-day diary collects long-distance travel data for a very small proportion of travelers and households. In fact, analysis of the results of the CSHTS daily diary survey showed that only five percent of respondent households made a long-distance trip on the appointed diary date.

Since daily diaries are designed to collect information for only the assigned travel day, it is often impossible to determine the true purpose for long-distance travel. For example, a person may travel for a business meeting scheduled for the day following the assigned travel day. That traveler's final trip (or tour) on the assigned travel day may end at a hotel, leaving the true purpose of the trip unreported.

Nevertheless, the strength of the daily diary survey is that it provides a good mechanism for identifying all long-distance travel completed by members of respondent households on the assigned travel day. The information collected using the daily diary method is much more accurate than the recall data collected with the long-distance travel log. Thus, it is a very strong tool for validating overall rates of long-distance travel estimated using data from long-distance recall surveys.

Long-distance trips were estimated from the daily diary data using a process similar to determining tours for tour-based travel models:

- A TOUR was defined by listing all PLACES visited between two stops at the HOME location.
- For each TOUR, the PLACE farthest from the HOME location (based on straight line distances) was determined.
- If the farthest place visited was 50 miles or more from the HOME location, the location was identified as the long-distance DESTINATION.
- Distances were calculated using GIS to calculate the straight-line distance between geocoded HOME and DESTINATION locations.
- Each long-distance DESTINATION determined from the above three steps defined an end-point for two, one-way long-distance trips (since the traveler, in the case defined by the above three steps, left and returned home on the assigned travel day).
- For trips that began or ended the travel day at a location other than HOME, the trip was counted as a single one-way long-distance trip if the non-HOME location was 50 miles or more from HOME.
- Long-distance trips that included a stop outside the State of California were not counted as long-distance trips, even if the TOUR defining the long-distance trip included a stop within California that was 50 or more miles from HOME.

This process avoided double-counting long-distance trips from the daily diary and maintained consistency with the long-distance travel data reported in the recall surveys. The goal was to "link out" intermediate stops for incidentals such as gas or food.

The above analysis identified 3,210 long-distance tours completed by 3,199 persons (i.e., 11 persons participated in more than one long-distance tour on their diary day). A significant portion (53 percent) of the long-distance travel involved overnight stays, so those travelers were credited with completing one-half of a long-distance tour. Therefore, the 3,210 long-distance tours recorded in the survey accounted for 4,713 one-way trips, or the equivalent of 2,356 long-distance tours for a single travel day. Since multiple household members traveled together to a significant number of the identified long-distance locations, 1,201 of the long-distance person trips were consolidated into larger group trips. Thus, the survey identified long-distance trips to 2,009 unique locations. In all, long-distance trips were identified for 1,965, or 5 percent of the 38,787 households included in the CSHTS data used for the analysis.

CS expanded the surveyed long-distance trips to represent long-distance travel for all California households on the assigned travel day. The expansion factors were based on geographic and demographic characteristics of the surveyed households as compared to those characteristics for all households in California (see section titled *Expansion Process* for details). After the expansion factors were applied to the CSHTS daily diary database, over 1.5 million one-way long-distance trips were estimated to be made by California residents on an average day. Based on expanded results from the CSHTS data, the long-distance trips account for approximately two percent of all intrastate trips made by California residents.

The 1.5 million daily one-way long-distance trips equate to an average trip rate of 8.2 annual intrastate long-distance round-trips per capita for California household residents. In comparison, a National Passenger

Transportation Survey (NPTS) Brief from 2006[11] estimated the national average of 9.4 annual long-distance round-trip rate per capita; for the Pacific Region the annual average was 8.7 long-distance trips per capita. When interstate and international long-distance trips reported in the CSHTS daily diary are also included in the analysis, the average round-trip rate is 8.6 annual long-distance trips per capita, which is almost identical to the value reported in the NPTS for the Pacific Region.

Summary of Findings Regarding Usefulness of CSHTS Daily Diary Data for Long-Distance Travel Analysis

The data from the CSHTS Daily Diary provided a good basis for determining the overall amount of intrastate long-distance travel made by California residents. However, even though the CSHTS dataset included information from 38,787 households, long-distance trip-making is such a rare occurrence that making estimates of variations in trip rates by geographic region of the State or different socioeconomic strata has not been performed. In addition, since the diary covered only one day of travel, it is not possible to reliably determine the purposes of the long-distance trips reported in the diary. Therefore, the daily diary data were supplemented with data from the Long-Distance Travel Recall survey also conducted by Caltrans.

2012 to 2013 CSHTS Long-Distance Travel Recall Survey

The Long-Distance Recall survey was an optional survey conducted by Caltrans that requested long-distance travel performed by the members of the respondent households during the eight weeks preceding the assigned travel day. The longer survey period (56 days, as compared to one day for the daily diary) greatly increased the amount of long-distance travel data available for analysis.

Data Collection and Analysis Process

The Long-Distance Travel Log used for the Recall survey was designed to reduce respondent burden by requesting information deemed relevant for most transportation planning studies:

- Trip origin and destination;
- Trip purpose;
- Group size (total and household members); and
- The main mode of travel used on the trip.

Respondents were instructed to record the information listed above for all long-distance trips completed during the eight-week reporting period to places 50 miles or more from their home. One recall survey form with spaces for up to eight long-distance trips was provided for each household member. Respondents were instructed to record outbound and return trips separately and to record details for trips in excess of the eight spaces available on the travel log on a separate sheet of paper.

Long-distance travel data were provided by only about one-half of CSHTS respondent households since it was optional. The Long-Distance Recall survey collected data for 32,641 long-distance person trips completed by 22,555 individuals from 12,183 households. Another 9,834 households completed the Long-

[11] NPTS Brief, March 2006, U.S. Department of Transportation Federal Highway Administration, http://nhts.ornl.gov/briefs/LongDistanceTravel.pdf, accessed July 30, 2013.

Distance Recall survey, but indicated either no long-distance trips or long-distance trips only to non-California locations. Approximately nine times as many trips to unique locations, 18,023, were identified in the Long-Distance Recall survey as were identified in the daily diary. The larger number of trips to unique locations resulted in a much richer database for analyzing and understanding long-distance travel in California.

When the 32,641 long-distance person trips reported in the Long-Distance Recall survey were initially expanded to represent the entire population of California, approximately 680,000 daily one-way long-distance trips, or an average of 3.6 annual long-distance round-trips per capita were estimated. By comparison, this estimate accounts for less than half the 1.5 million daily long-distance trips – or 8.2 annual long-distance round-trips per capita – calculated using the data derived from the CSHTS daily diary. The analysis and processes used to account for and correct these differences is documented in following sections of this report.

Summary of Findings Regarding Usefulness of CSHTS Long-Distance Recall Survey Data for Long-Distance Travel Analysis

The Long-Distance Recall survey provided a rich database for determining long-distance trip purposes and the destination and main mode choice characteristics of intrastate long-distance travel made by California residents. Since discrete choice models of trip frequency, destination choice, and mode choice were being developed for the Version 2 model, the unexpanded trip data could be used to estimate model forms and coefficients. Thus, the fact that the total amount of long-distance travel based on the Long-Distance Recall survey was less than one-half the amount of travel estimated using the daily diary did not preclude the use of the Long-Distance Recall survey data for model estimation. However, procedures to adjust the Long-Distance Recall survey data to reflect all intrastate long-distance travel had to be developed for the data to be useful for final calibration of the BPM-V3.

The initial analysis of the Long-Distance Recall survey data revealed several survey design issues that had to be addressed:

- The Long-Distance Travel Logs did not include a “repetition frequency” question, which would have allowed respondents who made multiple long-distance trips to the same location via the same travel mode to quickly report the repeated trips. An analysis of the responses along with the number of Long-Distance Travel Logs with exactly eight trips suggested that respondent fatigue coupled with a lack of understanding of the need for respondents to report all long-distance travel was an important issue.

- The Long-Distance Recall survey required respondents to remember and report travel completed as far back as eight weeks prior to their assigned travel day. The recall survey was subject to memory lapses resulting in underreporting of long-distance trips.

- Many respondents failed to record both directions of travel. On average, for every outbound trip, only 65 percent of return trips were recorded.

- The long-distance recall survey was not subject to the same rigorous process to make sure that all trips completed by all household members were reported by the survey respondent.

- Since completion of only the CSHTS Daily Diary was required for a survey to be considered to be complete, only about one-half of the respondent households completed the Long-Distance Recall survey.

Household characteristics and trip-making characteristics for households completing and households choosing not to complete the Long-Distance Recall survey were therefore different.

Since the data from the Long-Distance Recall survey were the primary data source used to compile validation datasets of total long-distance travel made by California residents, each of the issues outlined above had to be addressed before reasonable estimates of travel could be produced. The following sections describe how the 2011 Harris Panel survey and CSHTS daily diary survey were used to complete the compilation of the validation datasets.

2011 Harris On-Line Panel Long-Distance Survey

CS subcontracted with Harris Interactive to conduct an on-line panel long-distance survey in May and June 2011, in an effort to collect information for corroborating trip rates and shares of trips by trip purpose forecast using the Version 1 Model. The Harris Panel survey was used to update the Version 1 model for use in the 2012 Business Plan.[12] The survey design[13] was similar to the CSHTS long-distance recall survey in that travel over the previous eight-week period was requested. However, there were several distinct differences:

- Survey respondents were drawn from established on-line panels that respond to selected surveys in order to accrue credit for awards and prizes.
- Demographic information on the panelists, such as age, sex, household size, and household income, was obtained from panelists' on-line panel registration information. Worker status of the survey respondents was collected later to aid in the socioeconomic classification of the participants.
- Due to the need to limit response time for the survey, only the destination city or zip code, rather than detailed address information, was requested for each trip.
- Also due to the need to limit the response time for the on-line survey, respondents were requested to provide a repeat frequency for multiple trips made to the same destination for the same purpose and using the same mode during the eight-week recall period. This shortcut resulted in the finding that many long-distance trips are repeated on a regular basis.
- The survey collected long-distance travel information only for the panel member rather than for all household members. This allowed survey respondents to provide information about their own long-distance travel during a single Internet session without requiring interviews of other household members.
- The survey panel included only adult household members.
- The survey was conducted over a two-month period rather than over a complete year.

[12] Revised 2012 Business Plan, April 2012, California High-Speed Rail Authority. http://www.hsr.ca.gov/docs/about/business_plans/BPlan_2012_rpt.pdf. Accessed July 30, 2013.

[13] California High-Speed Rail 2012 Business Plan Ridership and Revenue Forecasting, April 22, 2012. Prepared by Cambridge Systematics, Inc. for the California High-Speed Rail Authority. http://www.hsr.ca.gov/docs/about/business_plans/BPlan_2012Ch5_RidershipRevForecasting.pdf. Accessed July 30, 2013.

Data Collection and Analysis Process

The two-month recall period covered by the 2011 Harris Panel survey (April and May 2011) represented a typical time of year when most employed residents were working and most students were in school. More long-distance trips would be expected during the summer months for vacation travel, and fewer long-distance trips would be expected during the winter months. The survey timeframe included a major holiday weekend (Memorial Day) that is often associated with recreational weekend travel. The inclusion of one major holiday weekend was appropriate for the two-month survey timeframe since almost any two-month time period during the calendar year includes one such major holiday weekend.

The 2011 Harris Panel survey collected useful long-distance travel information for 11,986 California residents. These residents reported making over 25,000 one-way long-distance trips during the two-month survey recall period. This total included over 11,200 one-way long-distance trips to unique locations. Each unique trip was factored by the reported repeat frequency over the previous two months. The average trip repetition frequency reported by the Harris Panel survey respondents was 2.23 repetitions for each trip. The repeat frequency varied significantly by trip purpose (commute trips had by far the highest repeat frequency) and trip length (shorter trips had higher repeat frequencies than longer trips). Based on the reported trips coupled with repeat frequencies and adjustments for household members accompanying the survey respondents on trips, the Harris survey identified approximately 1.13 million daily long-distance trips within the State of California, or an annual average of 6 long-distance intrastate round-trips per capita. This average trips rate is approximately 65 percent higher than the trip rate calculated for the CSHTS Long-Distance Recall survey, but 30 percent lower than the trip rate calculated for the CSHTS Daily Diary.

Summary of Findings Regarding Usefulness of 2011 Harris Panel Long-Distance Survey Data for Long-Distance Travel Analysis

The 2011 Harris Panel survey was designed to collect long-distance travel characteristics of adult California residents. The original intent of the survey was to validate long-distance trip-making forecast using the Version 1 Model. With limited time and resources available, and with the knowledge that a more comprehensive statewide household survey would not be ready for another 12 months, the Harris Panel survey was used as a stop-gap measure to evaluate long-distance trip frequency, shares of trips by trip purpose, average trip lengths, travel group sizes, and mode shares.

The following issues impact the usefulness of the 2011 Harris Panel survey data for long-distance travel analysis:

- The survey was not a random sample of California residents since respondents were drawn from an established on-line panel that responds to selected surveys in order to accrue credit for awards and prizes.

- Long-distance trip information was collected for only the respondents, not all members of the respondents' households. While adjustments were made for household members accompanying respondents on their reported trips, trips made by other household members independently of the survey respondents were not recorded.

- The survey did not collect detailed origin and destination location information.

The 2011 Harris Panel survey data provides information for one important variable that is missing from the Long-Distance Travel Log: an estimate of repeat frequency for long-distance trips. The following section describes how this information was combined with the data collected via the 2012-2013 CSHTS Long-Distance Recall survey to improve estimates of total intrastate long-distance travel made by California residents.

Methods for Expanding and Adjusting the 2012-2013 CSHTS Long-Distance Recall Survey

The previous section provided background on the three sets of survey data available for estimating total intrastate long-distance travel made by California residents.[14] Issues were identified with each of the surveys that limited the usefulness of the data for the estimates of total travel. However, by combining information from each of the surveys, a reasonable estimate of the total travel can be made:

- The 2012-2013 CSHTS Daily Diary data provided a reasonable estimate of the amount of average daily intrastate long-distance trips made by California residents, which corresponds closely with the estimate of long-distance trip-making from the NPTS. The Daily Diary estimate was used to adjust for underreporting of long-distance trips in the 2012-2013 CSHTS Long-Distance Recall survey.

- The 2012-2013 CSHTS Long-Distance Recall survey data provided the most complete data regarding the purpose, origins and destinations, and mode shares of long-distance trips.

- The 2011 Harris Panel survey provided data regarding the repeat frequency for long-distance trips, which was used to adjust reported trips by trip purpose and trip length in the 2012-2013 CSHTS Long-Distance Recall survey.

The 2012-2013 CSHTS Long-Distance Recall survey was adjusted using the following procedure:

- Only information from one direction of travel was used. This solved the issue that 35 percent of respondents reported information only for outbound trips, and a much smaller number reported information only for return trips. All intrastate long-distance trips were assumed to be symmetrical, meaning that every one-way trip was accompanied by an identical return trip.

- An imputation procedure was developed to account for repeat frequency. It randomly assigned repeat frequencies from the 2011 Harris Survey on Long-Distance Travel Log data based on trip purpose, trip distance, and traveler socioeconomic data.

- Based on the observation of a systematic under-reporting of long-distance trips under 200 miles in length, distance-based adjustment factors were applied based on the 2012-2013 CSHTS Daily Diary data to address remaining differences between overall trip rates from the adjusted Long-Distance Recall survey data.

Expansion Process

The survey was conducted in 2012 and 2013, but it was factored to match 2010 socioeconomic characteristics of California households summarized from a synthesis of the California population produced by HBA Specto from their work on the California Statewide Travel Demand Model (CSTDM) for Caltrans.

[14] Expanded data from the 2012-2013 CSHTS were used for model calibration. Unexpanded data from the 2005 and 2013-2014 RP/SP surveys were used for model estimation only; expansion of those data was not required.

Surveyed trip records were expanded to represent over 12.58 million households in California by comparing the numbers of completed surveys to the number of households within the State. The four-dimensional cross-classification scheme developed originally for the Version 1 model, and continues to be used in the BPM-V3, resulted in 99 possible socioeconomic strata (Table 2-2).

Table 2-2 Four-Dimensional Socioeconomic Cross-Classification Scheme

Dimension	Strata
Household size	1, 2, 3 or 4+ persons
Worker per household	0, 1 or 2+ workers
Vehicles per household	0, 1 or 2+ vehicles
Annual household income range for 2010	Low-income: < $45,000 Medium-income: $45,000-$89,999 High-income >= $90,000

Source: Cambridge Systematics, Inc.

The expansion factors were also stratified by five geographic regions. Four of the regions were defined by the major metropolitan planning regions:

- Los Angeles metropolitan area as defined by SCAG region;
- San Francisco Bay area as defined by the MTC region;
- San Diego Association of Governments (SANDAG) region;
- The Sacramento Area Council of Governments (SACOG) region; and
- Remainder of the State.

The Long-Distance Recall survey records were tabulated for each cell of the cross-classification scheme. Cells were aggregated to maintain at least 15 observations for use in survey expansion. Expansion factors for each cell of the cross-classification were developed by dividing the number of households in the 2010 population synthesis by the number of survey households.

Expansion factors varied from 102 to 4,427 with a weighted average expansion factor of 572. The wide range for the expansion factor resulted from several factors, including both intentional sampling procedures to achieve minimum quotas in geographical regions and unintentional biases due to the willingness of different demographic groups to participate in the survey. The intentional oversampling of smaller regions resulted in smaller expansion factors for those regions, especially in comparison to the SCAG and MTC regions.

Correction Process

Imputation of Repeat Trips. The Long-Distance Recall survey did not include a trip repetition frequency question; an average frequency of 1.2 was estimated by summarizing the numbers of long-distance trips in the Long-Distance Recall survey made by each respondent to the same location, for the same trip purpose, and by the same mode. In comparison, the average trip repetition frequency summarized from the 2011

Harris Panel survey, which did include a question regarding trip repetition frequency, was 2.2 repetitions for each trip.

A procedure to adjust for the underreporting of repeat trips was developed in the Long-Distance Recall survey to replace the trip repetition frequency information from the Long-Distance Recall survey with imputed trip repetition derived from the 2011 Harris Panel survey. The 2011 Harris Panel data showed that trip repetition frequency was correlated with trip purpose (commute trips have the highest repetition frequency) and trip length (shorter trips have higher repetition frequency than longer trips). In addition, for the commute trip purpose it was clear that household income was important to trip repetition frequency. Double counting of reported repeat trips in the Long-Distance Recall survey was averted by removing the reported repeat trips so that only "unique" long-distance trips were included in the database. The imputation process was then completed by randomly assigning a repeat frequency rate from the Harris Survey data based on the trip purpose, trip length and, in the case of commute trips, income group of the respondent.

Table 2-3 shows the result of the trip repetition frequency imputation. The imputed repetition frequency rates are substantially higher for commute trips than for the other trip purposes. The expanded data in the last two columns show the results for each of the categories before and after imputation. Imputation increased the number of trips for all trip purposes with the greatest impact on the commute trip purpose. The average repetition frequency reported for commute trips in the Long-Distance Recall survey was two repeats per unique trip, whereas the average repetition frequency reported for commute trips in the Harris Survey was 15. Imputation increased the number of commute trips from 23,250, or 3 percent of total long-distance trips, to 87,285, or 15 percent of total long-distance trips.

Correction for Missing Trips. After imputation, the adjusted trips were expanded to represent the total intrastate long-distance trip-making by California residents. The adjusted, expanded trips summed to approximately 1.15 million daily intrastate long-distance one-way trips, or an average of 6.1 annual long-distance round-trips per capita – significantly lower than the 1.5 million daily long-distance trips (8.2 per capita) calculated from the CSHTS Daily Diary.

The difference noted above was surmised to be due to the underreporting of trips for the reasons described previously:

- Only eight spaces on the Long-Distance Travel Log forms used for the Recall survey;
- Forgotten trips due to the eight-week recall period; and
- Differences between the respondents that reported long-distance travel and those who did not complete the long-distance recall survey.

It was not possible to isolate these sources of underreporting independently. However, when the expanded, adjusted Long-Distance Recall survey dataset and the expanded long-distance trips from the CSHTS Daily Diary were tabulated and compared by trip distance, it was clear that most of the trips missing from the imputed/expanded Long-Distance Recall survey dataset were shorter trips, particularly those between 50 and 200 miles. For trip lengths of more than 200 miles, almost identical numbers of trips were estimated from the two expanded datasets. This probably occurred since shorter trips are more likely to be forgotten with the recall survey, especially trips made more than a month prior to the reporting date and trips made by household members other than the survey respondent.

Table 2-3 Impact of Trip Repetition Frequency Imputation on Long-Distance Trips

Trip Purpose	Distance Range (Miles)	Income Range(s)	Reported Repetition Frequency (LDTL)[a]	Imputed Repetition Frequency (2011 Harris)[a]	Expanded Daily Long-Distance Trips	
					Before Imputing	After Imputing
Commute	50-75	Medium, High	2.5	24.5	11,200	115,130
	50-300	Low	1.2	6.2	1,190	5,040
	75-300	Medium	1.6	18.2	2,660	31,970
	75-300	High	1.9	6	6,560	20,960
	Over 300	All	1.4	1.4	1,640	1,470
	All (Over 50)	All	2	15	23,250	174,570
	Percent of Total Long-Distance Trips				3%	15%
Business	50-75	All	1.2	2.2	23,790	44,890
	75-100	All	1.2	1.9	13,740	21,080
	100-150	All	1.1	1.8	12,170	18,810
	150-300	All	1.1	1.7	8,980	13,490
	Over 300	All	1.1	1.6	11,370	16,080
	All (Over 50)	All	1.2	1.9	70,050	114,350
	Percent of Total Long-Distance Trips				10%	10%
Recreation and Other	50-75	All	1.2	1.9	190,560	318,920
	75-100	All	1.2	1.7	126,370	185,510
	100-150	All	1.1	1.5	120,410	164,590
	150-300	All	1.1	1.4	92,440	119,760
	Over 300	All	1.1	1.2	60,900	68,890
	All (Over 50)	All	1.1	1.6	590,680	857,670
	Percent of Total Long-Distance Trips				86%	75%
All Purposes					**683,980**	**1,146,590**

[a] During the eight-week recall period.

Source: Cambridge Systematics, Inc. based on summaries of the 2012-2013 CSHTS and 2011 Harris survey data.

Adjustment factors stratified by 25-mile bins were calculated to correct the differences between the Daily Diary and the Long-Distance Recall surveys (see Table 2-4).

Table 2-4 Adjustment Factors to Account for Missing Trips by Trip Length

Trip Length (Miles)	Adjustment Factor
50 and 75	1.41
75 to 100	1.38
100 to 125	1.36
125 to 150 miles	1.34
150 to 175 miles	1.31
175 to 200 miles	1.27
200 to 225 miles	1.22
225 to 250 miles	1.14
250 to 275 miles	1.06
>275	1.00

Source: Cambridge Systematics, Inc. based on summaries of the 2012-2013 CSHTS and 2011 Harris survey data.

Summary of the Adjusted 2012-2013 CSHTS Long-Distance Recall Survey Results

Comparison to Other Long-Distance Survey Data

The overall results of the survey expansion and correction have been compared to other data sources to demonstrate the reasonableness of the results. This analysis presents a comparison of the following data sources:

- 1995 American Travel Survey (ATS), in which long-distance trips are defined as greater than 100 miles.
- Version 1 Model (calibration year 2000).
- 2001 National Household Travel Survey (NHTS).
- 2009 NHTS, which did not have a separate long-distance component.
- 2011 Harris Survey (long-distance trips only, interstate travel not included).
- 2012-2013 CSHTS:
  - Daily Diary survey;
  - Long-Distance Recall survey – Uncorrected; and
  - Long-Distance Recall survey – Corrected.

Overall Long-Distance Trip Rates. The long-distance trip rates from the data sources listed above (Table 2-2) were compared recognizing that some comparisons could not be performed due to different data collection methods and definitions of long-distance trips. For example, the 1995 ATS defines long-distance trips as over 100 miles; the 2009 NHTS does not include a separate long-distance component; and both the Version 1 model and the Harris Survey do not include short-distance travel.

Comparing long-distance data sources is complicated further by the fact that some sources report data aggregated to households, and others are aggregated to persons. The data in Table 2-5 is aggregated to households. This explains why the overall trip rates are approximately three times the trips rates reported elsewhere in this document for persons.

The corrections applied to the CSHTS Long-Distance Recall survey dataset results in reasonable estimates of long-distance travel. For example:

- For long-distance round-trips over 100 miles long, the overall trip rate (11.32 annual trips per household) is close to the midpoint of the national data collected for the 1995 ATS (10.15 annual trips per household) and 2001 NHTS (12.32 annual trips per household).
- For long-distance round-trips over 300 miles long, the overall trip rate (3.88 annual trips per household) is almost identical to the rate reported for the 2001 NHTS (3.87).
- The trip rate for round-trips over 300 miles within California (1.27 annual trips per household) is significantly lower than the similar rate calculated for the 2011 Harris Survey (1.77).

Table 2-5 Comparison of Annual Long-Distance Round-Trip Rates per Household

				2000 HSRA Model 1	Harris Survey	2012-2013 CSHTS Daily Diary		2012-2013 CSHTS Long-Distance Recall Survey (Corrected)	
Trip Length	**1995 ATS**	**2001 NHTS**	**2009 NHTS**	**CA Only**	**CA Only**	**CA Only**	**Total USA**	**CA Only**	**Total USA**
Total LD Trips									
Over 50 miles		23.85		18.15	16.37	22.79	23.89	22.28	26.05
Over 100 miles	10.15	12.32		7.25	6.8	6.67	7.5	7.73	11.32
Over 300 miles	3.51	3.87		2.39	1.77	0.95	1.52	1.27	3.88
100 to 300 miles	6.64	8.45		4.85	5.02	5.71	5.98	6.46	7.44
50 to 100 miles		11.53		10.91	9.58	16.12	16.39	14.55	14.73
Daily Person Trips and Person Miles per Household (CSHTS Data Include Short-Distance Trips from CSHTS Daily Diary)									
Person Trips per Household	10.49	9.66	9.5			9.96	9.96	9.94	9.97
PMT per Household	94.41	95.24	90.42			62.09	67.61	58.23	81.49

Source: Cambridge Systematics, Inc.

Note: Analysis of the 1995 ATS, 2001 NHTS, and 2009 NHTS is presented in the NCHRP 735 Final Report.

Long-Distance Trip Length Frequency. The overall trip length frequencies for long-distance trips in 100-mile bins are compared in Table 2-6 across the three long-distance data sources available for California: There is a wide variation between the data sources.

Table 2-6 Trip Length Frequency Distribution by 100-Mile Bins

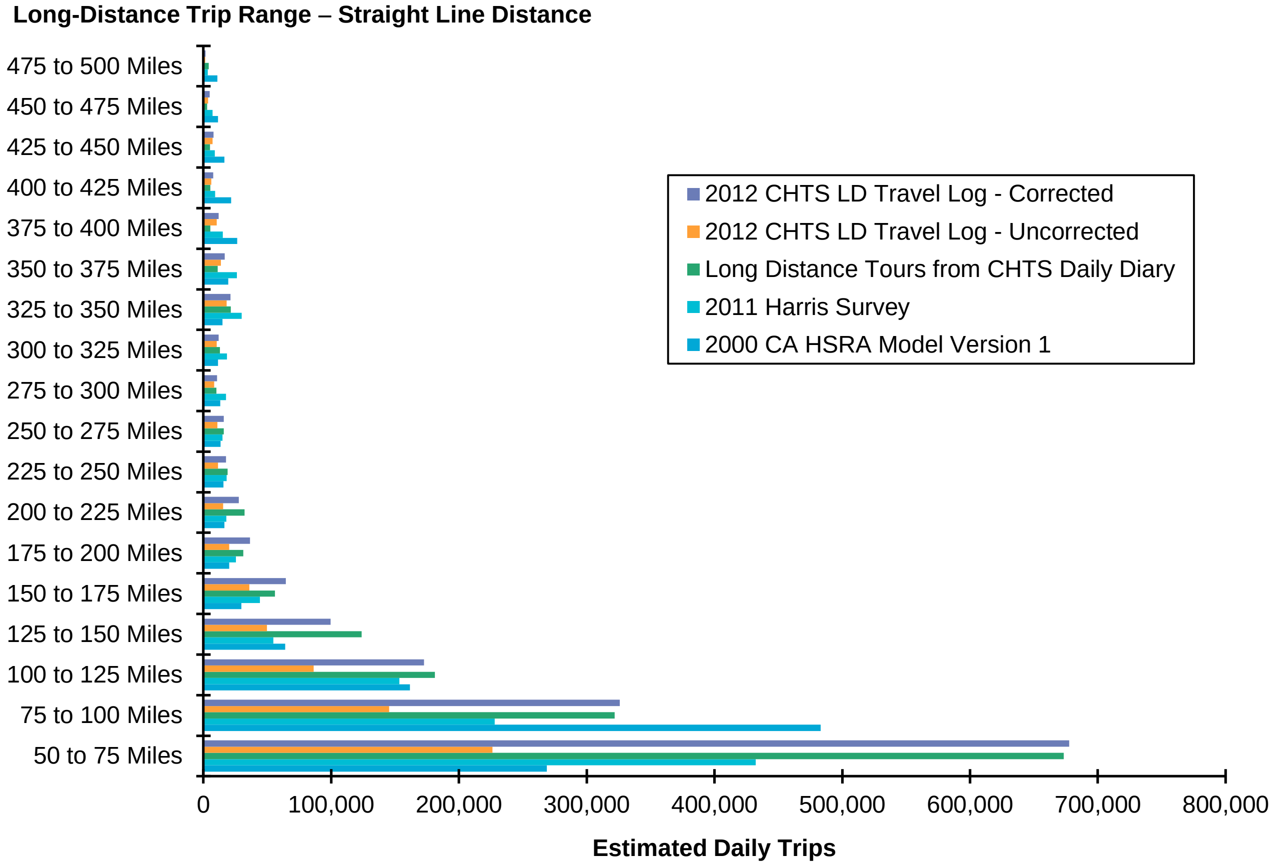
Bin (Miles)	2000 CA HSRA Model Version 1		2011 Harris Survey		2012-2013 CSHTS Daily Diary		2012-2013 CSHTS Long-Distance Recall Survey – Corrected	
	Expanded	Cum. %	Expanded	Cum. %	Expanded	Cum. %	Expanded	Cum. %
50 to 100	751,957	60.10%	660,278	58.50%	995,252	64.80%	1,003,404	65.30%
100 to 200	275,662	82.10%	277,832	83.10%	392,042	90.30%	373,266	89.60%
200 to 300	58,809	86.80%	68,600	89.20%	77,228	95.30%	72,025	94.30%
300 to 400	72,257	92.60%	89,892	97.10%	50,867	98.60%	61,683	98.30%
400 to 500	60,532	97.40%	28,579	99.70%	17,591	99.80%	22,266	99.80%
500 to 600	24,699	99.40%	3,249	100.00%	2,754	100.00%	2,871	100.00%
600 to 700	5,336	99.80%	369	100.00%	478	100.00%	647	100.00%
700 to 800	2,286	100.00%	0	100.00%	0	100.00%	39	100.00%
Total	**1,251,539**		**1,128,799**		**1,536,211**		**1,536,200**	

Source: Cambridge Systematics, Inc. based on summaries of the 2012-2013 CSHTS and 2011 Harris survey data.

As discussed previously, the 2012-2013 CSHTS Long-Distance Recall survey provides the most comprehensive source of information regarding long-distance trips in California. Applying the adjustments documented in the previous section of this report results in overall long-distance trip generation and trip length frequency distributions that are much more reasonable, as compared to other data sources (2001 NHTS and 2012-2013 CSHTS Daily Diary).

The overall trip length frequencies for long-distance trips in 25-mile bins are compared in Figure 2-1 and Table 2-7. Once again, these figures illustrate the wide variation in the data sources. The exhibits also demonstrate that the 2000 Version 1 model, which was validated using less comprehensive data and fewer independent data sources, varies from the data used to validate the current version of the Version 2 model and BPM-V3, especially for long-distance trips of over 350 miles in length.

Figure 2-1 Trip Length Frequency Distribution for Long-Distance Trips



Source: Cambridge Systematics, Inc. based on summaries of the 2012-2013 CSHTS and 2011 Harris survey data.

Table 2-7 Trip Length Frequency Distribution by 25-Mile Bins

Bin (Miles)	2000 CA HSRA Model Version 1		2011 Harris Survey		2012-2013 CSHTS Daily Diary		2012-2013 CSHTS Long-Distance Recall Survey – Corrected	
	Expanded	Cum. %	Expanded	Cum. %	Expanded	Cum. %	Expanded	Cum. %
50 to 75	268,846	21.50%	432,213	38.30%	673,301	43.80%	677,640	44.10%
75 to 100	483,111	60.10%	228,065	58.50%	321,950	64.80%	325,764	65.30%
100 to 125	161,642	73.00%	153,331	72.10%	181,099	76.60%	172,690	76.60%
125 to 150	64,122	78.10%	54,838	76.90%	123,940	84.60%	99,485	83.00%
150 to 175	29,736	80.50%	44,271	80.90%	55,914	88.30%	64,544	87.20%
175 to 200	20,162	82.10%	25,393	83.10%	31,088	90.30%	36,547	89.60%
200 to 225	16,363	83.40%	17,868	84.70%	32,081	92.40%	27,611	91.40%
225 to 250	15,751	84.70%	18,270	86.30%	18,994	93.60%	17,784	92.60%
250 to 275	13,462	85.80%	14,899	87.60%	15,964	94.70%	15,950	93.60%
275 to 300	13,233	86.80%	17,562	89.20%	10,190	95.30%	10,681	94.30%
300 to 325	11,536	87.70%	18,424	90.80%	12,823	96.20%	11,992	95.10%
325 to 350	14,884	88.90%	30,053	93.50%	21,416	97.60%	21,192	96.50%
350 to 375	19,491	90.50%	26,296	95.80%	11,267	98.30%	16,649	97.50%
375 to 400	26,346	92.60%	15,118	97.10%	5,360	98.60%	11,850	98.30%
400 to 425	21,689	94.30%	9,168	98.00%	5,382	99.00%	7,711	98.80%
425 to 450	16,524	95.60%	8,945	98.80%	5,052	99.30%	7,984	99.30%
450 to 475	11,424	96.50%	7,049	99.40%	2,900	99.50%	4,874	99.70%
475 to 500	10,895	97.40%	3,417	99.70%	4,258	99.80%	1,696	99.80%
500 to 525	11,003	98.30%	968	99.80%	2,361	99.90%	1,406	99.90%
525 to 550	6,867	98.80%	530	99.80%	393	100.00%	834	99.90%
550 to 575	3,713	99.10%	1,036	99.90%	0	100.00%	106	99.90%
575 to 600	3,116	99.40%	714	100.00%	0	100.00%	525	100.00%
600 to 625	2,235	99.60%	210	100.00%	478	100.00%	398	100.00%
625 to 650	1,182	99.70%	29	100.00%	0	100.00%	31	100.00%
650 to 675	963	99.70%	110	100.00%	0	100.00%	69	100.00%
675 to 700	956	99.80%	21	100.00%	0	100.00%	149	100.00%
700 to 725	1,102	99.90%	0	100.00%	0	100.00%	23	100.00%
725 to 750	883	100.00%	0	100.00%	0	100.00%	16	100.00%
750 to 775	198	100.00%	0	100.00%	0	100.00%	0	100.00%
775 to 800	103	100.00%	0	100.00%	0	100.00%	0	100.00%
Total	1,251,539		1,128,799		1,536,211		1,536,200	

Source: Cambridge Systematics, Inc. based on summaries of the 2012-2013 CSHTS and 2011 Harris survey data.

Long-Distance Recall Survey Results

This section describes the CSHTS Long-Distance Recall survey results after expansion and correction, covering: trip frequency, trip length frequency, trip distribution, and mode shares. These tabulations are classified further by trip purpose, geographic region, socioeconomic characteristics, and group travel status.

Long-Distance Trip Frequency. Following the adjustment of the 2012-2013 CHSTS Long-Distance Recall survey expansion, 1.536 million daily intrastate long-distance trips have been estimated to be made by California residents. That level of trip-making represents an average of 8.2 annual long-distance round-trips per capita, which compares reasonably to the 9.4 annual long-distance round-trip rate per capita reported in the NPTS Brief from 2006. The reported NPTS rate included all long-distance trips, not just intrastate trips. For the Pacific Region, the NPTS Brief reported an annual average of 8.7 long-distance round-trips per capita. When interstate and international long-distance trips reported in the CSHTS are included in the analysis, the average annual long-distance round-trip rate is 8.6 trips per capita.

Long-Distance Trip Frequency by Purpose. The shares of trips by purpose are shown in Table 2-8. The most frequent type of trip was recorded to be "other," and the second most common was recreational.

Table 2-8 Long-Distance Trip Frequency by Purpose

Purpose	Percent
Business	10%
Commute	16%
Recreation	33%
Other	41%

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Trip Frequency by Geographic Region. Table 2-9 summarizes the variation in average long-distance trip rates per capita by geographic region. The average trip rates are generally higher in rural areas and lower in urban areas. Average annual long-distance trip rates for the four largest urban areas vary from 7.2 to 8.4 per capita, whereas these rates are greater than 10 trips per capita in rural areas.

Table 2-9 Average Annual Intrastate Round-Trips per Capita by Geographic Region

Home Region	Average Annual Long-Distance Round-Trips per Capita
Southern California (SCAG) Region	7.2
Bay Area (MTC) Region	8.4
San Diego (SANDAG) Region	7.8
Sacramento (SACOG) Region	7.5
San Joaquin Valley Counties	11.6
Rest of State	10.1
Statewide	8.2

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Trip Frequency by Socioeconomic Characteristics. Table 2-10 presents long-distance trip rates by socioeconomic classifications, cross-classified by trip purpose. The most powerful variables for explaining long-distance travel behavior are household income and auto availability – residents with higher incomes or more vehicles are more likely to make long-distance trips than residents with lower incomes or fewer automobiles available. There is also a strong inverse correlation with household size, i.e. residents of smaller households exhibit higher rates of long-distance travel than larger households, possibly due to the increased mobility of residents who do not have children.

Long-Distance Trip Length

Trip Length Frequency by Trip Purpose. Figure 2-2 displays the trip length frequency distributions of long-distance trips by trip purpose within California. The shares of commute trips decrease most rapidly with increasing trip distance while the other three trip purposes show similar decreases in shares with increasing trip distances. The trip length frequency distributions for the business, recreation, and other trip purposes show a slight "hump" in shares in the 300- to 375-mile distance range. That slight increase in trips in that distance range reflects travel between the major metropolitan areas in northern California – the San Francisco and Sacramento areas – and the major metropolitan areas in southern California – the Los Angeles and San Diego areas.

The average straight line distance between origin and destination locations for all long-distance trips within California was estimated to be 111 miles. Long-distance trip lengths vary by trip purpose with commute trips being the shortest (79 miles) and business trips being the longest (125 miles). Average trip distances for recreational and other trip purpose are 115 miles and 116 miles respectively.

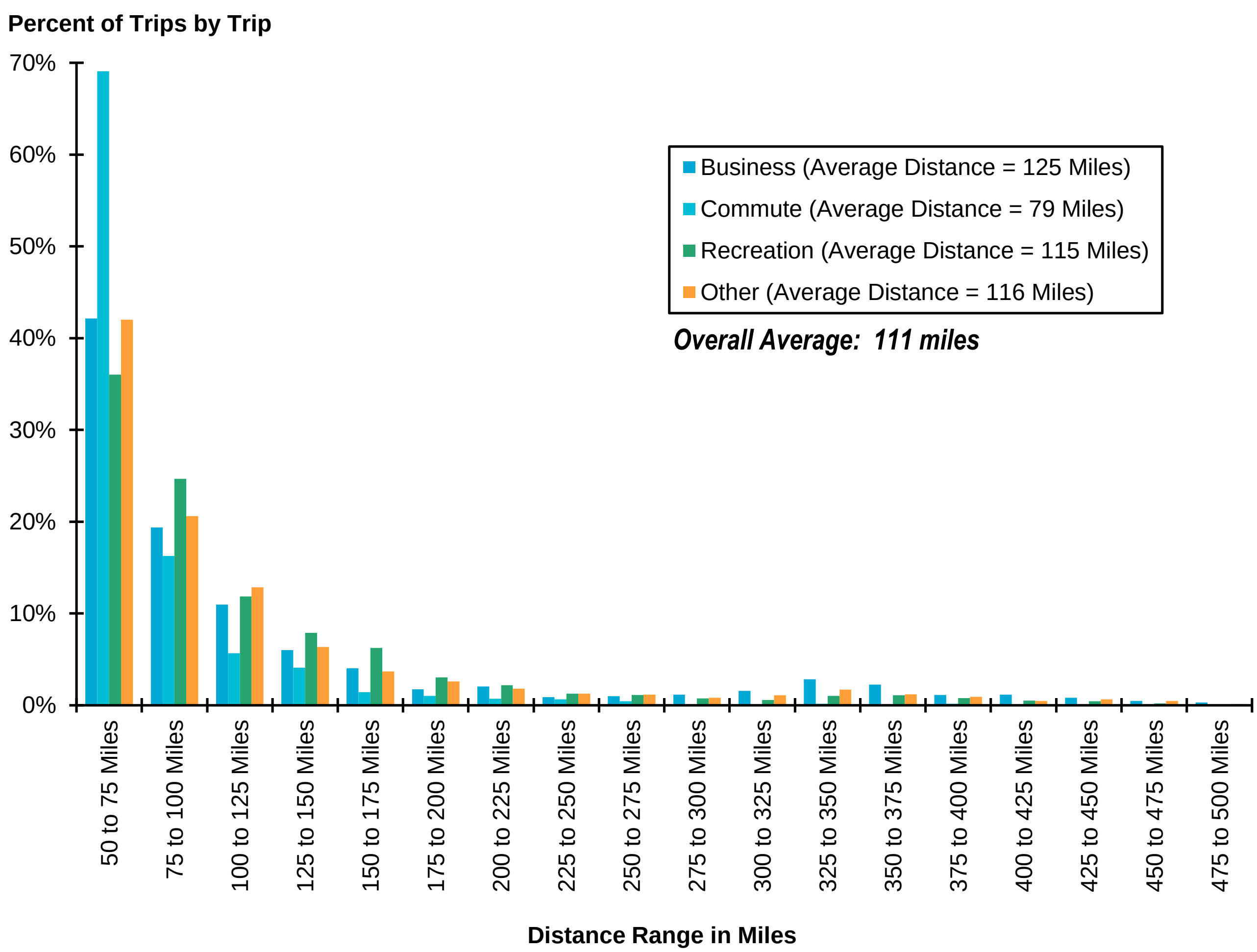
Table 2-10 Annual Long-Distance Trip Rates by Socioeconomic Characteristics

	Annual Long-Distance Round-Trip Rates per Capita				
Value	**Business**	**Commute**	**Recreation**	**Other**	**Total**
Variable: Household Size					
1	1.23	2.25	2.75	5.12	**11.35**
2	1.19	1.6	3.21	4.39	**10.39**
3	0.78	1.39	2.41	3.14	**7.71**
4+	0.58	0.97	2.64	2.71	**6.9**
Total	0.8	1.29	2.73	3.35	**8.17**
Variable: Number of Workers					
0	0.49	0.44	2.19	4.1	**7.21**
1	0.82	1.51	2.73	3.42	**8.48**
2+	0.9	1.4	2.91	3.03	**8.25**
Total	0.8	1.29	2.73	3.35	**8.17**

	Annual Long-Distance Round-Trip Rates per Capita				
Value	**Business**	**Commute**	**Recreation**	**Other**	**Total**
Variable: Number of Vehicles					
0	0.25	0.16	1.53	2.01	**3.94**
1	0.67	1.1	2.07	3.55	**7.39**
2+	0.89	1.44	3.04	3.4	**8.77**
Total	0.8	1.29	2.73	3.35	**8.17**
Variable: Income Range					
Low	0.37	0.21	1.55	2.8	**4.94**
Med	0.76	1.69	2.46	3.51	**8.43**
High	1.08	1.63	3.57	3.56	**9.84**
Total	0.8	1.29	2.73	3.35	**8.17**

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Figure 2-2 Long-Distance Trip Length Distribution by Purpose



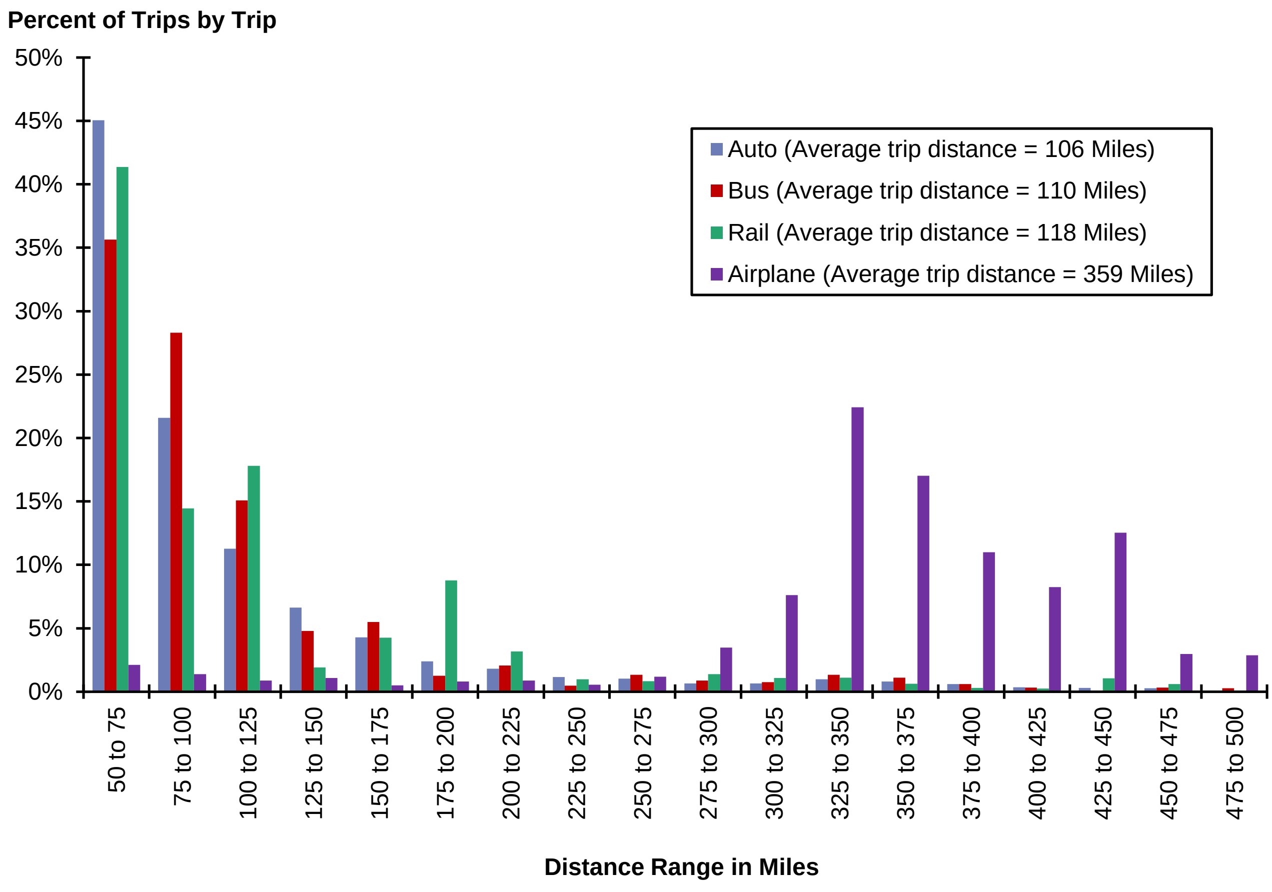
Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Trip Length Frequency by Main Travel Mode. Figure 2-3 shows the trip length frequency distributions by main travel mode within California. The shares of trips by auto and bus decrease rapidly and smoothly with increasing distance.

Shares of trips by rail also decrease rapidly, but less smoothly, with increasing distance. The trip length distribution probably reflects two different types of rail travel: commuter rail within the San Francisco, Los Angeles and San Diego metropolitan regions (for trips between 50 and 100 miles) and intercity rail travel between urban areas such as Sacramento and San Francisco or San Diego and Los Angeles (for trips over 100 miles). Note that only 213 long-distance rail trips were reported in the CSHTS Long-Distance Recall survey, and expanded to represent long-distance rail travel in the State of California.

The trip length frequency distribution for air travel peaks between 300 and 450 miles, which reflects the travel distances between the major metropolitan areas in northern and southern California.

Figure 2-3 Long-Distance Trip Length Distribution by Mode



Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Trip Distribution by Geographic Region

Tabulated observed/expanded long-distance trips between six regions in California are shown in Table 2-11. These data are expressed in "production to attraction" format, so that the directionality of travel between regions can be understood. The larger urbanized areas – SCAG and MTC – are both net producers of long-distance trips. This may seem counter-intuitive, since regional travel models typically exhibit a net external-to-internal traffic flow across external cordons, especially in peak commute periods. However, since the majority of long-distance travel is associated with recreational and other nonwork trip purposes, it is understandable that long-distance travel flow follows the patterns of recreational travel behavior (i.e., trips from population centers to recreation areas such as the coastline or the mountains).

Table 2-11 Average Daily Long-Distance Trips between Regions

	To Region						
From Region	**SCAG**	**MTC**	**SANDAG**	**SACOG**	**San Jose Valley**	**Rest**	**Total**
SCAG	358,556	24,004	162,119	7,397	36,109	66,854	**655,038**
MTC	22,422	73,067	5,648	77,210	30,385	93,773	**302,505**
SANDAG	101,611	4,465	2,834	1,440	4,406	7,569	**122,326**
SACOG	4,624	41,346	1,039	11,138	6,577	23,723	**88,448**
San Joaquin Valley	52,039	51,037	3,434	19,389	56,306	49,904	**232,109**
Rest of State	15,315	46,762	1,645	20,195	11,354	40,030	**135,302**
Total	554,567	240,682	176,720	136,769	145,137	281,853	**1,535,728**

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Table 2-12 is a tabulation of the major flows between regions in California. The table shows:

- More than half of long-distance travel produced by the geographically large SCAG region is destined for locations that are also within the SCAG region.
- The most popular source of interregional travel is between the adjacent southern California urban areas – SCAG and SANDAG – followed by the adjacent northern California urban areas – MTC and SACOG.
- The most popular source of interregional travel between nonadjacent regions is observed between the SCAG and MTC regions.

Table 2-12 Major Long-Distance Flows between Regions

	Long-Distance Recall Survey		
Major Flows	Daily Long-Distance Trips	Total Productions	Percent of Total Productions on Major Flow
Intra-SCAG	358,556	655,038	55%
Intra-MTC	73,067	302,505	24%
Intra-SJV	56,306	232,109	24%
Intra-SACOG	11,138	88,448	13%
Intra-SANDAG	2,834	122,326	2%
SCAG to SANDAG	162,119	655,038	25%
SCAG to SJV	36,109	655,038	6%
SCAG to MTC	24,004	655,038	4%
SCAG to SACOG	7,397	655,038	1%
MTC to SACOG	77,210	302,505	26%
MTC to SJV	30,385	302,505	10%
MTC to SCAG	22,422	302,505	7%
SJV to MTC	51,037	232,109	22%
SJV to SCAG	52,039	232,109	22%
SJV to SACOG	19,389	232,109	8%
SACOG to MTC	41,346	88,448	47%
SACOG to SJV	6,577	88,448	7%
SACOG to SCAG	4,624	88,448	5%
SANDAG to SCAG	101,611	122,326	83%

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Long-Distance Mode Shares

Mode Share by Trip Purpose. Table 2-13 summarizes long-distance mode shares by trip purpose. Auto is the dominant mode for all trip purposes, and bus mode shares are similar to those for rail for all trip purposes. The airplane mode is much more popular for business travel (over six percent) than for other trip purposes.

Table 2-13 Long-Distance Mode Shares by Trip Purpose

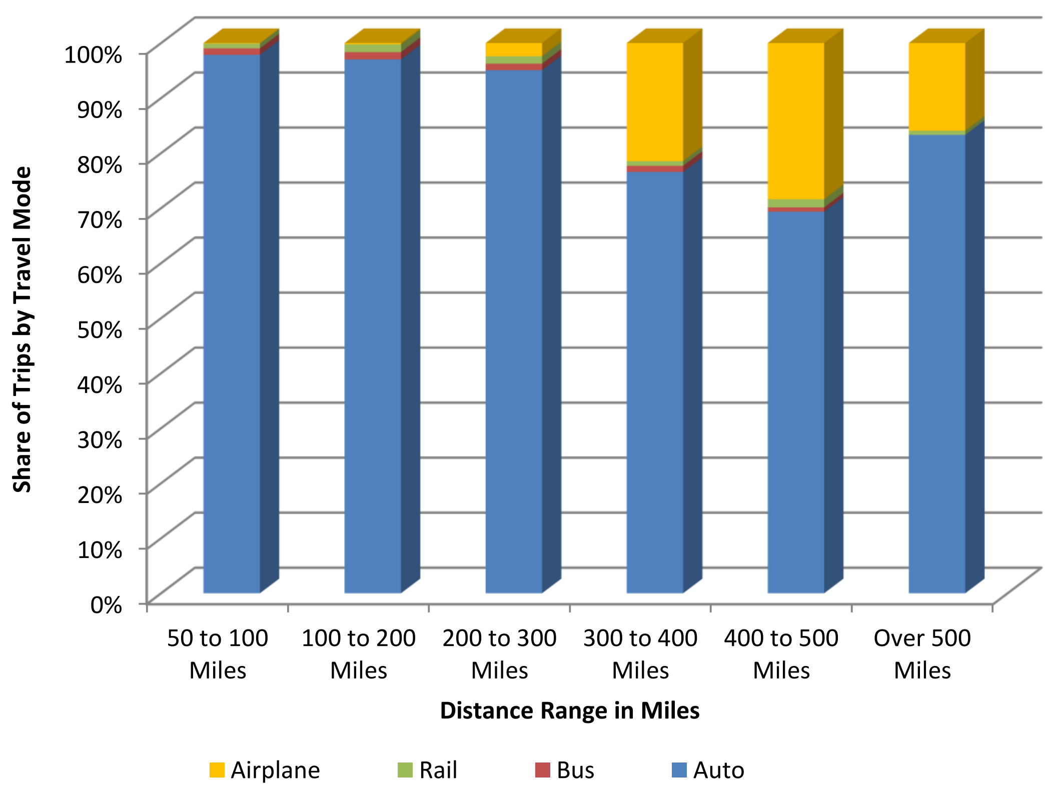
	Main Travel Mode			
Trip Purpose	**Auto**	**Bus**	**Rail**	**Airplane**
Business	91.50%	0.90%	1.40%	6.20%
Commute	97.90%	1.00%	0.90%	0.20%
Recreation	97.30%	1.00%	0.90%	0.90%
Other	96.10%	1.30%	1.10%	1.40%
All Purposes	96.30%	1.10%	1.00%	1.50%

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Mode Share by Trip Length. Figure 2-4 summarizes long-distance mode shares by trip distance range. The figure also demonstrates the dominance of the auto mode for all distance ranges. However, the figure also shows that air travel captures significant portions of the travel market in the distance ranges over 300 miles.

Airplane mode shares are significantly lower for this analysis, based on the 2012-2013 CSHTS Long-Distance Recall survey, than for the survey data previously documented for the 2011 Harris Survey and for the Version 1 Model. The 2012-2013 CSHTS Long-Distance Recall survey shows an average airplane mode share of 27 percent for trips over 300 miles, while the 2011 Harris Survey expanded shows an average airplane mode share of 34 percent for trips over 300 miles.

Figure 2-4 Long-Distance Mode Shares by Trip Length



Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Mode Share by Area Type. Table 2-14 is a tabulation of main mode shares for long-distance travel according to the model's area type coded for both the production (home) and attraction (non-home) end of long-distance trips. The table shows:

- There is a strong correlation between mode choice and area type at the production end, and that the correlation is even stronger at the attraction end;
- Airplane mode shares for long-distance travel are consistently higher for higher density area types; and
- Rail mode shares are significantly higher for long-distance travel to attractions in CBD areas.

Table 2-14 Long-Distance Mode Shares by Area Type

	Main Travel Mode			
	Auto	Bus	Rail	Airplane
Area Type of Production TAZ				
Rural	97.20%	1.10%	0.50%	1.20%
Suburban	96.70%	0.70%	1.30%	1.30%
Urban	94.70%	1.40%	1.60%	2.30%
CBD Fringe	93.20%	1.80%	0.90%	4.20%
CBD	91.30%	3.00%	1.40%	4.40%
Total	96.10%	1.10%	1.00%	1.70%
Area Type of Attraction TAZ				
Rural	97.90%	1.00%	0.50%	0.50%
Suburban	96.80%	1.00%	0.80%	1.40%
Urban	96.30%	1.10%	0.60%	2.00%
CBD Fringe	92.80%	1.30%	1.60%	4.30%
CBD	88.60%	1.90%	4.60%	5.00%
Total	96.10%	1.10%	1.00%	1.70%

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Mode Share by Group Travel. Table 2-15 is a tabulation of the main travel mode shares for long-distance travel according to the group size data reported by survey respondents. There is a strong correlation between mode choice and group travel. Auto mode is much more popular for group travel, given the ability to share costs for auto travel, whereas similar cost savings are not typically available for group travel.

Table 2-15 Long-Distance Mode Shares by Group Status

	Main Travel Mode			
Group Type	Auto	Bus	Rail	Airplane
Alone	92.80%	1.80%	2.20%	3.20%
Group	97.80%	0.80%	0.40%	1.00%
Total	**96.10%**	**1.10%**	**1.00%**	**1.70%**

Source: Cambridge Systematics, Inc. based on expanded of the 2012-2013 CSHTS data.

Comparison to Observed Ridership Data

This section presents comparisons of the expanded CSHTS Long-Distance Recall survey data to observed ridership data for the rail and airplane travel modes.

Comparison with Rail Ridership Data. Amtrak provided city-to-city ridership data collected from ticket purchases, were used to check the reasonableness of the rail ridership estimates from the expanded/ corrected CSHTS Long-Distance survey data. Short-distance trips (i.e. less than 50 miles) were eliminated using straight line distances between stations.

Table 2-16 compares the total ridership estimates from the Amtrak data as well as ACE ridership between the San Joaquin Valley and MTC region to the rail ridership estimates from the expanded/corrected CSHTS Long-Distance survey. The results were remarkably similar, especially considering how few observed records of rail travel were used to generate the CSHTS estimates. For example, the estimate of long-distance rail travel between the SANDAG and SCAG regions was based on expanded/corrected from 44 survey records, and the resulting estimates are within one percent of each other.

Overall, the CSHTS data are within three percent of matching the total volume of long-distance travel for the seven regional pairs tabulated in Table 2-16. This is evidence that, in spite of the small number of rail trips observed in the CSHTS Long-Distance survey, the resulting expanded/corrected data provide a reasonably well validated source of data.

Table 2-16 Comparison of Average Daily Long-Distance Rail Ridership Estimates

Regions	Route(s)	Total Riders	Percent Less than 50 Miles	LD Riders	CSHTS LD Survey	Ratio
SANDAG-SCAG	Pacific Surfliner	4,345	8%	3,998	3,951	99%
SACOG-MTC	Capitol Corridor	3,641	11%	3,241	2,672	82%
SCAG-Central Coast	Pacific Surfliner	1,047	10%	942	1,634	173%
SJV-MTC	San Joaquin, ACE	2,418	40%	961	951	99%
MTC-SCAG	Coast Starlight	500[a]	0%	500a	600	120%
SANDAG-Central Coast	Pacific Surfliner	316	0%	316	444	141%
SJV-SACOG	San Joaquin	316	9%	287	336	117%
Total		**12,583**		**10,244**	**10,587**	**103%**

[a] Estimate. City-to-city data not available for this route.

Source: Cambridge Systematics, Inc. based on data from ACE and Amtrak and expanded 2012-2013 CSHTS data.

Comparison with Airplane Passenger Data. A 10 percent sample of air passenger ticket data are available from the Bureau of Transportation Statistics, referred to as DB1B. This data source was analyzed by Aviation System Consulting, LLC, who estimated that in 2009 (the most recent year available at the time) over 12.5 million passengers traveled between major airports in northern California (MTC and SACOG regions) and Southern California (SCAG and San Bernardino Association of Government regions). This equates to over 34,000 air passengers per day, as displayed in Table 2-17. However, the air passenger estimates from the expanded/corrected CSHTS Long-Distance survey identify only 19,000 air passengers per day, 55 percent of the total estimated from the 10 percent O&D Survey. CSHTS data for all four regional markets between northern California and Southern California are significantly less than the 10 percent O&D Survey data.

Table 2-17 Comparison of Daily Long-Distance Air Passenger Estimates

Regions	Passenger Count (2009)	2012-2013 CSHTS LD Expanded	Ratio
MTC-SCAG	20,419	11,836	58%
MTC-SANDAG	6,495	4,201	65%
SACOG-SCAG	5,594	2,436	44%
SACOG-SANDAG	1,858	563	30%
Major Market Total	**34,366**	**19,035**	**55%**

Sources: Aviation System Consulting, LLC and Cambridge Systematics, Inc.

Several hypotheses were tested to try to explain this difference; an explanation that could account for the full magnitude of the difference was not found. A portion of the difference can be explained by out-of-state visitors traveling within California, but this probably does not account for the full difference. As documented previously, the comparison of the CSHTS Long-Distance survey to the Harris survey completed in 2011 shows a difference between the two surveys in the number of long-distance air passengers on trips over 300 miles in length. The 2012-2013 CSHTS Long-Distance Recall survey expanded and corrected shows an average airplane mode share of 27 percent for trips over 300 miles, while the 2011 Harris Survey expanded shows an average airplane mode share of 34 percent for trips over 300 miles.

No systemic bias that would explain this difference was identified. One possibility was that the differences resulted from the Harris Survey panels were biased leading to oversampling of older and higher income residents more likely to choose air travel for their main travel mode. However, since there was no definitive data source to confirm otherwise, the lower values for airplane travel from the 2012-2013 CSHTS have been used for analyses.

2.3 2005 and 2013-2014 RP/SP Surveys

This section discusses the two RP/SP surveys. They are combined in this section due to a number of common characteristics of the two surveys.

The 2005 RP/SP survey conducted to develop the Version 1 model included RP and SP data from air, rail, and auto trip passengers. The RP portion of the survey asked about a trip actually made by the respondent, while the SP portion of the survey pivoted off of the actual trip, but asked the respondent to consider hypothetical trip attributes and make hypothetical mode choices, for which high-speed rail was one option.

In total, 3,172 surveys were conducted, including:

- 1,234 airline passenger intercept surveys;
- 430 rail passenger intercept and telephone surveys; and
- 1,508 auto trip telephone surveys.

The objectives of the 2013-2014 RP/SP survey were to provide a recent travel behavior dataset to quantify the post-recession price/service tradeoffs, contrast them with the earlier surveys, and explore whether HSR attractiveness has changed during the 8 to 9 years since the 2005 survey. An effort was made to collect a significantly larger number of conventional rail surveys than the 2005 survey. Like the 2005 survey, the 2013-2014 RP portion of the survey asked about a trip actually made by the respondent, while the SP portion of the survey pivoted off of the actual trip, but asked the respondent to consider hypothetical trip attributes and make hypothetical mode choices, for which high-speed rail was one option.

In total, 4,347 surveys were conducted, including:

- 1,306 airline passenger surveys;
- 1,848 rail passenger surveys; and
- 1,133 auto trip surveys.

The 2013-2014 dataset has several advantages over the 2005 dataset, including the following:

- Larger sample size;
- Sampling at LAX and on Caltrain;
- Multiple media survey approach;
- Greater degrees of survey customization based on the RP trip reference;
- "Single contact" surveys to improve response rates;
- Changes in survey design to clarify past questions;
- Continuous input by the RTAP on survey content; and
- New data that include attitudes towards and familiarity with HSR.

2005 RP/SP Data Collection Process

Airline Passenger Surveys

Airline passenger surveys were conducted at six key airports throughout California:

- Surveys conducted inside terminals at boarding gates:
  - Sacramento,
  - San Jose,
  - San Francisco, and
  - Fresno.

- Surveys conducted outside security areas:
  - Oakland, and
  - San Diego

In the airports where surveying was done at the boarding gates, teams of surveyors were assigned to specific flights that were going to targeted destination airports in California. Potential respondents at Oakland and San Diego were approached, and asked their travel destinations. California-bound travelers were administered the survey.

Mailback envelopes with postage paid were offered to respondents who did not complete the questionnaire in time to give it back to surveyor at the airport. Most surveys completed at the Sacramento, San Jose, San Francisco, and Fresno airports were collected at the airport from passengers who filled them out while waiting for their planes. Nearly all of the surveys distributed at Oakland and San Diego were mailed back by respondents because passengers at these two airports did not have as much time to complete the survey outside the security area.

Rail Passenger Surveys

The rail passenger survey was conducted using two methodologies: 1) as an on-board self-administered survey similar to the air passenger survey; and 2) as a telephone survey conducted among qualified users of existing rail services. On-board surveys were conducted on two commuter rail systems:

- Altamont Commuter Express (ACE) trains; and
- Metrolink trains.

Telephone surveys were conducted using a rider database from Amtrak that included riders from the following services:

- Capitol Corridor,
- Pacific Surfliner, and
- San Joaquin.

Rail passenger intercept (on-board) surveys were conducted on-board the ACE and Metrolink trains. Teams of surveyors were assigned to specific routes that were traveling across targeted regions served by this system. For example, on the Metrolink trains, routes that traveled between the San Diego and Los Angeles region were targeted. Mailback envelopes with postage paid were offered to respondents who did not complete the questionnaire in time to give it back to surveyor on the train.

Auto Passenger Surveys

To capture the mode choice decisions of interregional travelers who have chosen to use autos, a random digit dial sample of household surveys was conducted among residents of the study area. A stratified sampling approach was utilized. This entailed dividing the State into the relevant regions, and setting a targeted number of completes for households within each region. The final target quotas for the retrieval surveys were:

- A minimum of 120 responses from nine regions = 1,080 plus;
- Approximately 120 additional responses from some combination of the six smaller areas (Bakersfield, Tulare/Visalia, Fresno, Merced, Modesto/Stockton, and Sacramento); plus
- About 250 additional responses from some combination of the three larger areas (San Diego, Los Angeles, and San Francisco Bay).

The final retrievals by region are as follows:

- San Diego (158),
- Los Angeles (243),
- Bakersfield (144),
- Tulare County/Visalia (98),
- Fresno (149),
- Merced (155),
- San Francisco Bay Area (283),
- Modesto/Stockton (145), and
- Sacramento (133).

Table 2-18 presents a summary of the air, rail, and auto passenger surveys collected. These are presented by trip purpose and mode.

Table 2-18 2005 RP/SP Air, Rail, and Auto Passenger Surveys by Mode and Purpose

Purpose	Auto	Air	Rail	Total
Business	172	543	64	779
Commute	9	12	123	144
Recreation/Other	1,059	283	91	1,433
Total	**1,240**	**838**	**278**	**2,356**

Sources: Corey, Canapary, & Galanis Research and Cambridge Systematics, Inc.

2013-2014 RP/SP Data Collection

Airline passenger surveys were conducted at only two airports: San Francisco (SFO) and Los Angeles (LAX). It was important to survey at LAX since the 2005 survey did not.

The rail passenger survey was conducted on the following four conventional rail systems:

- Caltrain (not surveyed in 2005), surveyed stations include the following:
  - Lawrence,
  - Santa Clara,
  - San Jose,
  - San Francisco – 4th and King,
  - San Francisco – 22nd Street,
  - San Francisco – Bayshore
  - Tamien, and
  - Sunnyvale.
- Metrolink, surveyed stations include the following:
  - Anaheim,
  - Irvine,
  - Lancaster,
  - Los Angeles – Union Station,
  - Palmdale,
  - San Bernardino, and
  - Vincent Grade/Acton.
- Amtrak Routes – Capitol Corridor, San Joaquin, Pacific Surfliner, and Coast Starlight surveyed stations include the following:
  - Bakersfield,
  - Davis,
  - Emeryville,
  - Fresno,
  - Hanford,
  - Los Angeles – Union Station,

- Martinez,
- Oakland – Coliseum,
- Oakland – Jack London Square.
- Richmond,
- Sacramento,
- San Diego – Santa Fe Depot,
- San Jose,
- Santa Clara – Great America, and
- Santa Clara – University.

For both air and conventional rail travelers, multiple media surveys were used after intercepting travelers at stations/airports. Options for taking the survey included a print version with mail-back option, an online option, and tablet interviews (in cases where respondents agreed to be interviewed at that time).

Auto travelers were interviewed via telephone surveys and web-only surveys.

Table 2-19 presents a summary of the air, rail, and auto passenger surveys collected. These are presented by trip purpose and mode.

Table 2-19 2013-2014 RP/SP Air, Rail, and Auto Surveys by Mode and Purpose

Purpose	Auto	Air	Rail	Total
Business	176	637	311	1,124
Commute	26	24	628	678
Recreation/Other	921	692	899	2,512
Total	**1,123**	**1,353**	**1,838**	**4,314**

Sources: Corey, Canapary, & Galanis Research and Cambridge Systematics, Inc.

Stated-Preference Survey Component

The stated-preference portion of the surveys pivoted off of the actual trip taken by the respondent. Individuals were asked to envision a trip similar in most ways to this trip, but with some important differences. Those differences included modal attributes which were presented to the respondents as part of the experiments. In addition, the high-speed rail alternative was always presented as a possible alternative. Each respondent to the 2005 survey completed four SP exercises, while 2013-2014 respondents completed six SP exercises.

2005 SP Questionnaire

Each respondent was asked to complete four SP experiments; each of which had three or four modal choice alternatives to select from. For each experiment and each modal alternative, a list of attributes of that alternative was presented to the respondent. These attributes included travel time, travel cost, headway for non-auto modes, and reliability. Figure 2-5 shows an example of one SP experiment from the 2005 survey.

Figure 2-5 Example SP Experiment – 2005 RP/SP Survey

Choice Exercise A

28. Your choices are…

TRAVEL BY CAR	TRAVEL BY AIR	TRAVEL BY HIGH SPEED RAIL
	Travel to and from the airports is the same as you described earlier in the survey (questions 15 - 19) You should arrive at the airport at least **1 hour** before your flight.	Travel to and from the stations is the same as you described earlier in the survey (questions 20 - 27) You should arrive at the station at least **10 min.** before your train
You travel whenever you would like	There is a flight **every 1 hour**	There is a train **every 1 hour**
The typical travel time in the car is **6 hrs 30 min** (not including stops for rest, food, etc.)	The scheduled travel time in the plane is **1 hr 20 min**	The scheduled travel time in the train is **2 hrs 40 min**
50% chance of arriving within **15 min.** of the typical time	80% of flights arrive within **15 min.** of schedule	85% of trains arrive within **5 min.** of schedule
The roundtrip fuel cost is **$70**	The roundtrip fare is **$320**	The roundtrip fare is **$140**
Travel by Car ☐	***Travel by Air*** ☐	***Travel by High Speed Rail*** ☐

Sources: Corey, Canapary, & Galanis Research and Cambridge Systematics, Inc.

Across the four SP experiments, the levels of each attribute were varied so that the respondent would consider several possible choice environments. The only thing that did not vary across experiments was the amount of time respondents were told to arrive early at the airport or train station. For air travel, it was indicated to respondents to arrive one hour prior to flight time and for train travel, 10 minutes prior to train departure.

It should also be noted that different reliability measures between car/air travel and HSR travel were used in the 2005 SP experiments as noted in Figure 2-5 above. For the HSR alternative, the reliability measure was presented as the percentage of time trains will arrive within 5 minutes of schedule, while for all other modes, the reliability measure was presented as the percentage of time for being within 15 minutes of scheduled.

Finally, for air, HSR, and CVR travel, the experiments always indicated that travel to/from the station/airport would be identical to the way the respondent described earlier in the survey. In cases where the individual chose air or CVR as their RP mode, this refers to the actual way in which the respondent traveled to the airport/station and the actual way the respondent intends to travel from the airport/station at egress. In addition, this information includes the travel time and travel cost for access and egress.

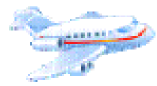
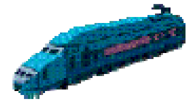
In cases where the individual did not choose the SP mode as their RP mode (which includes all instances of HSR), the survey asked the respondent to provide information about how the respondent believed they would access and egress the stations/airports. This included selecting the stations/airports they would use, the mode they believed they would use to access and egress, and the travel time and cost they believed they would encounter.

2013-2014 SP Questionnaire

Each respondent was asked to complete six SP experiments; each of which had three modal choice alternatives to select from. For air travelers, air, auto, and high-speed rail were presented as potential alternatives. For conventional rail travelers, rail, auto, and high-speed rail were presented as potential alternatives. For auto travelers, auto and high-speed rail were presented as potential alternatives in addition to either air or conventional rail, depending on the attributes of the trip.

For each experiment and each modal alternative, a list of attributes of that alternative were presented to the respondent. These attributes included four main mode attributes: travel time, travel cost, reliability, and headway for non-auto modes. It also included access and egress travel times for non-auto modes. Figure 2-6 shows an example of one SP experiment from the 2013-2014 survey.

Figure 2-6 Example SP Experiment – 2013-2014 RP/SP Survey

Your Travel Choices Service Attributes	Travel By Auto 	Travel By Air 	Travel By High Speed Rail 
	TOTAL cost by car is shared among all passengers.	You should arrive at the airport at least 75 minutes before your flight	You should arrive at the station at least 15 minutes before your train
Service Frequency: How often a flight or a train goes to your destination	Available all the Time	Every 20 minutes	Every 35 minutes
Travel Time in the Vehicle (auto, airplane, or rail car): Expected time in the vehicle	7 Hours 35 Minutes	1 Hour 5 Minutes	2 Hours 40 Minutes
Getting From Your Origin: Time to get to the station/airport	Not Applicable	40 minutes	30 minutes
Getting To Your Destination: Time to get from the station/airport to your final destination	Not Applicable	60 minutes	30 minutes
Schedule Reliability: Percent of trips that arrive within 15 minutes of the scheduled time	60 percent	90 percent	90 percent
Travel Cost: All costs are one way. Auto cost includes fuel, tolls and maintenance. Air and rail cost includes fares and the cost of getting to and from airports/stations.	$85	$65 Per Person	$70 Per Person
Which would you choose?	**( ) Auto**	**( ) Air**	**( ) High Speed Rail**

Sources: Corey, Canapary, & Galanis Research, Kevin Tierney, and Cambridge Systematics, Inc.

Nontrader Analysis

A common issue with stated-preference surveys is the prevalence of nontraders. Nontraders are defined as individuals who selected the same choice option for each SP experiment whereas traders are individuals who selected a different choice option for at least one of the SP experiments.

The main reason for examining the dataset in terms of traders and nontraders is simply to better understand the behaviors of each group. Since the mode choice models are reliant solely on the 2005 and 2013-2014 SP data to model HSR preferences, the SP data is quite important. This section examines the SP choice patterns of traders and nontraders, and offers a detailed analysis of drivers, passengers, and rail riders.

Transition Matrix

One key to understanding the behaviors observed in the SP data is simply looking at the choices of respondents, for which a transition matrix can be useful. A transition matrix, here, refers to a table that shows the SP choice behaviors of respondents split out by what observed RP behavior was. That is, for existing car travelers, the transition matrix will show the SP choice behavior of those respondents, and similar for existing air and CVR travelers.

Table 2-20 shows the transition matrix of all traders in the dataset. The transition matrix shows the RP choice of the respondent on the left versus the SP choices of these individuals on the right. Keep in mind that all of these respondents are traders, meaning that across the four SP experiments, they selected at least two different modes of travel.

Table 2-20 SP Transition Matrix for Traders

RP Choices		Total Respondents	Stated Preferences				Stated Preference Shares			
			Car	Air	CVR	HSR	Car	Air	CVR	HSR
	2005 SP Survey									
	Car	674	1,088	66	175	1,365	40%	2%	6%	51%
	Air	497	136	631	0	1,147	7%	33%	–	60%
	CVR	224	120	11	298	451	14%	1%	34%	51%
	Total	1,395	1,344	708	473	2,693	24%	13%	9%	54%
	2013-2014 SP Survey									
	Car	546	1,365	163	223	1,433	43%	5%	7%	45%
	Air	945	148	2,844	0	2,676	3%	50%	–	47%
	CVR	1,378	1,484	0	3,364	3,409	18%	0%	41%	41%
	Total	2,869	2,997	3,007	3,587	7,518	18%	18%	21%	44%

Source: Cambridge Systematics, Inc.

As shown in the table, the share of traders selecting their own RP mode varies from about 33 percent for air and CVR travelers in the 2005 survey to about 50 percent for air travelers in the 2013-2014 survey. The difference between surveys is largest for air travelers, which may say something about changing perceptions of HSR for long-distance travel by air travelers.

Table 2-21 shows the transition matrix of all nontraders in the dataset. The transition matrix for nontraders in the 2005 survey is starkly different than that of traders. While car travelers are more likely to stay with their existing mode (52 percent compared to 40 percent for traders), air and CVR travelers are less likely to stay with their existing mode (15 percent and 22 percent for air and CVR compared with 33 percent and 34 percent for traders). Moreover, the HSR share is higher for nontraders than it is for traders.

The 2013-2014 survey data is more tempered. Car nontraders in 2013-2014 are much more likely to stay with their current mode (about 76 percent compared to 43 percent among traders). Air and CVR nontraders, on the other hand, have roughly the same likelihood of staying with their current mode (49 and 40 percent for nontraders and 50 and 41 percent for traders). In addition, 2013-2014 has a lower incidence of nontraders than the 2005 survey (34 percent in 2013-2014 versus 45 percent in 2005).

Table 2-21 SP Transition Matrix for Nontraders

RP Choices		Total Respondents	Stated Preferences				Stated Preference Shares			
			Car	Air	CVR	HSR	Car	Air	CVR	HSR
	2005 SP Survey									
	Car	625	1,304	16	8	1,172	52%	1%	0%	47%
	Air	418	28	248	–	1,396	2%	15%	–	83%
	CVR	112	8	–	100	340	2%	–	22%	76%
	Total	1,155	1,340	264	108	2,908	29%	6%	2%	63%
	2013-2014 SP Survey									
	Car	568	2,310	35	19	681	76%	1%	1%	22%
	Air	420	36	1,224	–	1,253	1%	49%	–	50%
	CVR	470	360	–	1,113	1,338	13%	–	40%	48%
	Total	1,458	2,706	1,259	1,132	3,272	32%	15%	19%	39%

Source: Cambridge Systematics, Inc.

HSR market share is much lower in 2013-2014 compared to 2005 among nontraders. This pattern also is true among traders, but the drop in HSR share among nontraders is greater. Overall, the HSR market share dropped in 2013-2014 versus 2005 among all travelers as follows:

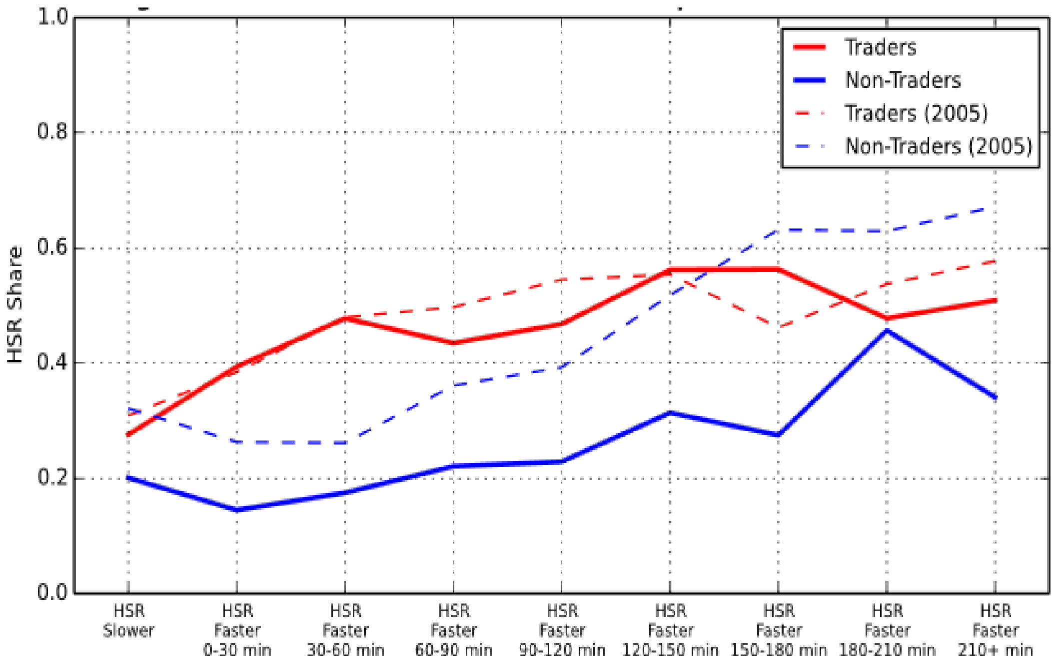
- **HSR SP share** – 33 percent vs. 49 percent among auto drivers;
- **HSR SP share** – 48 percent vs. 71 percent among air passengers; and
- **HSR SP share** – 36 percent vs. 60 percent among CVR riders.

One thing is quite clear from Tables 2-19 and 2-20, there is a strong prevalence for choosing either the RP mode in the SP experiments or the new HSR mode.

Car versus HSR

This section examines the prevalence of individuals choosing the HSR mode when their RP mode was car. This is done by using travel time and cost differences and their effect on HSR share. Figure 2-7 shows the effect of travel time difference (measured between car and HSR) on the percentage of time HSR is the selected SP mode. Traders and nontraders are plotted separately, and separate plots are made for 2005 and 2013-2014 datasets. Keep in mind that the figure includes only those using car in the RP portion of the survey.

Figure 2-7 Effect of Travel Time Difference on HSR Share among Car Travelers

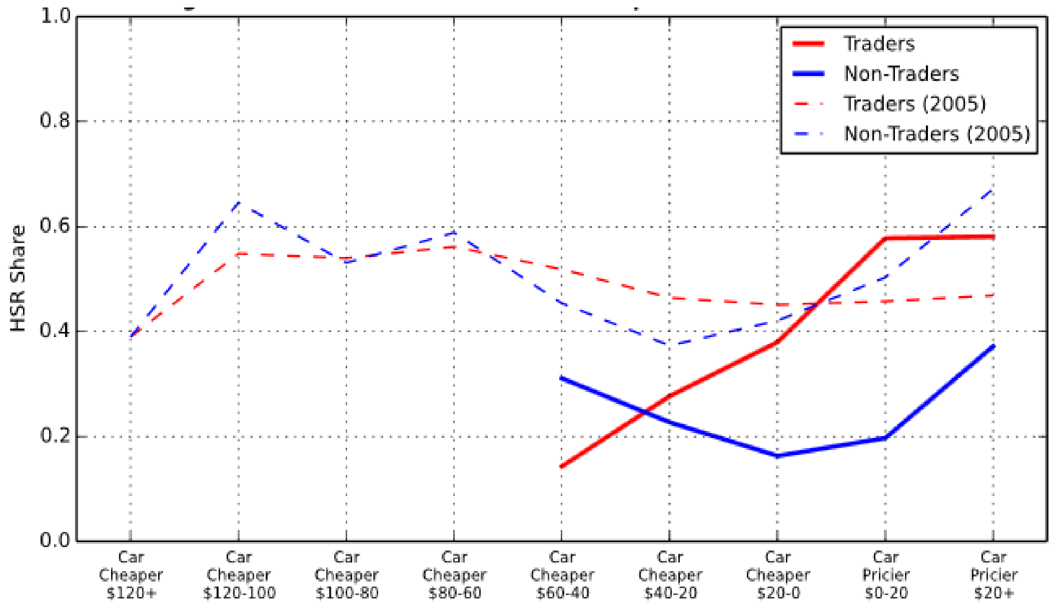


Source: Cambridge Systematics, Inc.

As shown by the figure, the more competitive HSR travel times are, the higher share HSR attracts for both traders and nontraders and in both 2005 and 2013-2014 datasets. The 2013-2014 nontrader diversion curve is more reasonable (and much lower) than in 2005.

Figure 2-8 shows the effect of cost differences on the percentage of time HSR is selected as the SP mode. In the 2013-2014 survey, a more realistic, narrower range of lower auto costs was used than was used in the 2005 survey. The slope of the HSR market share curve is very strong for traders in 2013, while it is rather flat for nontraders in 2013. The 2005 patterns are somewhat insensitive for both traders and nontraders, and 2013-2014 HSR diversion patterns appear to be more reasonable.

Figure 2-8 Effect of Cost Difference on HSR Share among Car Travelers

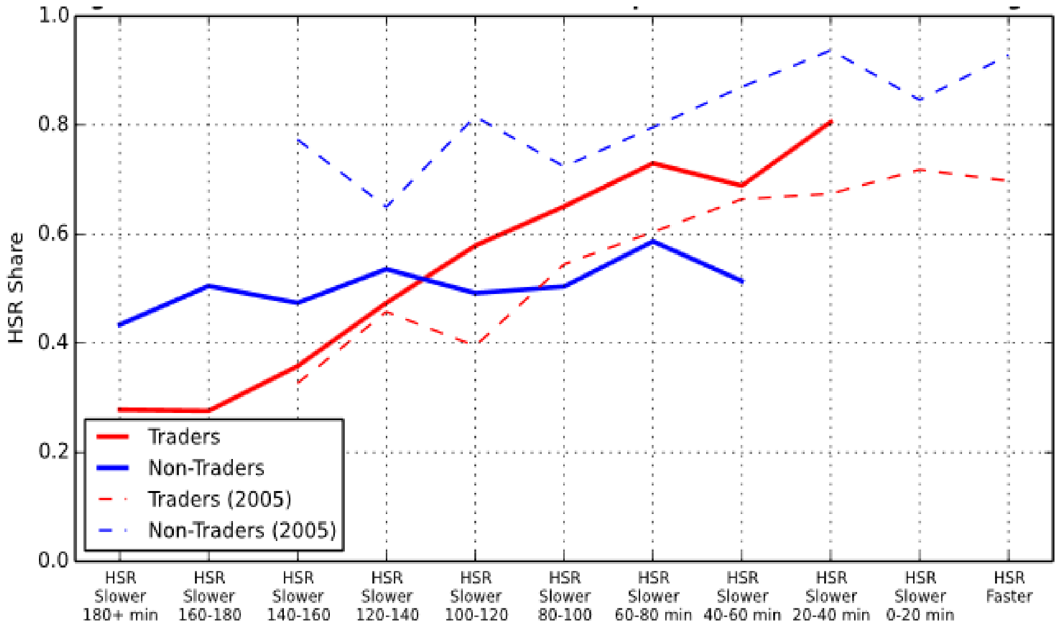


Source: Cambridge Systematics, Inc.

Air versus HSR

This section examines the prevalence of individuals choosing the HSR mode when their RP mode was air. Figure 2-9 shows the effect of travel time differences on HSR share among air travelers. As illustrated, more realistic differences in travel times were used in the 2013-2014 survey. HSR was shown as slower than air in the 2013-2014 survey, relative to 2005. Traders' slope of HSR market share is very reasonable in 2013-2014 and is shifted slightly upward compared to 2005. The 2013-2014 trader behavior also is reasonable relative to nontraders in 2013, whose slope is generally flat. In 2005, nontraders had a very high HSR share and a much higher HSR share compared to traders, which is questionable.

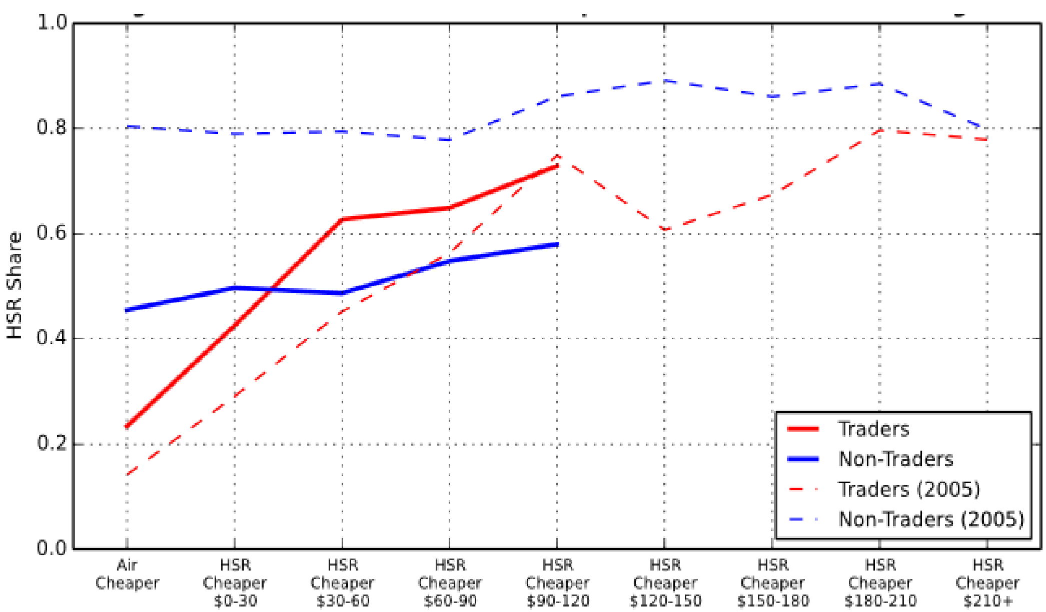
Figure 2-9 Effect of Travel Time Difference on HSR Share among Air Travelers



Source: Cambridge Systematics, Inc.

Figure 2-10 shows the effect of cost differences on the percentage of time HSR is selected as the SP mode among air travelers. Again, a more realistic, narrower range of lower HSR fares was used in the 2013-2014 survey. The slope of HSR share among 2013-2014 traders is strong; whereas, the nontrader patterns are less clear, but still reasonable. In contrast, the HSR market share among nontraders in 2005 was too high and was consistently higher than traders.

Figure 2-10 Effect of Cost Difference on HSR Share among Air Travelers

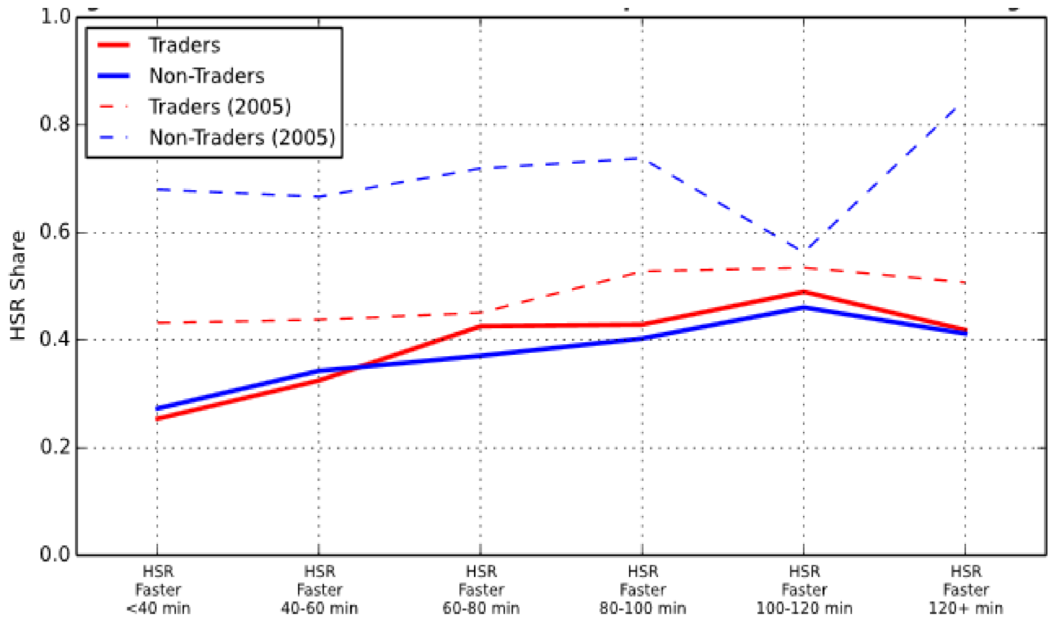


Source: Cambridge Systematics, Inc.

CVR versus HSR

This section examines traders and nontraders among CVR travelers; again from the perspective of travel time and cost differences. Figure 2-11 shows the HSR share as travel time difference between HSR and CVR changes.

Figure 2-11 Effect of Travel Time Difference on HSR Share among CVR Travelers

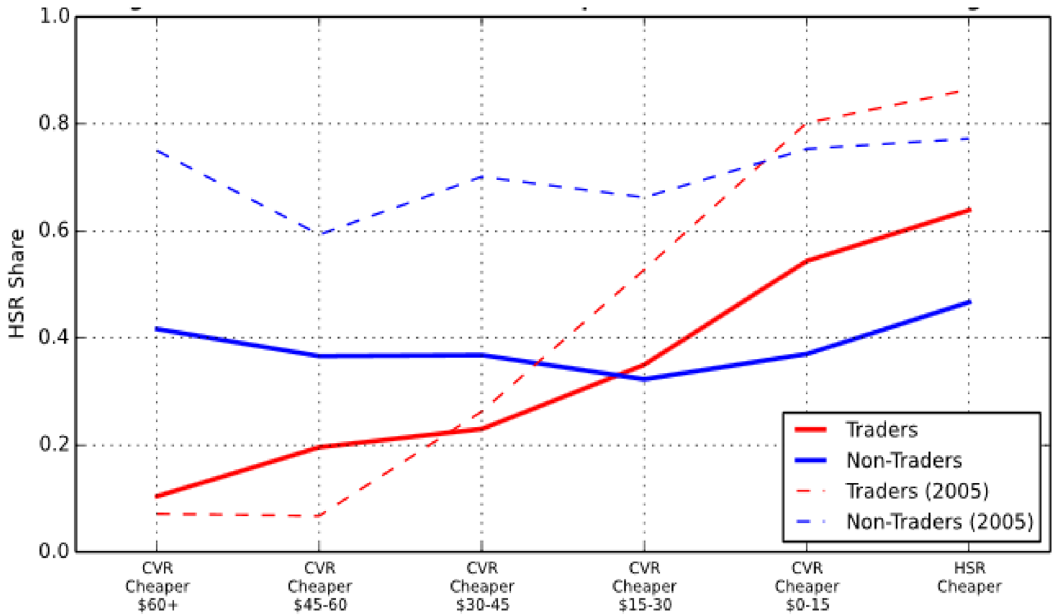


Source: Cambridge Systematics, Inc.

The slope of the 2013-2014 HSR market share is similar between traders and nontraders, and trader behavior is similar between 2005 and 2013-2014 datasets. However, nontrader patterns in 2005 are less reasonable, with HSR market share being very high and higher than nontraders.

Figure 2-12 shows the effect of cost differences on the percentage of time HSR is selected as the SP mode. Again, HSR market shares are more realistic in 2013-2014 compared to 2005. The 2013-2014 trader slope is strong and reasonable in 2013, while the nontrader response is flatter, but still responds to competitive HSR fares. Trader slopes are similar in both years, but nontrader HSR share is very high in 2005, though the slope is similar to 2013.

Figure 2-12 Effect of Cost Difference on HSR Share among CVR Travelers



Source: Cambridge Systematics, Inc.

Summary

Overall, there appears to be some important differences between traders and nontraders in the RP/SP datasets, and there also are important differences between 2005 and 2013-2014 datasets. In general, the 2013-2014 HSR market shares are more reasonable than those found in the 2005 data. This extends for nearly all segments of the data, from car travelers to air and conventional rail travelers, and from traders to nontraders. Nonetheless, the 2005 data remains an important and useful dataset for the model development purposes, particularly since the original model design was developed using that dataset.

While traders and nontraders seemed to be effected in similar ways by differences in travel times, traders were much more sensitive to travel costs than were nontraders. This trend was evidenced across all of the travelers, including car, air, and CVR travelers. Overall, the behaviors of traders in the dataset appear to be more rational than those of nontraders; even across datasets.

3.0 Long-Distance Model – 2010 Input Data

3.1 Socioeconomic Data

The variables included in the input socioeconomic dataset are shown in Table 3-1. The employment and household data for year 2010 are consistent with the CSTDM since they were converted from the CSTDM zone system to the CHSRA zone system. The methodology for developing the socioeconomic data within the CSTDM is described in the following sections.

Table 3-1 Socioeconomic Dataset Variables

Column Number	Column Header	Description
1	TAZ	CHSRA TAZ System: TAZs 123-6698 are internal TAZs
2	County	County number: California county code – numerically in alphabetical order
3	Region	Region number: CHSRA 14 regions
4	Prim_Sec	Primary and secondary employment: NAICS 11, 21, 23,31-33
5	Whole	Wholesale trade employment NAICS 42
6	Tran_U	Transportation and utility employment NAICS 22,48-49
7	Office	Office employment: NAICS 51-56,92
8	Retail	Retail employment: NAICS 44-45
9	EduMed	Education and medical employment: NAICS 61-62
10	LeisHosp	Leisure and hospitality employment: NAICS 71-72
11	OthServ	Other service employment: NAICS 81
12	Military	Military employment, all industries
13	SpecGen	Special generators: 1 = Disneyland (TAZ 5796); 2 = Yosemite (TAZ 745)
14	Sqmile	Area of TAZ (square miles)
15	TotPop	Total population (includes group quarters)
16	TotHH	Total households (excludes group quarters)
17-115		Number of households segmented by HH size (0, 1, 2, 3, 4+); Number of HH Workers (0, 1, 2+); Income Group (Low: <$30K; Mid: $30-$65K; High: >$65K (2005$)); Number of HH Vehicles (0, 1, 2+)[a]

[a] 4 household size groups x 3 number of worker groups x 3 income groups x 3 household vehicle groups results in 108 strata. However, the "2+ workers in 1 person households" group is illogical and the 9 income group x household vehicle strata for that illogical group are dropped from the file.

Overview of CSTDM Population Synthesizer

The CSTDM forecasts all personal travel made by every California resident, plus all commercial vehicle travel, made on a typical weekday in the fall/spring (when schools are in session). Included in the CSTDM framework is a synthetic population that represents every person and housing unit in California; it is based on sampling U.S. Census Public Use Microdata Sample (PUMS) five percent person and household data to match targets that can be derived from sources such as CTPP Summary File 3, the American Community

Survey (ACS), or other sources of data. The population synthesizer uses a large number of marginal targets representing categories such as household sizes, housing types, household income groups, person age categories, auto ownership categories, employed workers by occupation category, and students by education level.

The population synthesizer developed by HBA Specto works by combining a trial population of households and altering it by substituting new possible households to better match marginal distribution targets. If the match with the targets improves, the new household is kept. A detailed description of the algorithms used in this process is part of the detailed documentation of the population synthesizer (and can be found in *CSTDM09_Population_Final.pdf*). The population synthesizer is capable of handling multiple nested geographies, of matching categorical totals or averages, and of weighting possible targets. The weighting capability is useful if some targets are considered to be more important than others, or if the scales differ (such as with an average income category).

In general, synthesizing the population consists of four steps: 1) creating sample tables or individual household records; 2) creating target tables or control totals for available geographies; 3) testing the goodness of fit; and 4) aggregating the synthesized population by TAZs. To enhance the accuracy of the population synthesis, population is synthesized by the Census Bureau's Public Use Microsample Areas (PUMA). Each PUMA has a sample table and a target table. The population synthesizer data from the CSTDM was then queried into the CSHTS zone system by the 99 household strata shown in Table 3-1.

The year 2010 synthesized population was based on the 2010 U.S. Census and ACS population and household statistics. Data directly from the U.S. Census was used without much modification, because these data were available in small geographies for the required time period. For example, the population total could be found by Census block for the year 2010. The block totals were then aggregated to the TAZ level, and the population synthesizer was run to cross-tabulate these totals.

Overview of CSTDM Employment Data

The CSTDM includes nine industry categories that are aggregated from 13 North American Industrial Classification System (NAICS) categories, as shown in Table 3-1. Three data sources were used together to develop the year 2010 industry categories by TAZ: California Employment Development Department (EDD), ACS Equal Employment Opportunity (EEO), and the Longitudinal Employment and Household Dynamics (LEHD) On the Map (OTM).

California Employment Development Department

The Division Labor Market Information (LMI) provides data to the public for the Employment Development Department on California labor markets. The QCEW, or Quarterly Census of Employment and Wages, release data by industry, including the number of employees in each industry for each county. The QCEW is a program involving the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor and the State Employment Security Agencies (SESAs). Employment and wage information for workers is tabulated for all employees covered by state unemployment insurance (UI) laws and Federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program. At the state and area level, the QCEW program publishes employment and wage data down to the 6-digit NAICS industry level, if disclosure restrictions are met. In accordance with BLS policy, data provided to the bureau in confidence are not published and are used only for specified statistical purposes. BLS withholds publication of UI-covered employment and wage data for any industry level when necessary to protect the identity of cooperating employers.

ACS Equal Employment Opportunity

The ACS had recently published employment by industry. An advantage of this data is that it is derivative of a household survey and includes all types of employment, an advantage over QCEW employment by industry data. The recently released data included this information by place of work as well, whereas it was previously related to household location and not the location of employment. This data also provides a more internally consistent definition of worker within the CSTDM because ACS data is used for workers on the population/household side.

A disadvantage of the ACS EEO data is that it does not publish data for counties with low numbers of employees for certain industries or occupations.

Longitudinal Employment and Household Dynamics on the Map

OTM data are a product of the LEHD project of the US Census Bureau. The LEHD combines Federal and state administrative data on employers and employees with census data on where people live, to provide information on home-to-work flows. OTM data are synthesized using Unemployment Insurance Wage Records reported by employers and maintained by each state for the purpose of administering its unemployment insurance system. Each state assigns employer locations, but actual business locations are not used in the dataset to retain the confidentiality of the workforce. Instead, the underlying data are modeled to produce a synthetic dataset which incorporates noise into the data to produce an accurate, but not exact, representation of employment.

The main advantage of OTM data are the geographic units it uses (i.e., census blocks). The disadvantages of using this dataset include the fact that it is a synthetic dataset and that several problems have been identified with the data, especially in the early years of publications (e.g., employees being linked to headquarters of companies rather than branch offices, which overestimates state workers in the State Capitol) but the industry has recognized the importance of the data and the improvements that have been made over the years, including the data from year 2010.

Methodology for Processing the Employment Data

The following method of combining the above data sources was used to produce a reasonable estimation of 2010 employee counts by industry. Total employment for each county, as reported by the EDD data, provides county-level targets, and the distribution of employment by industry from the ACS EEO data was applied to those EDD totals. However, there were a few counties for which there was no ACS EEO employment by industry. For those counties (less than one percent of the statewide employment), the state industry distributions were assumed. The final step was to use OTM data to spatially distribute those county-level employment totals by industry to each CSTDM TAZ. A cross-walk was used to reassign the CSTDM TAZ totals to the CHSRA TAZ system.

Each dataset was evaluated using the most of the same industry categories, based on NAICS. The single exception to this is for Military jobs. While CTPP 2000 provides total employment for the military, the other datasets (EDD and OTM) do not. For this reason, the growth in military employed persons by county between 2000 and 2010 was applied to the year 2000 military employment. It should be noted that Military employment is not used in the CHSRA model.

Table 3-2 shows the specific breakdown of the types of employment included within each employment category used within the BPM-V3.

Table 3-2 Employment Categorization

NAICS Category	NAICS Code	CHSRA Model Category
Agriculture, Forestry, Fishing, Hunting	11	Primary Sector
Mining, Quarrying, Oil/Gas Extraction	21	
Construction	23	
Manufacturing	31-33	
Wholesale Trade	42	Wholesale Trade
Retail Trade	44-45	Retail Trade
Utilities	22	Transportation
Transportation and Warehousing	48-49	
Information	51	Office
Finance and Insurance	52	
Real Estate and Renting/Leasing	53	
Professional, Scientific, Technical Services	54	
Management of Companies and Enterprises	55	
Administrative/Support and Waste Management and Remediation Services	56	
Public Administration	92	
Educational Services	61	Education/Medical
Health Care and Social Assistance	62	
Arts, Entertainment, Recreation	71	Leisure/Hospitality
Accommodation and Food Services	72	
Other Services (except Public Administration)	81	Other Services

Source: Cambridge Systematics, Inc.

3.2 Highway Network

The representation of highway network supply is primarily determined by the level of detail in the highway network and the attributes associated with the roadway system, such as lanes, distances, speed, and capacity. A base Year 2010 Network was built for the Version 2 model.[15] A Master Network that contained information for year 2000 and build-out information for forecast years from 2010 through 2040 was also built for Version 2 model. The 2010 and Master networks continue to be used for the BPM-V3.

[15] Cambridge Systematics, Inc., *California High-Speed Rail Ridership and Revenue Model Version 2.0 Model Documentation*, prepared for the California High-Speed Rail Authority, April 11, 2014.

3.3 Air Operating Plan and Fares

Level of service assumptions for air developed for the Version 2 model were used for the BPM-V3. The level of service assumptions were based on the information provided by Aviation System Consulting, LLC (ASC-LLC)[16]. Since the most recent year for which air headways and fares were provided was 2009, those values were used and assumed to be the same for 2010. All fares were converted to 2005 dollars[17] for the model. The information provided by ASC-LLC did not contain headways and fares for several minor markets, such as Monterey Regional Airport to Los Angeles International Airport. The Version 2 and, thus, the BPM-V3 fares and headways for those services were calculated from fares and headways used in the Version 1 model using the following approach:

- Each minor market was first assigned a segment type based on a straight-line distance of either less than 280 miles or greater than 280 miles.
- The average percentage changes in headways and fares were calculated from the existing ASC-LLC data and the previous air LOS data from the Version 1 and 2 models. These percentage changes were calculated for both the market segments of less than or greater than 280 miles.
- The calculated percentage changes were applied to the headways and fares obtained from the LOS file from the Version 1 and 2 models for the minor markets for which ASC-LLC did not supply data.

Average in-vehicle travel times for air were based on an Internet search of published departure and arrival times for direct flights between airport pairs.

3.4 Transit Operating Plans and Fares

The Version 2 base year model transit service and fare information for year 2010 was used for the BPM-V3. The general methodology for coding transit routing and frequency included keeping local bus service assumptions consistent with Version 1 and 2 models and updating rail services. Updating the local bus lines in the state would have provided little change in the overall accessibility and path-building required for connections to and from long-distance transit services. For rail services, MPO modeling files were used for travel time and headway information. Where MPO modeling files were not obtained, on-line published schedules from 2011 were used for 2010 network coding. Table 3-3 provides a list of all transit services included in the BPM-V3 and details the data source used to obtain the operating plan and fares.

As shown in Table 3-3, the following transit services are considered as CVR: ACE, Amtrak – Capitol Corridor, Amtrak – Pacific Surfliner, Amtrak – San Joaquin, Caltrain, Coaster, Metrolink, and Sprinter. These eight lines are included as CVR in the main mode choice model. The other lines are only used as access and egress modes to HSR, Air, and CVR.

[16] Aviation System Consulting, *Potential Airline Response to High-Speed Rail Service in California*. Prepared for Cambridge Systematics, Inc., August 2011.

[17] As with the Version 1 and Version 2 models, the BPM-V3 model uses 2005 as the base year for expressing costs. Conversions between years are based on California Consumer Price Index data maintained by the California Department of Industrial Relations: https://www.dir.ca.gov/oprl/CPI/EntireCCPI.PDF.

Table 3-3 Transit Service Included in Model with Data Source for Year 2010 Operating Plan and Fares

Operator/Line	Transit Service	Data Source of Operating Plan	Data Source of Fare
AC Transit	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
ACE	CVR	MTC Year 2010 Model	On-line published fares – Year 2011
AirBART	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
American Canyon	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Amtrak – Capitol Corridor	CVR	On-line published schedule – Year 2011	On-line published fares – Year 2011
Amtrak – Pacific Surfliner	CVR	SCAG Year 2008 Model	On-line published fares – Year 2011
Amtrak – San Joaquin	CVR	On-line published schedule – Year 2011	On-line published fares – Year 2011
Amtrak Shuttles	Bus	On-line published schedule – Year 2011	On-line published fares – Year 2011
BART	Urban Rail (URBR)	MTC Year 2010 Model	On-line published fares – Year 2010
Benicia	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Caltrain	CVR	MTC Year 2010 Model	On-line published fares – Year 2010
Coaster	CVR	On-line published schedule – Year 2011	On-line published fares – Year 2011
Contra Costa County	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Dumbarton Express	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Fairfield	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Ferry	Ferry	MTC Year 2010 Model	On-line published fares – Year 2010
Golden Gate Transit	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Kern County Transit	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	On-line published fares – Year 2010
Metrolink	CVR	SCAG Year 2008 Model	On-line published fares – Year 2011
MetroRail	URBR	SCAG Year 2008 Model	On-line published fares – Year 2010
Sacramento Regional Transit	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	On-line published fares – Year 2010

Operator/Line	Transit Service	Data Source of Operating Plan	Data Source of Fare
Sacramento Regional Transit	Light Rail Transit (LRT)	On-line published schedule – Year 2011	On-line published fares – Year 2010
SamTrans	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
SamTrans	Express Bus	MTC Year 2010 Model	MTC Year 2010 Model
San Diego	Bus	SANDAG Transit Route File – Year 2011	On-line published fares – Year 2010
San Diego	LRT	SANDAG Transit Route File – Year 2011	On-line published fares – Year 2010
Santa Rosa	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
SCAG	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	On-line published fares – Year 2010
SCVTA	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
SCVTA	LRT	MTC Year 2010 Model	MTC Year 2010 Model
SFMTA	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
SFMTA	Cable Cars	MTC Year 2010 Model	MTC Year 2010 Model
SFMTA	Metro	MTC Year 2010 Model	MTC Year 2010 Model
Sonoma	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Sprinter	CVR	On-line published schedule – Year 2011	On-line published fares – Year 2010
Tri Delta	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Union City	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Vacaville	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	On-line published fares – Year 2010
Vallejo	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
VINE	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
WestCat	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model
Wheels	Bus	CHSRA Model Version 1 & 2 Models – updated Year 2006	MTC Year 2010 Model

Source: Cambridge Systematics, Inc.

3.5 Parking Costs and Availability

Auto Parking Costs

Auto parking costs for each TAZ were determined from parking costs obtained from SCAG, MTC, and SACOG MPOs. For areas that were outside those three regions, parking costs were assumed to be the same as the Version 2 model. Parking costs from each MPO were translated to the CHSRA zone system as explained below.

- Parking costs obtained from MTC were available in the MTC zonal system, which exactly match the CHSRA zonal system boundaries. Hence, parking costs were assigned to CHSRA TAZs in the MTC area based on the parking cost of the corresponding MTC zone.

- Parking costs obtained from SACOG were in the SACOG zonal system, which was more detailed than the CHSRA system. Since SACOG TAZs were smaller, each CHSRA zone had more than one SACOG zone. Parking costs of CHSRA TAZs within the SACOG area were extracted by taking the average parking cost based on the number of SACOG TAZs that fell within each CHSRA TAZ.

- Parking costs obtained from SCAG area were in the more detailed SCAG Tier 1 zonal system. Since SCAG TAZs were smaller than CHSRA TAZs, the average parking cost of each CHSRA TAZ was calculated by summing the product of area and parking cost of each SCAG TAZ, and then dividing the resultant sum by the total area of all SCAG TAZs within each CHSRA TAZ. This area-based averaging of parking cost ensured a more even distribution of parking costs in the CHSRA zonal system.

All parking costs were converted to 2005 dollars.

Airport Parking Costs

Airport parking costs were obtained from each airport's respective web site in January 2013. These costs were assumed for Year 2010 and converted to year 2005 dollars. For airports with varying daily long-term parking costs, parking cost for the airport were calculated as the straight average of all daily long-term parking cost options.

For the BPM-V3, the total daily parking cost is used, since each modeled trip is one-half of a round-trip (i.e., either an outbound or an inbound trip). Since two-day trips are assumed, daily parking cost is input into the model. Table 3-4 shows the parking cost assumptions for each airport.

Table 3-4 Airport Daily Parking Cost

Airport	2005 Dollars
San Diego International Airport	$20
John Wayne Airport (Orange County)	$18
Long Beach Airport	$15
Los Angeles International Airport	$18
Ontario International Airport	$11
Bob Hope Airport (Burbank)	$16
Mineta San Jose International Airport	$19
San Francisco International Airport	$23
Oakland International Airport	$19
Sacramento International Airport	$12
Monterey Regional Airport	$15
Oxnard Airport	$7
Palm Springs International Airport	$10
Santa Barbara Airport	$12
Arcata/Eureka Airport	$9
Meadows Field Airport (Bakersfield)	$9
Fresno Yosemite International Airport	$8
Modesto City-County Airport	$0

Source: Cambridge Systematics, Inc.

Conventional Rail Parking Costs

Conventional rail parking costs were obtained from each station's respective web site in January 2013. These costs were assumed for year 2010 and converted to year 2005 dollars. Table 3-5 shows the parking cost assumptions for each station.

Table 3-5 Conventional Rail Daily Parking Cost

CVR Line	Parking Cost (2005 Dollars)	CVR Line	Parking Cost (2005 Dollars)
Caltrain	$3 at all stations	ACE	San Jose: $3
Metrolink	LA Union Station: $12		Santa Clara: $3
	Burbank Airport: $16		All other stations: Free
	6 other stations: $1-$3	San Joaquin	Free at all stations
	All other stations: Free	Pacific Surfliner	Free at all stations
Capitol Corridor	Oakland: $11	Coaster	Free at all stations
	San Jose: $3		
	Sacramento: $3		
	All other stations: Free		

Source: Cambridge Systematics, Inc.

Parking and Rental Car Availability

In addition to parking costs, parking and rental car availability were collected at CVR stations and airports. All airports had parking and rental car facilities. No parking was available at Metrolink's Cal State LA station or Pacific Surfliner's San Diego and Old Town stations. Rental cars were available at only Los Angeles Union Station and the Burbank Airport Metrolink station.

3.6 Auto Operating Cost

Consistent with the Version 2 model, an estimate of 20 cents per mile, in 2005 dollars, was used for auto operating cost for the 2010 base year. That auto operating cost was based on a $2.80 per gallon average cost of fuel in 2005 dollars as estimated by the U.S. Energy Information Administration for California,[18] and an average fuel efficiency of 22.5 miles per gallon based on data published by Caltrans[19] resulting in a 12 cent per mile average fuel cost. Non-fuel costs were kept consistent with the Version 2 model at 8 cent per mile.

[18] Equates to $3.40 per gallon in 2014 dollars. Source is U.S. Energy Information Administration: Annual All Grades All Formulations Retail Gasoline Prices.

[19] Source: *2007 California Motor Vehicle Stock, Travel, and Fuel Forecast,* California Department of Transportation Division of Transportation System Information, May 2008, Table 7, page 63.

4.0 Long-Distance Model Skims

4.1 Overview of Skims Required by Model

An important component of any travel demand model is an estimate of the level of service between each pair of zones in the transportation network. The process to calculate these values is referred to as network "skimming," which produces network "skims." There are four types of skims that the model uses:

Auto Mode:

1. **Auto skims**, representing averages of highway peak and off-peak travel times, distances, toll costs, parking costs at destination TAZs, and straight line distances for all TAZ-to-TAZ interchanges. Long-distance trips by auto are likely, during some portion of their journey, to travel during both congested peak periods with slower travel speeds and uncongested off-peak periods with free flow travel speeds. Averages of the congested and free flow travel times provide reasonable estimates of the interchange travel times.

Public Modes (Air, CVR and HSR) (see Figure 4-1):

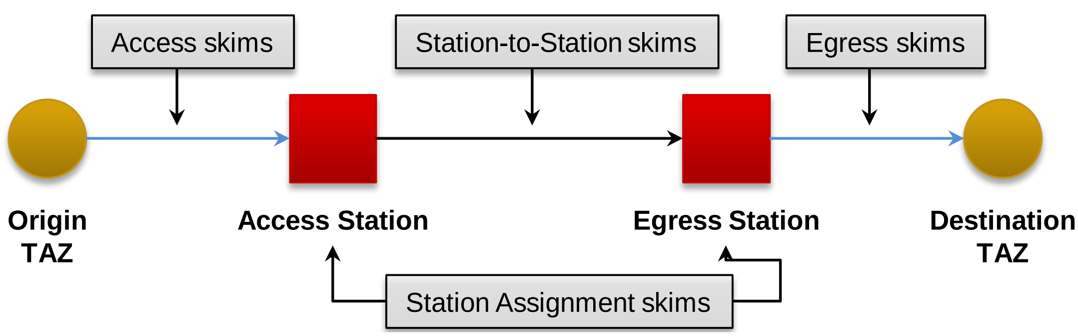
2. **Station-to-station**[20] **skims** that provide fares, in-vehicle travel times, headways, and reliabilities between station pairs for both peak and off-peak conditions.

3. **Station assignment skims** that identify the best access station and egress station utilized for each TAZ-to-TAZ interchange for both peak and off-peak conditions.

4. **Access and egress skims** between TAZs and airports, CVR stations, and HSR stations for both peak and off-peak conditions. The skims provide the auto highway distances, congested auto times, toll costs, transit fares, bus in-vehicle times, total transit in-vehicle times, out-of-vehicle times, drive access times, drive egress times, drive access distances, drive egress distances, parking costs at station (access only), parking availabilities (access only), and rental car availabilities (egress only).

Details of each of these types of skims are provided in the sections below.

Figure 4-1 Skims for Public Modes (Air, CVR, and HSR)



[20] Note that stations also refer to airports in this discussion.

4.2 Auto Skims

Procedure for Developing Congested Skims

The congested travel times represent the sum of origin and destination TAZ terminal times and the congested travel times for the minimum time paths obtained from the congested speeds on the CSTDM network. The congested speeds are a result of an equilibrium assignment output from the CSTDM model. The average of AM and PM peak skims for the single-occupant vehicle mode for the peak period and an average of midday and off-peak SOV skims for the off-peak period. Since long-distance trips on the auto network are likely to include travel in both peak and off-peak periods, the peak and off-peak travel times are averaged using a weighted average approach to obtain average daily travel times.

Auto terminal times represent the average time to access one's vehicle at each end of the trip and are added to the congested travel time to get the total congested travel time skim. They are based on the area type of each of the trip ends (see Table 4-1). The terminal time assumptions are the same as the Version 1 and Version 2 models.

Table 4-1 Auto Terminal Times

Area Type	Origin Terminal Times (Minutes)	Destination Terminal Time (Minutes)
Central Business District	2	5
Urban	1	2
Small Urban	1	1
Suburban	1	1
Rural	1	1

Source: Cambridge Systematics, Inc.

A definition of the area types is provided in Table 4-2. "People per square mile" was taken to be the maximum of either the residential or employment population of the zone.

Table 4-2 Area Type Definitions

Area Type	Area Type Number	People per Square Mile
Central Business District	1	Over 20,000
Urban	2	10,001 to 20,000
Small Urban	3	6,001 to 10,000
Suburban	4	1,001 to 6,000
Rural	5	1,000 or Less

Source: Cambridge Systematics, Inc.

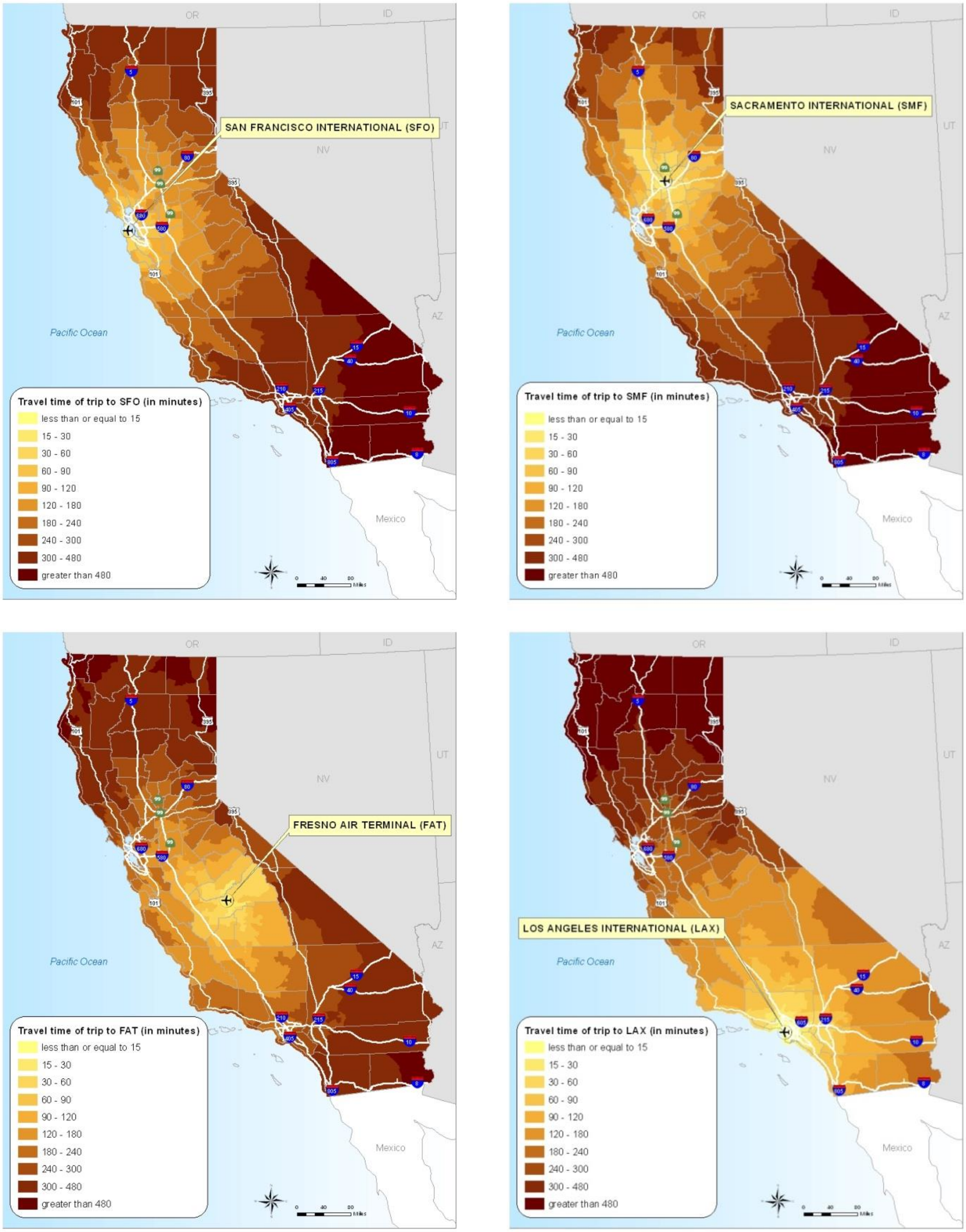
Intrazonal travel times are calculated as a portion of the average travel time to the three closest zones. The portion varies with the area type of the zone: two-thirds for the Central Business District; one-half for urban areas, one-third for small urban and suburban areas, and one-half for rural areas. This methodology is consistent with the Version 1 and Version 2 models.

Several checks were employed to ensure accuracy and reasonableness of the congested travel times. The first check was to map travel time from selected airports to assess spatial reasonableness. Figure 4-2 shows travel times to the San Francisco, Sacramento, Fresno, and Los Angeles airports from all TAZs in California. These maps indicate that as distances increase from the airports, travel times also reasonably increase.

Another check mapped average speeds to selected airports to ensure that travel times were reasonable in relation to the distances traveled to the locations. Figure 4-3 shows average travel speed to the San Francisco, Sacramento, Los Angeles, and San Diego airports. Travel speeds are lowest the closer the origins are to the airports, indicating lower percentages of travel on highways for the interchanges. As distances increase, average speeds increase, indicating higher percentages of the interchanges occurring on highways.

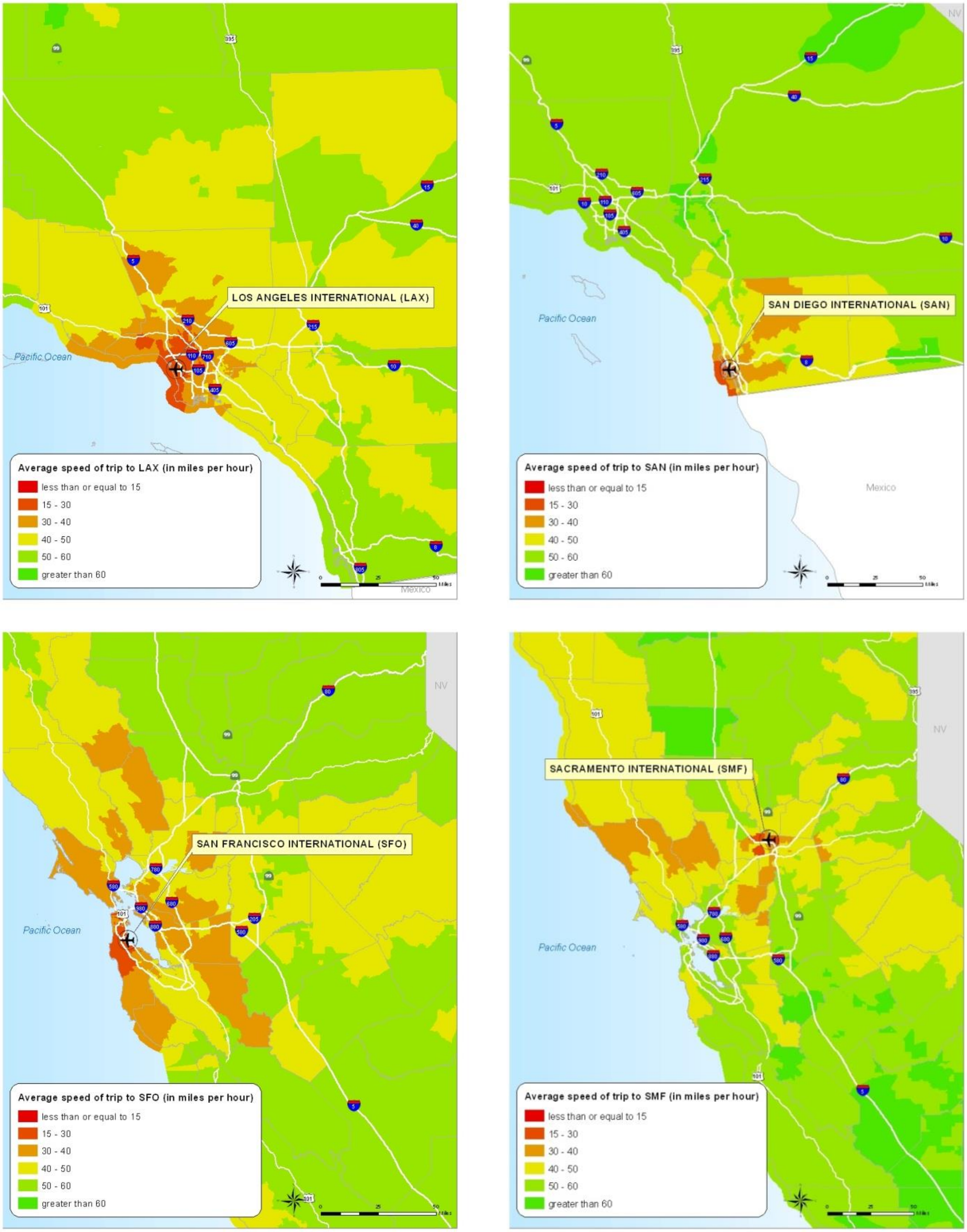
The final check compared the travel times from the highway skims to the stated travel times of survey respondents who reported driving to/from an airport or CVR station in the year 2005 revealed-preference survey. After correcting for survey data entry errors (such as switching the access and egress stations) the highway skim travel times were appended to the survey data. For the intercept surveys, respondents reported categorical travel times (i.e., 0 to 15 minutes, 15 to 30 minutes, 30 to 60 minutes, 60 to 90 minutes, 90 to 120 minutes, more than 2 hours) so the differences between the skimmed travel times and stated travel times were computed as the minimum of the differences for each travel time category (e.g., if the stated travel time was 0 to 15 minutes and the skimmed travel time was 17 minutes, the travel time difference was reported as 2 minutes, or 15 minutes subtracted from 17 minutes). For the telephone surveys, respondents reported their travel times so the differences were computed directly by subtracting the stated travel times from the highway skimmed travel times.

Figure 4-2 Travel Time to Select Airports



Source: Cambridge Systematics, Inc.

Figure 4-3 Average Speed to Select Airports



Source: Cambridge Systematics, Inc.

Table 4-3 shows the comparison of the highway skim travel times to the travel times from the stated-preference survey responses. The highway skims match very well to the stated travel times. Close to 79 percent of the surveys have skimmed and stated travel times within 10 minutes of each other. Almost 88 percent of the surveys have skimmed and stated travel times within 30 minutes of each other. Select TAZ pairs from the surveys with stated and skimmed travel times more than 45 minutes apart were spot checked to ensure that the highway skims were accurate. In all of these cases, the stated travel times appeared to be reported as unrealistically high or low.

Table 4-3 Highway Skim Travel Time in Comparison to Revealed Preference Survey Stated Travel Time

Highway Skim in Relation to Stated Travel Time	Percentage
Greater than 45 minutes lower	8.2%
30 to 45 minutes lower	1.6%
10 to 30 minutes lower	8.9%
Less than 10 minutes lower	66.5%
Less than 10 minutes higher	12.4%
10 to 30 minutes higher	0.0%
30 to 45 minutes higher	0.0%
Greater than 45 minutes higher	2.3%

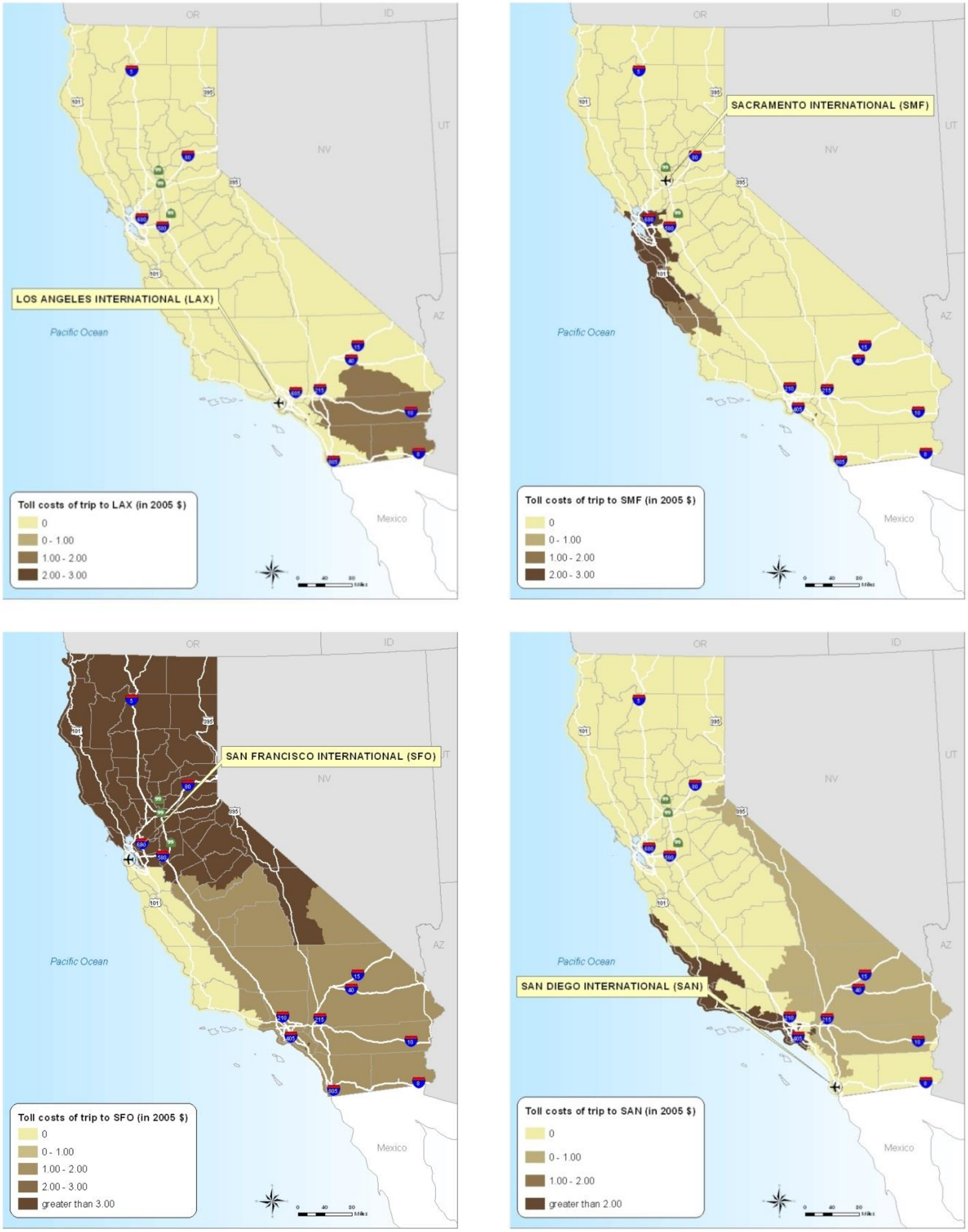
Source: Cambridge Systematics, Inc.

Toll Cost

Toll costs were imported from networks developed for the CSTDM and documented in *CSTDM09 – California Statewide Travel Demand Model, Model Development, Network Preparation and Coding*, converted to 2005 dollars. Tolled and general purpose lanes were coded separately in the CSTDM network and input to the CSTDM by time of day and by auto occupancy. Tolls corresponding to SOV were used for the BPM-V3. Peak and off-peak tolls were averaged where costs differed.

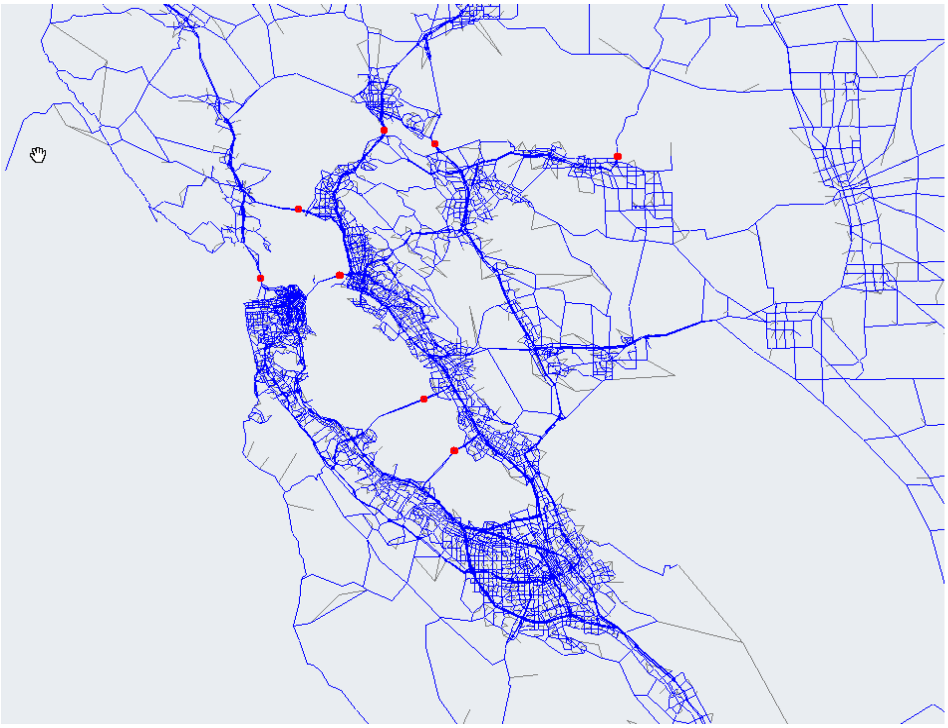
Toll costs to selected airports were mapped to ensure that toll costs were reasonable in relation to trip origin location. Figure 4-4 shows total toll costs to the San Francisco, Sacramento, Los Angeles, and San Diego airports, respectively. Tolls included in the updated network include congestion pricing on I-15 north of San Diego and SR 91, as well as tolls on a number of other facilities across the State, as shown in Figures 4-5 and 4-6.

Figure 4-4 Total Toll Cost to Select Airports



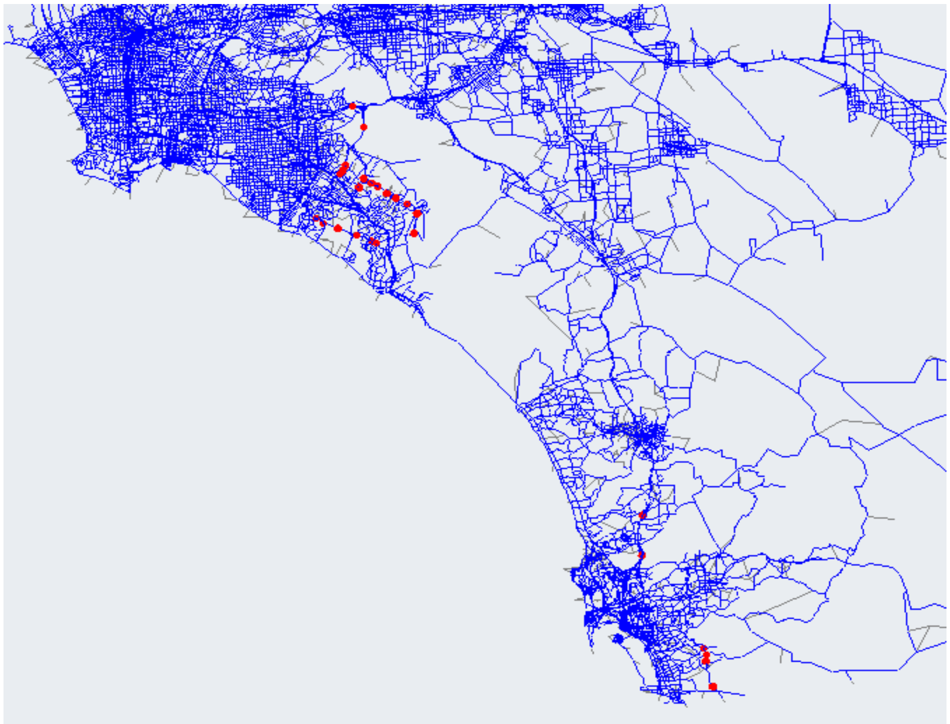
Source: Cambridge Systematics, Inc.

Figure 4-5 Toll Locations in Bay Area



Source: Cambridge Systematics, Inc.

Figure 4-6 Toll Locations in Southern California



Source: Cambridge Systematics, Inc.

4.3 Station-to-Station Skims

The station-to-station skims for Air, CVR, and HSR include fare, in-vehicle travel time, headway, and reliability between station pairs. The air station-to-station fares, in-vehicle travel times, and headways are computed outside of the Cube skimming process, as described in Section 3.3. For CVR and HSR, the Cube skimming process is used to calculate the optimal path between station pairs using the given level-of-service information and a generalized cost function that converts all travel characteristics to the same unit of measure. Table 4-4 provides the assumptions for developing the generalized cost function used for calculating the best path between stations for CVR and HSR.

Table 4-4 CHSRA Station-to-Station Skimming: Specifications and Assumptions Used for the Generalized Cost Function

	CVR		HSR	
	Peak	**Off-Peak**	**Peak**	**Off-Peak**
Cube Skimming Process	Best Path	Best Path	Best Path	Best Path
Fares considered in Path Evaluation	No	No	No	No
Maximum Transfers	Unlimited	Unlimited	Unlimited	Unlimited
Initial Wait Time	20% of headway	20% of headway	20% of headway	20% of headway
Transfer Wait Time	One-half of headway	One-half of headway	One-half of headway	One-half of headway
Transfer Penalty	5 minutes	5 minutes	5 minutes	5 minutes
Transfer Penalty Time Weight in Relation to IVTT	2.5	2	2.5	2.5

Source: Cambridge Systematics, Inc.

Reliability also is added onto the Air, CVR, and HSR skims. Reliability is defined as the percentage of scheduled trips arriving within 15 minutes of the scheduled arrival time. For flights, the Bureau of Transportation Statistics (BTS) provides information on the percentage of air trips that arrive within 15 minutes of their scheduled arrival time into each airport (see Table 4-5 for year 2010 information). Reliability information for CVR was obtained from CVR operator web sites and documentation, and also from the documentation for the Version 1 and Version 2 models. The percentage of trains arriving within 15 minutes of scheduled arrival time for each CVR operator, for year 2010, is shown in Table 4-6.

If the journey requires transferring from one train to another, the product of the reliabilities of each associated leg is used. Thus, the resultant reliability reflects the number of transfers in the path since the more you have to transfer, the greater the likelihood you will encounter a delay.

Table 4-5 Percentage of Air Trips Arriving within 15 Minutes of Scheduled Arrival Time to each Airport, Year 2010

Airport	Percentage of Trips Arriving within 15 Minutes of Scheduled Time
San Diego International Airport	82%
John Wayne Airport (Orange County)	84%
Long Beach Airport	83%
Los Angeles International Airport	82%
Ontario International Airport	82%
Bob Hope Airport (Burbank)	82%
Mineta San Jose International Airport	82%
San Francisco International Airport	71%
Oakland International Airport	81%
Sacramento International Airport	80%
Monterey Regional Airport	77%
Oxnard Airport	88%
Palm Springs International Airport	82%
Santa Barbara Airport	83%
Arcata/Eureka Airport	64%
Meadows Field Airport (Bakersfield)	81%
Fresno Yosemite International Airport	80%
Modesto City-County Airport	61%

Source: Cambridge Systematics, Inc.

Table 4-6 Percentage of CVR Trips Arriving within 15 Minutes of Scheduled Arrival Time by Operator, Year 2010

Operator	Percentage of Trips Arriving within 15 Minutes of Scheduled Time
Caltrain	95%
Capitol Corridor	86%
ACE	94%
Amtrak Shuttles	83%
San Joaquin	77%
Metrolink	95%
Coaster	95%
Pacific Surfliner	95%

Source: Cambridge Systematics, Inc.

4.4 Station Assignment Skims

The sole purpose of the station assignment skims is to identify the best access station and egress station used for each TAZ-to-TAZ interchange for air, HSR, and CVR. The skims consider only drive access to and egress from the stations, so only the highway network and the line files for each respective mode are included as input into the skims. The Cube skimming process calculates the optimal path between TAZs using the congested highway network, the line file corresponding to each mode, and a generalized cost function. Table 4-7 provides the assumptions for developing the generalized cost function that are used for calculating the best paths between stations. Once the best path is determined, only the access station and egress station for each TAZ-to-TAZ interchange are outputted in the skim matrices.

Table 4-7 CHSRA Station Assignment Skimming: Specifications and Assumptions Used for the Generalized Cost Function

	CVR		Air		HSR	
	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
Cube Skimming Process	Best Path	Best Path	Best Path	Best Path	Best Path	Best Path
Fares considered in Path Evaluation	No	No	No	No	No	No
Maximum Drive Distance to Other Transit Lines	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles
Maximum Transfers	4	4	4	4	4	4
Initial Wait Time	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes
Transfer Wait Time	1/2 headway	1/2 headway	1/2 headway	1/2 headway	1/2 headway	1/2 headway
Value of Time	$45	$15	$45	$15	$45	$15
Boarding Penalty	None	None	None	None	None	None
Transfer Penalty	5 minutes	5 minutes	5 minutes	5 minutes	5 minutes	5 minutes
Walk Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2
Drive Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2
Transfer Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2
Transfer Penalty Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2

Source: Cambridge Systematics, Inc.

4.5 Access-Egress Skims

The Access/Egress Mode Choice Model has six modal options: drive and park, rental car, drive and drop-off/pick-up, taxi, transit, and walk. The level-of-service variables are obtained from the sources shown in Table 4-8. Table 4-9 reflects the final set of specifications and assumptions used for the generalized cost function used to build the transit access and egress skims.

Table 4-8 Sources of Travel Time and Cost Variables for CHSRA Access/Egress Mode Choice Model

	In-Vehicle Travel Time	Out-of-Vehicle Travel Time	Cost
Drive and Park	Travel time from highway skims	N/A	Toll cost from highway skims
			Network distance x auto operating cost
			Parking cost at station
Rental Car	Travel time from highway skims	N/A	Toll cost from highway skims
			Network distance x auto operating cost
Drive and Drop-off/Pick-up	Travel time from highway skims	N/A	Toll cost from highway skims
			Network distance x auto operating cost
Taxi	Travel time from highway skims	N/A	Network distance x taxi cost per mile
Transit	In-vehicle travel time from transit skims	Walk/Drive Access Time + Initial Wait Time + Transfer Wait Time + Transfer Time + Walk/Drive Egress Time	Fares from transit skims
			Drive access + egress distance x auto operating cost
Walk	N/A	Network distance x 3 mph	N/A

Source: Cambridge Systematics, Inc.

Table 4-9 Transit Access/Egress Skimming: Specifications and Assumptions Used for the Generalized Cost Function

	To/From CVR Stations		To/From Airports		To/From HSR Stations	
	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
Cube Skimming Process	Multirouting	Multirouting	Multirouting	Multirouting	Multirouting	Multirouting
Fares considered in Path Evaluation	Yes	Yes	Yes	Yes	Yes	Yes
CVR Transit Lines	Not Included	Not Included	Included	Included	Included	Included
Amtrak Shuttle Bus Treatment	Transfers allowed to/from any mode	Transfers allowed to/from any mode	Transfers allowed to/from CVR	Transfers allowed to/from CVR	Transfers allowed to/from CVR	Transfers allowed to/from CVR
Maximum Drive Distance to CVR	N/A	N/A	200 miles	200 miles	200 miles	200 miles
Maximum Drive Distance to Other Transit Lines	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles	Varies from 0 to 6 miles
Maximum Transfers	4	4	4	4	4	4
Initial Wait Time	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes	1/2 headway up to 15 minutes
Transfer Wait Time	1/2 headway	1/2 headway	1/2 headway	1/2 headway	1/2 headway	1/2 headway
Value of Time[a]	$45	$15	$45	$15	$45	$15
Boarding Penalty	None	None	None	None	None	None
Transfer Penalty	5 minutes	5 minutes	5 minutes	5 minutes	5 minutes	5 minutes
Walk Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2
Drive Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2
Transfer Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2
Transfer Penalty Time Weight in Relation to IVTT	2.5	2	2.5	2	2.5	2

[a] The assumed values of time were adjusted to provide better access and egress skims in comparison to observed data. Note that the resulting value of time for access/egress path skimming is approximately 2.5 times the business/commute main mode values of time derived from the estimated in-vehicle time and cost coefficients; for off-peak, the value of time is approximately 2 times the recreation/other main mode values of time.

Source: Cambridge Systematics, Inc.

Several procedures to determine accuracy and reasonableness of the transit path travel times that are used as input into the Access and Egress mode choice models were developed. The first check was a mapping of total travel time from select airports and conventional rail stations to assess spatial reasonableness. Initial results from these maps showed missing transit path options from TAZs that should have transit availability. This finding led us to increase the maximum number of transfers from 3 to 4 in conjunction with increasing the transfer penalty and factor, allow for greater number of paths to be enumerated via the spread function[21], and fix some errors in the access path generation.

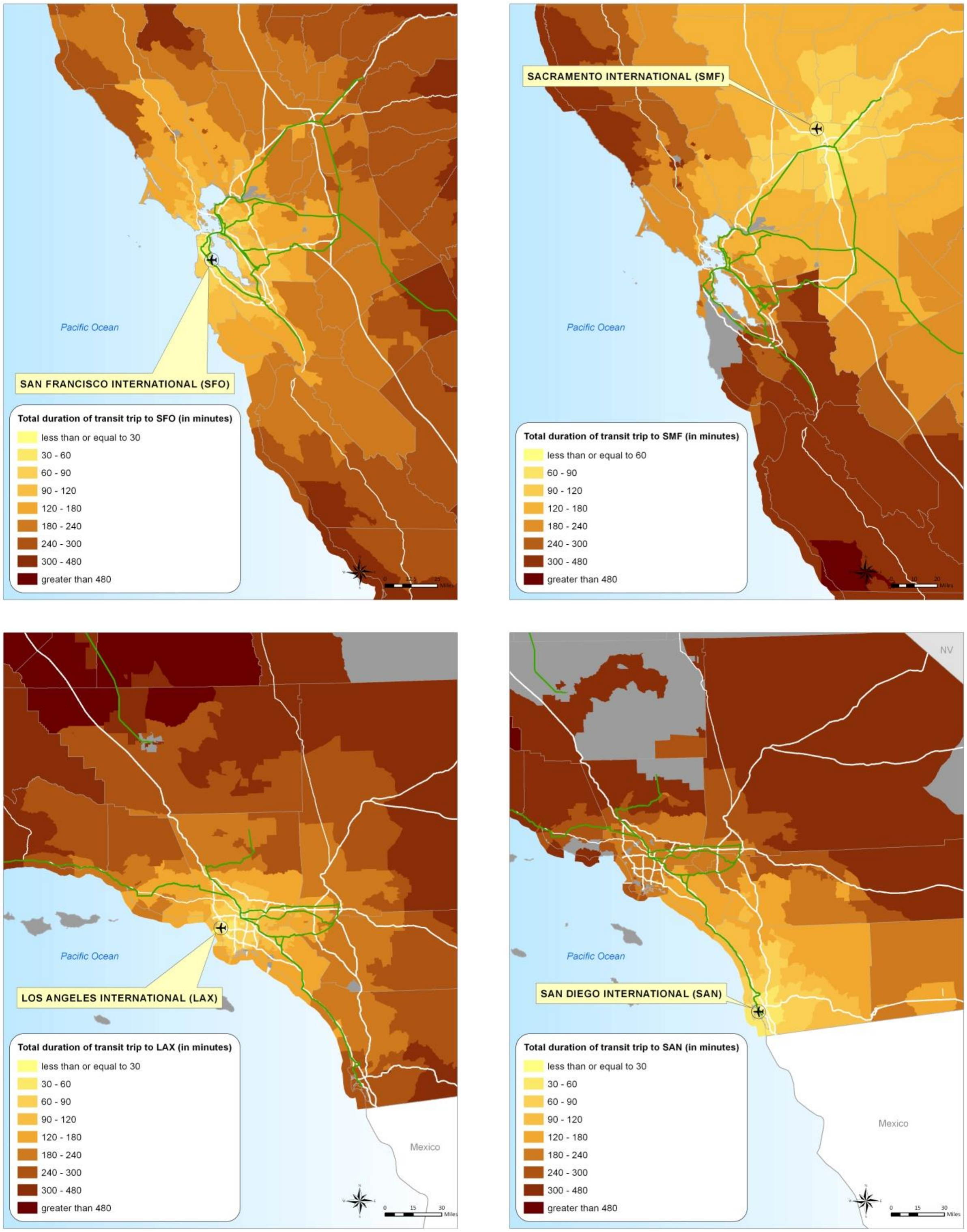
The following maps show total transit travel time to select airports for the final Air and CVR skims. Figure 4-7 shows transit total travel time to the San Francisco, Los Angeles, San Diego, Fresno, and Sacramento airports. Figure 4-8 shows transit total travel time to San Francisco Transbay, Los Angeles Union Station, and Bakersfield conventional rail stations. The figures illustrate the much higher accessibility by transit to airports compared to conventional rail stations. This is because conventional rail also is considered an access mode to air as well as a main travel mode. The skims allow an individual to drive up to 200 miles to access a conventional rail station. In contrast, an individual can only drive up to 5 miles to access an urban rail or bus station used as access to CVR. Hence, transit access to CVR stations are clustered around urban rail and major roadways.

The second check mapped walk and drive access times to transit for selected airports. This check was conducted to ensure that the skims developed reasonable walk and drive access times to transit in relation to the location of transit lines and the airports. Maps reflecting the drive access times to transit as percentages of total transit time were created to check that the skims did not reflect unusually high drive access times. The initial skim testing maps showed many paths with high percentages of drive access time in relation to total transit travel time. As a result, the weight on drive access time to and egress time from transit was increased.

Figure 4-9 shows walk and drive access times to San Francisco, Sacramento, Los Angeles, and San Diego Airports. Paths with walk access to transit are concentrated in downtown areas and near transit stations. Drive access time increases as distance from transit lines and highways increases. Figure 4-10 plots drive access times as percentages of total travel times to select airports. As distances increase from transit stations, the percentages of drive access time increase.

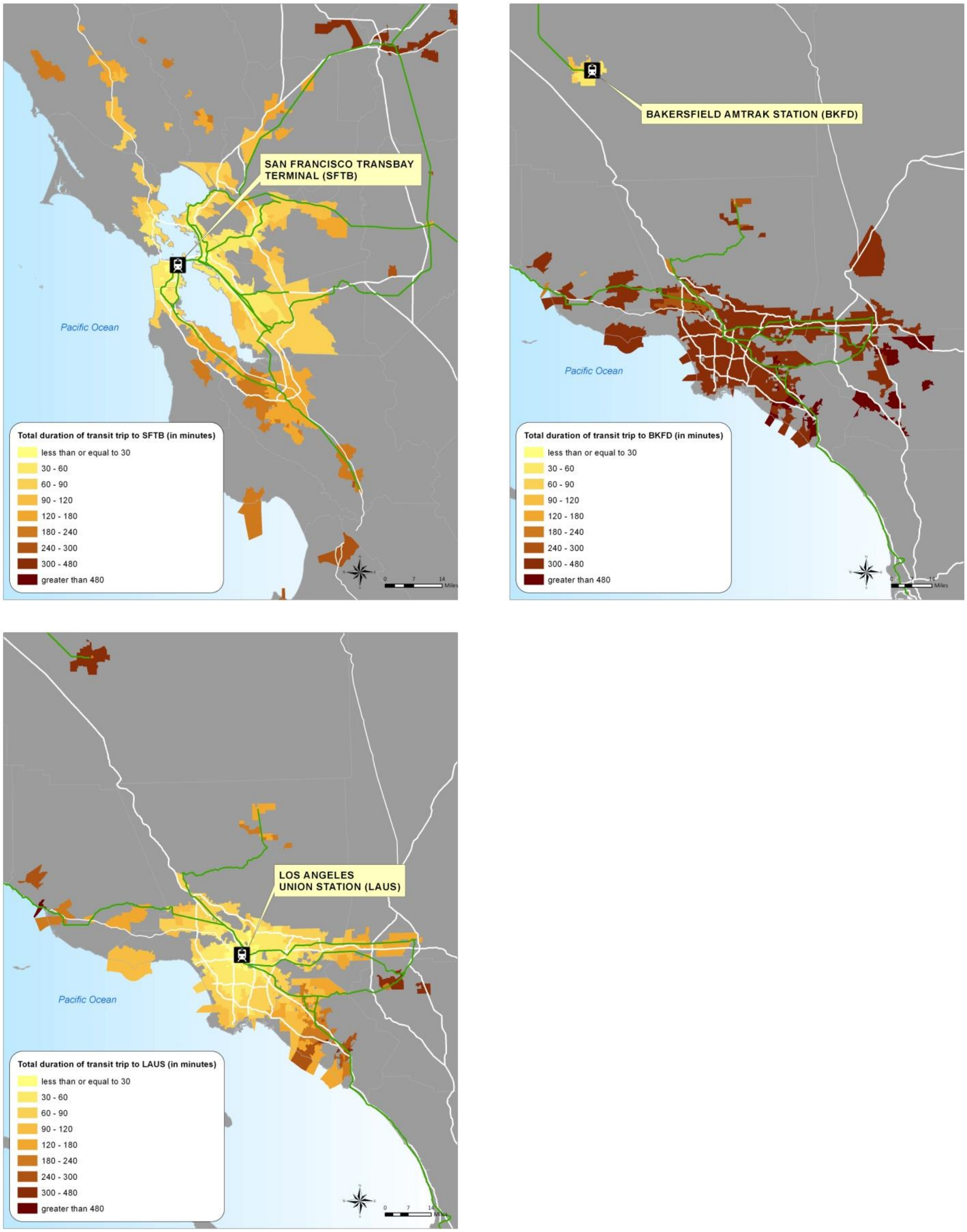
[21] The spread function allows the modeler to adjust the number of routes enumerated by telling the transit path-building algorithm when to stop looking for additional routes. Modelers can specify a "spread," an upper cost limit for routes between an OD pair when using multirouting. The route-enumeration process uses the costs from the minimum cost routes and the spread to determine a maximum cost value for "reasonable" routes to that destination.

Figure 4-7 Total Transit Travel Time to Selected Airports



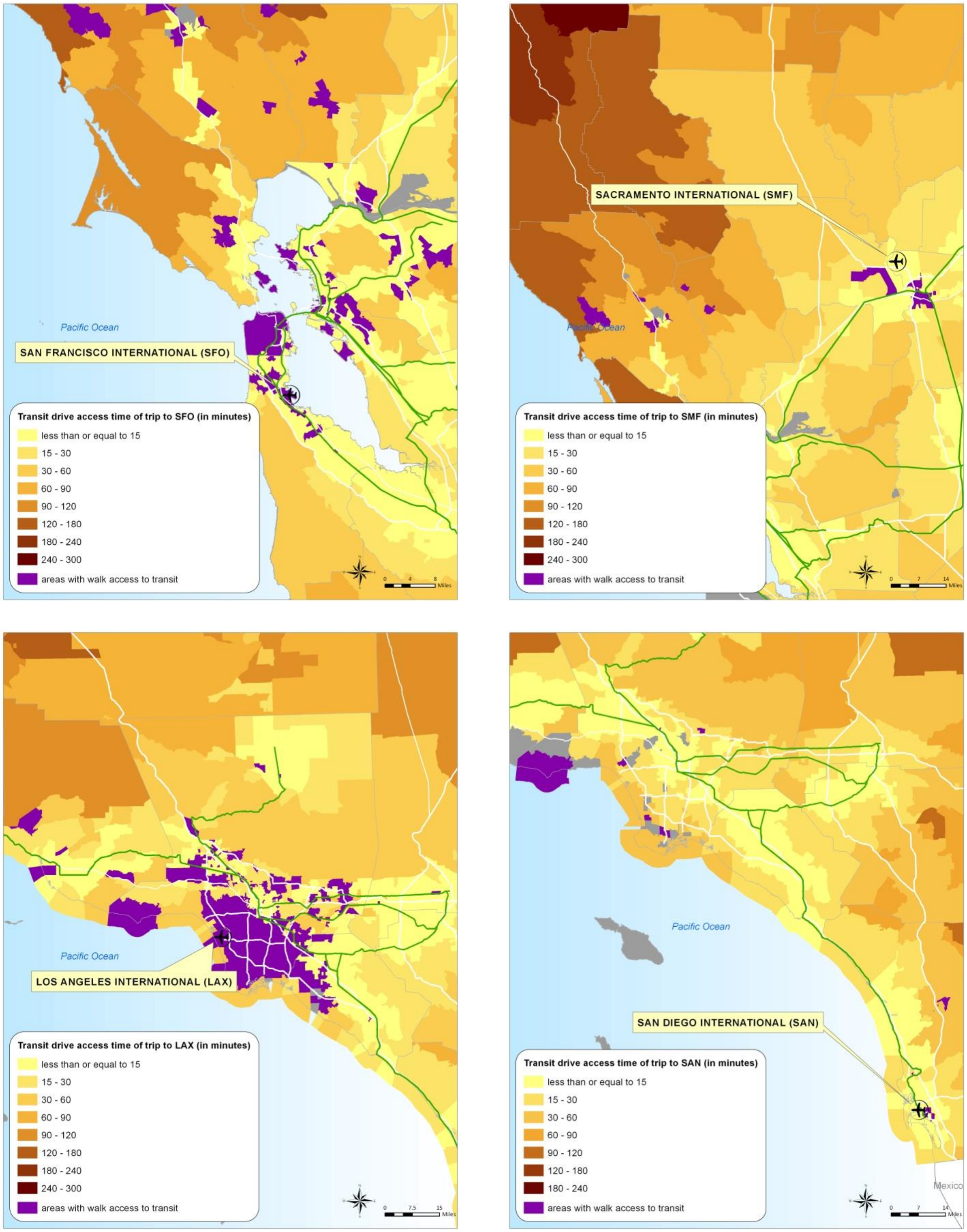
Source: Cambridge Systematics, Inc.

Figure 4-8 Total Transit Travel Time to Selected Conventional Rail Stations



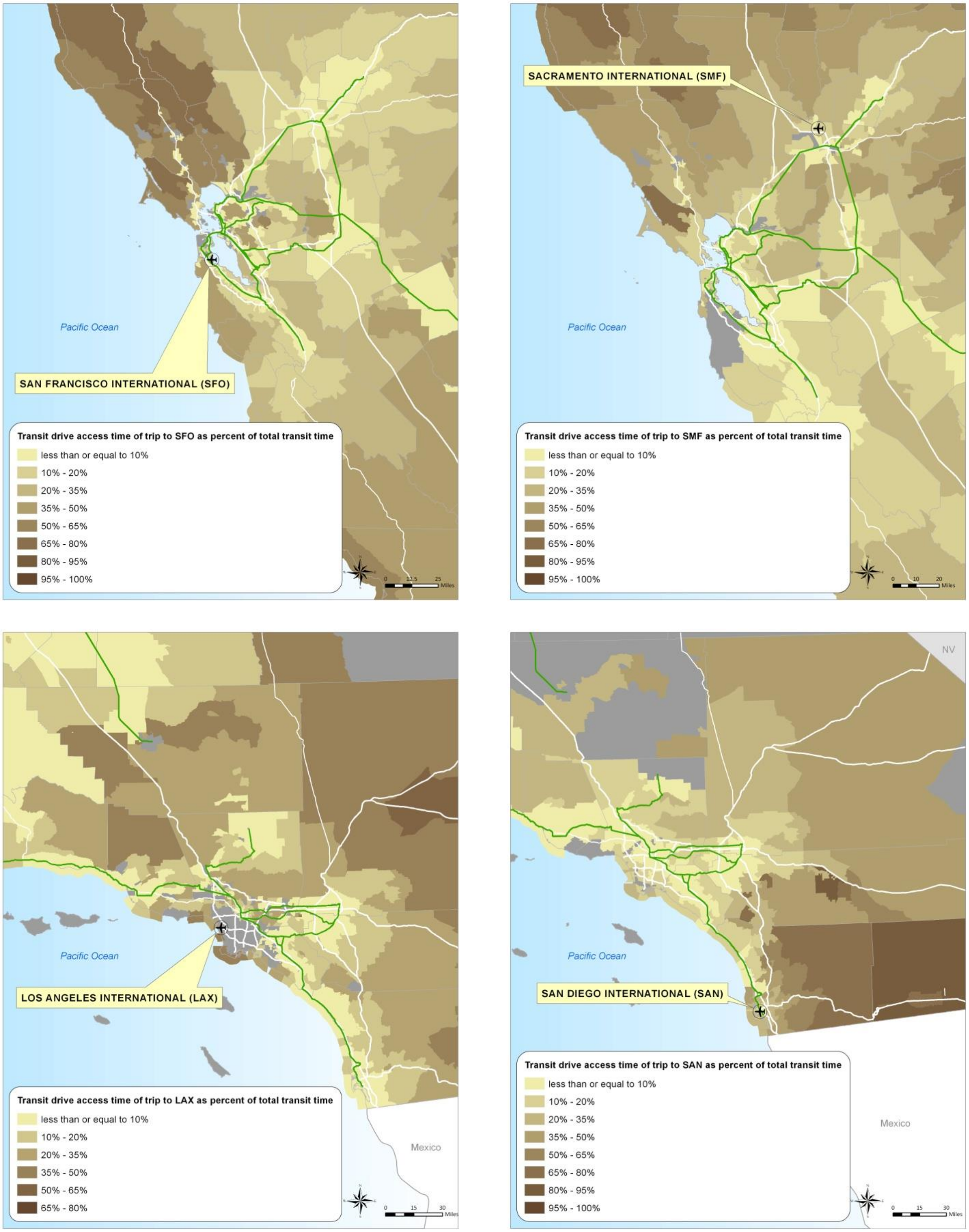
Source: Cambridge Systematics, Inc.

Figure 4-9 Drive Access Time to Transit for Selected Airports



Source: Cambridge Systematics, Inc.

Figure 4-10 Drive Access Time as a Percentage of Total Transit Travel Time for Selected Airports



Source: Cambridge Systematics, Inc.

The final check was a comparison of the travel times from the transit access/egress skims to the reported travel times from survey respondents who reported using transit to/from an airport or conventional rail station in the revealed preference portion of the year 2005 RP/SP survey[22]. The intercept surveys reported categorical travel times, so the differences between the skimmed travel times and reported travel times were computed as the minimum differences for each travel time category. In initial comparisons, the skimmed travel times were, on average, much higher than reported travel times. Thus, the value-of-time in the skimming process was increased to ensure that cost was not the driving factor in choosing best paths. In addition, the initial wait time was capped at 15 minutes.

Table 4-10 shows the comparison of the transit skim travel times to the reported travel times from the surveys. The final transit skims matched well to the reported travel times. Close to 43 percent of the surveys had skimmed travel times within 10 minutes of reported travel times. Almost 75 percent of the surveys had skimmed and reported travel times within 30 minutes of each other. Select TAZ pairs from the surveys with reported and skimmed travel times more than 45 minutes apart were spot checked to ensure that the transit skims were accurate. In most of these cases, the reported transit travel times appeared to be unreasonably high or low. The observations that differed substantially either had reported transit travel times that appeared to be illogical or had high transfer times. Caps on transfer wait times were removed to reflect the impact of low service frequencies for paths requiring transfers and to further penalize routes that required transfers.

Table 4-10 Transit Skim Travel Time in Comparison to 2005 Revealed-Preference Air and Conventional Rail Survey Reported Transit Travel Time

Transit Skim in Relation to Stated Travel Time	Percentage
Greater than 45 minutes lower	5.1%
30 to 45 minutes lower	3.1%
10 to 30 minutes lower	3.9%
Less than 10 minutes lower	25.0%
Less than 10 minutes higher	14.1%
10 to 30 minutes higher	29.3%
30 to 45 minutes higher	8.6%
Greater than 45 minutes higher	2.3%

Source: Cambridge Systematics, Inc.

[22] The 2005 RP/SP survey asked respondents using air to provide their access and egress travel times. In contrast, the 2013-2014 RP/SP survey specified the access and egress travel times to the optional modes; observed access and egress times were not collected.

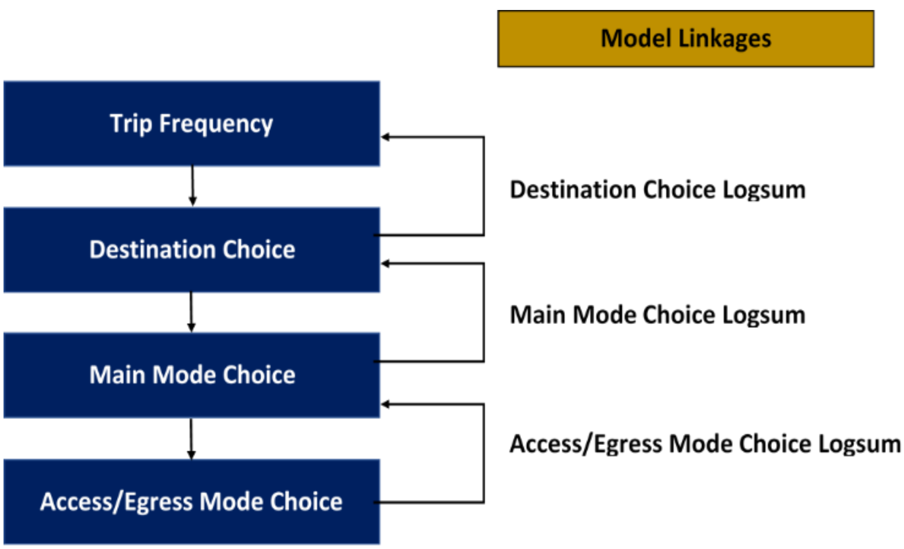
5.0 Long-Distance Model Estimation

The long-distance model estimates the numbers of business, commute, recreation, and other trips per average day that are made between TAZ pairs (greater than 50 miles) within California and the mode of travel used to make those trips. Long-distance trips are defined as any trip made to a TAZ 50 miles or more from the respondent's home TAZ with one end of the trip at the respondent's home. The model components are:

- Trip frequency model, which estimates whether a household undertook no long-distance trips, one long-distance trip alone, or one long-distance trip in a group on an average day;
- Destination choice model, which estimates the destinations of home-based trips, and
- Mode choice model, which estimates the choice of main mode of travel – auto, air, CVR, or HSR – as well as access/egress mode to/from air, CVR, or HSR.

These models interact with each other through logsums, which are fed up through the models, as shown in Figure 5-1. The next sections discuss the development of these models in the order they were estimated.

Figure 5-1 Long-Distance Model Structure



Source: Cambridge Systematics, Inc.

5.1 Access/Egress and Main Mode Choice Model Estimation

This section details the joint main mode choice and access/egress model estimation process and results.

Estimation Datasets

The estimation dataset includes data from three sources: 1) the 2012-2013 long-distance component of the CSHTS; 2) the 2005 RP/SP survey; and 3) the 2013-2014 RP/SP survey.

2012-2013 Long-Distance Component of the CSHTS

The BPM-V3 main mode choice model estimation dataset used responses from the entire long-distance survey results (about 42,000 households). Access/egress choice information from the CSHTS was not used for model estimation since the access/egress mode options coded in the survey did not specify the difference between drive-park and drop-off.

2005 and 2013-2014 RP/SP Surveys

The model uses both RP and SP choice information for main mode choice model estimation (supplementing the data from the CSHTS). RP access/egress choice information was used for access/egress mode choice model estimation. SP access/egress choice information was not used. Attributes for the access/egress options (and station/airport options) were not shown to respondents in the 2005 SP survey. While access and egress travel time were presented to respondents in the 2013-2014 SP survey, access and egress choice information was not collected in these experiments.

Each 2005 SP response was given a weight of 0.25 to account for the fact that four SP exercises were presented to each respondent. Since six SP exercises were presented to each respondent in the 2013-2014 SP survey, each of those responses was given a weight of 0.167. The final weights used in the model were rescaled so that the sum of model weights equaled the number of observations. Note that all observational weights were rescaled, including the CSHTS RP responses.

Table 5-1 shows the unweighted distribution of main mode choices by purpose for the RP and SP survey datasets.

Table 5-1 RP/SP and Main Mode Choice Distribution in Dataset

		Business/Commute			Recreation/Other		
Survey	Mode	Frequency	Percent within Mode Group	Percent of All Observations	Frequency	Percent within Mode Group	Percent of All Observations
RP	Car	4,158	65.9%	24.6%	15,188	87.7%	43.4%
	Air	1,448	22.9%	8.6%	1,213	7.0%	3.5%
	HSR	–	–	–	–	–	–
	CVR	704	11.2%	4.2%	909	5.3%	2.6%
	Total	6,310	100.0%	37.3%	17,310	100.0%	49.5%
SP	Car	1,328	12.5%	7.8%	5,551	31.4%	15.9%
	Air	2,436	22.9%	14.4%	2,099	11.9%	6.0%
	HSR	5,336	50.2%	31.5%	8,036	45.5%	23.0%
	CVR	1,527	14.4%	9.0%	1,973	11.2%	5.6%
	Total	10,625	100.0%	62.7%	17,659	100.0%	50.5%
Total		**16,935**		**100.0%**	**34,969**		**100.0%**

Source: Cambridge Systematics, Inc.

Estimation Procedures

As with the Version 2 model, full information maximum likelihood (FIML) techniques were used to simultaneously estimate the joint main mode and access/egress models. This approach allowed relationships between access/egress utility coefficients and main mode utility coefficients to be consistently estimated and, if necessary, constrained in ways that would otherwise not have been possible. In addition, normalized utility coefficients were estimated directly using R programming language.

Mode Availability

Mode availability criteria were based on modeling long-distance travel in production-attraction format. Under this approach, the home zone was always the production zone and the non-home zone was always the attraction zone. This approach allowed for reasonable assumptions regarding mode availability for access to and egress from the main mode. Availability criteria included the following:

- Main modes were marked as unavailable if the total access plus egress car time exceeded the direct origin to destination time by auto.
- For access mode choice, rental car was considered an invalid mode option.
- For access mode choice, drive-park was considered an invalid mode option if parking was not available at the access station.
- For egress mode choice, drive-park was considered an invalid mode option.
- For both access and egress mode choice to/from air (main mode), walk was considered an invalid mode option.
- For egress mode choice, rental car was considered an invalid mode option if no rental car facilities existed at the egress station.
- For access/egress mode choices, taxi was considered an invalid option if access/egress travel distance exceeded 75 miles. The outlier analysis in the Version 2 model estimation identified very high taxi distances as an issue in two cases.

Cost and Time Relationships between Access/Egress and Main Mode Choices

The model is estimated with the assumption that a unit of cost should be perceived the same whether it occurs during the access/egress portion of the journey or the main mode portion of the journey. This constraint was used in each model specification tested. The perception of cost was not the same for all travelers, since separate cost coefficients were estimated for different travel purposes and income groups.

In the Version 2 model and BPM-V3, a unit of travel time is treated differently depending on the leg of the trip. To ensure that ridership would not increase when a station was moved farther away from a zone, the model estimation approach was based on the assumption that the disutility associated with access/egress time should be at least as onerous as the disutility associated with main mode time.

A variable, "AE time to MM time Ratio," was included in the model estimation. This variable ($\beta_{ae,tt,ratio}$) was a factor on the access/egress time applied to the total access/egress time in addition to the relevant in-vehicle time coefficient (β_{ivt}). The (dis)utility associated with travel time at the access/egress level is given by the following equation:

$$U_{ae,tt} = \beta_{ivt}\left(\beta_{ae,tt,ratio}\left[IVT_{ae} + \beta_{ovt,ratio} * OVT_{ae}\right]\right)$$

$\beta_{ovt,ratio}$ is the out-of-vehicle time to in-vehicle time ratio, which was ultimately constrained in the business/ commute and recreation/other models to 2.5 and 2.0, respectively. The constraints were comparable to values used in many urban mode choice models.

For the BPM-V3, another term was added to the utility functions of access and egress modes to represent the disutility of long access and/or egress times in comparison to the total distance traveled.

$$U_{ae,2R} = \beta_{ae}\left[\max\left(0, \frac{Access\ Time}{OD\ Car\ Distance} - \gamma\right) + \max\left(0, \frac{Egress\ Time}{OD\ Car\ Distance} - \gamma\right)\right]$$

This formulation suggests there is an added disutility of access and egress to/from the main mode that depends on the distance between the trip's origin and destination. The greater the distance between origin and destination, the less onerous a minute of access and egress time become. Here, γ represents a threshold at which the disutility expression begins. It is not an estimated parameter, but set prior to estimating the model. Through model testing, $\gamma = 0.2$ was determined to be an appropriate value. This means that for very short access and egress times, the access and egress times do not contribute any added disutility over and above the disutility associated with all travel time.

Analysis showed that the coefficient associated with the expression differed depending on access/egress mode. Auto modes were associated with a greater disutility than non-auto modes. And, because the 2013-2014 SP exercises presented an access and egress time, but with no associated access/egress modes, a distinct coefficient was estimated for 2013-2014 SP responses. Since it only applies to SP observations, the coefficient is not used in model application.

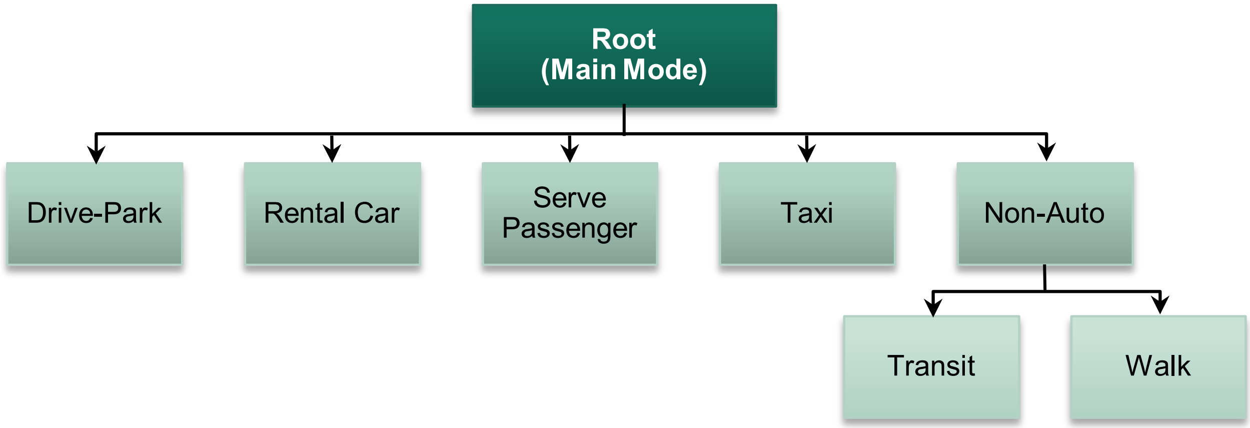
Due to the inclusion of the $U_{ae,2R}$ expression in the BPM-V3, the most appropriate ratio of access/egress time to main mode time was determined to be 1.0. This means that once the access and egress disutility as a function of overall trip distance is accounted for, the disutility of access and egress time is no different than the disutility associated with main mode time.

Nesting Structures

Access/Egress Nesting Structure

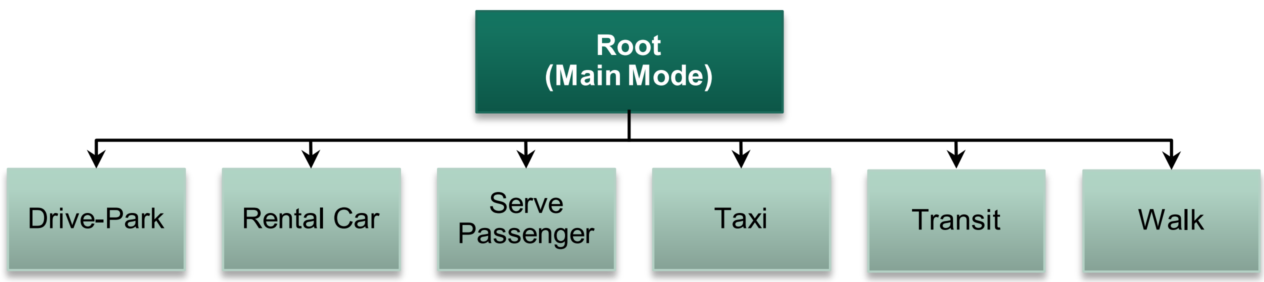
In the initial model estimation effort, several potential nesting structures for access/egress mode choice relative to the main mode were tested. The only structure that consistently yielded reasonable results is shown in Figure 5-2.

Figure 5-2 Initial Model Estimation Access/Egress Mode Nesting Structure



The nesting coefficients estimated using the nesting structure shown in Figure 5-2 were not very strong suggesting a simpler structure for the access and egress mode choices. The final model structure for access and egress mode choices used a multinomial logit structure as shown in Figure 5-3.

Figure 5-3 Final Model Estimation Access/Egress Mode Choice Structure



Main Mode Nesting Structure

In the initial model estimation effort, the main mode choice used the nesting structure shown in Figure 5-4. Access/egress mode choices nested below air, HSR, and CVR. Sub-optimal nesting coefficients were obtained using the Figure 5-4 nesting structure and, for the business/commute purpose, the nesting coefficient was estimated to be greater than 1, which is unreasonable. For the final models, the nesting structure was replaced with the structure shown in Figure 5-5. Better estimation results were obtained with the Figure 5-5 structure.

Figure 5-4 Initial Main Mode Choice Model Nesting Structure

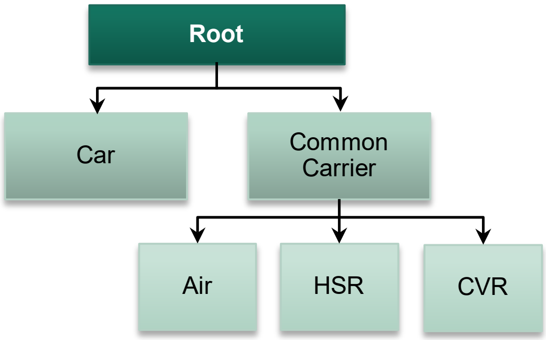
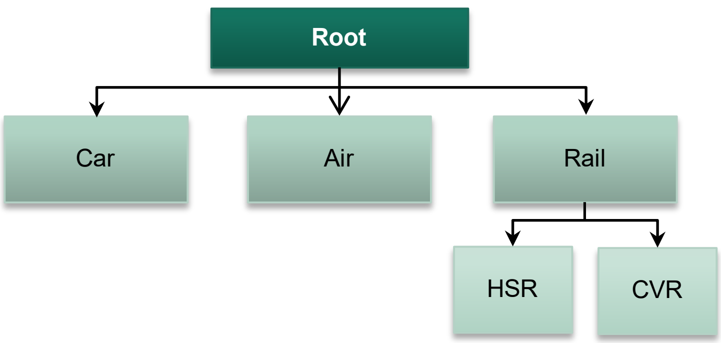


Figure 5-5 Final Main Mode Choice Model Nesting Structure



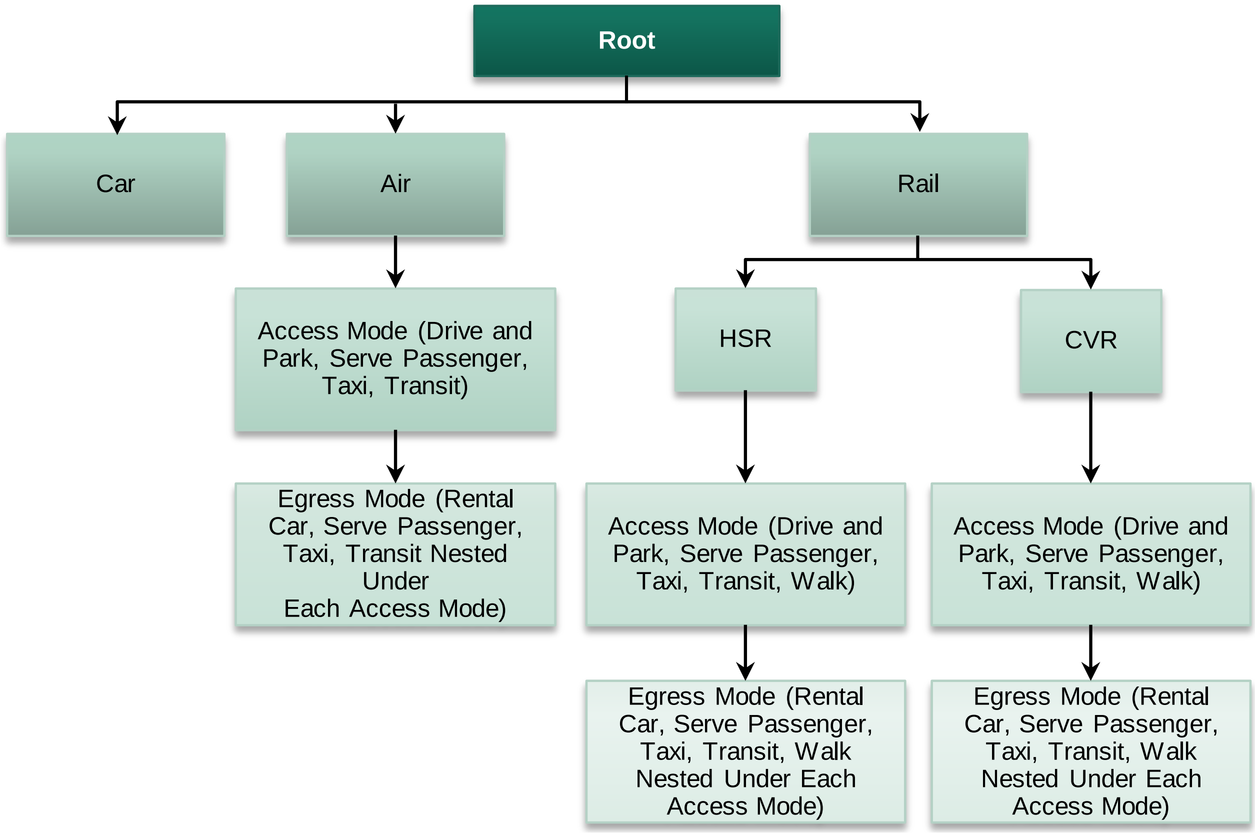
Overall Nesting Structure

In the FIML estimation procedure, access and egress choices appeared as nested alternatives under air, HSR, and CVR main mode choice alternatives. This overall nesting structure of the models is shown in Figure 5-6.

The nesting of egress mode choice under access mode choice may be deceiving. Since egress mode alternatives and utilities are identical for each access mode, the egress mode logsums have no impact on access mode choice. In effect, they are comparable to adding a constant to each of the access modes.

The resulting model is equivalent to having access and egress mode alternatives both nested directly (but independently) below the air or rail main modes.

Figure 5-6 Nesting Structure for Joint Estimation of Main Mode – Access/Egress Model



Estimation Results

The estimated models for the business/commute trip purposes are shown in Tables 5-2 and 5-3 and for recreation/other purposes in Tables 5-4 and 5-5.

Tables 5-2 and 5-4 show the coefficients for the level-of-service variables, model fit statistics, and important relationships. Tables 5-3 and 5-5 show the alternative-specific coefficients and constants as estimated using the FIML techniques.

The coefficients and constants shown in Tables 5-3 and 5-5 were adjusted during model calibration to better reproduce observed travel choices from the expanded 2012-2013 CSHTS, CVR boardings obtained from various operators, and airport-to-airport trips summarized from the BTS 10 percent ticket sample data, as described in Section 6.0.

The business/commute model estimation results have the following characteristics:

- All travel time and cost coefficients have correct signs and reasonable relative relationships.
- Values of travel time (in 2005 dollars) for the business purpose ranged from $18 per hour for low income to $24 per hour for high income. For the commute purpose, the values of time ranged from $12 per hour

for low income to $15 per hour for high income. In 2014 dollars, the ranges were $22 per hour to $29 per hour for business and $15 per hour to $18 per hour for commute.

- Cost coefficients are additive. For example, cost coefficient for low-income business travelers is made up of the base cost coefficient, -0.0174, plus the cost coefficient for low-income travelers, -0.0046, which yields a net cost coefficient of -0.0220.
- An attempt was made to estimate a commute-specific IVT coefficient. However, it produced larger values of time for the commute purpose than for the business purpose. This was deemed to be unreasonable and, therefore, the variable was dropped in the estimation of the final model.
- Nonlinear representations of main mode headways were adopted for the final models. Both log transformations of frequencies of service (the inverse of service headways) and headways were tested. Unreasonable coefficient estimates emerged in the business/commute model when frequencies were used in place of headways. Therefore, the final model specifications used a logarithmic transformation of headway.
- The access and egress time expressions that vary with origin-destination distance all have the correct negative sign. Long auto access times are more onerous than long non-auto access times.
- Nesting coefficient estimates for access and egress mode choices are 0.966 and 0.761, while the main mode rail nest coefficient estimate is 0.966.
- Main mode and access/egress alternative-specific coefficients and alternative specific constants (ASC) had reasonable signs and relative magnitudes.
- The coefficient for the “traveling in group” variable (a variable that is 0 for travelers traveling alone and 1 for group travelers) specific to car main mode was estimated to be 0.56, which is equivalent to reducing the cost of travel by car by $32 for medium-income business travelers and $21 for medium-income commute travelers. These utility contributions are in addition to the fact that car costs are divided by a party size of 2.5 for trips made by group travel.
- The positive coefficients for high-income travelers for air and HSR suggest that high-income travelers are more likely to use those “premium modes.”
- SP inertia variables for each existing main mode and each SP dataset were positive and highly significant, suggesting that RP choices were very likely to be repeated in the SP experiments.

Table 5-2 Level-of-Service Variables and Model Fit – Business/Commute Mode Choice Models

Modes	Variable	Units for Variable	Coefficient	t-statistic
LOS Variables				
MM and AE	IVT – All	Minutes	-0.0065	-15.1
	Cost – All	Dollars (in 2005$)	-0.0174	-11.4
	Cost – Low-Income (Additive to Cost-All)	Dollars (in 2005$)	-0.0046	-1.2
	Cost – High-Income (Additive to Cost-All)	Dollars (in 2005$)	0.0009	0.6
	Cost – Missing Income (Additive to Cost-All)	Dollars (in 2005$)	0.0042	2.1
	Cost – Commute (Additive to Cost-All)	Dollars (in 2005$)	-0.0094	-3.7
MM	Log (1+Headway/60)	(Headway in Minutes)	-0.9693	-12.4
	Reliability (excluding RP response for car)	Percent (0-100)	0.0115	3.7
AE	Taxi Cost per Mile	Miles	1.186	7.3
	OVT to IVT Ratio	–	2.50	Constrained
	AE Time to MM Time Ratio	–	1.00	Constrained
	AE Time / Car Distance – 0.2, Auto Modes	–	-5.830	-24.8
	AE Time / Car Distance – 0.2, Non-Auto	–	-1.215	-9.8
	AE Time / Car Distance – 0.2, 2013-2014 SP	–	-0.486	-1.8
Structural Parameters				
N/A	Scale – 2005 SP		0.438	-15.0[a]
	Scale – 2013-2014 SP		0.839	-2.4[a]
	Access Logsum		0.966	-0.6[a]
	Egress Logsum		0.761	-5.0[a]
	Rail Nesting Coefficient		0.966	-0.6[a]
Observations			16,935	
Log Likelihood – Constants Only			-18,746.5	
Log Likelihood at Convergence			-13,906.0	
Rho Squared			0.258	
			2005 Dollars per Hour	**2014 Dollars per Hour**
Main Mode Values of Time				
Low-Income, Business			$17.76	$21.57
Medium-Income, Business			$22.48	$27.30
High-Income, Business			$23.72	$28.81
Low-Income, Commute			$12.45	$15.12
Medium-Income, Commute			$14.60	$17.73
High-Income, Commute			$15.12	$18.36

[a] t-statistic measured in relation to 1.0, not 0.0.

Source: Cambridge Systematics, Inc.

Table 5-3 Alternative-Specific Variables – Business/Commute Mode Choice Models[a]

Modes	Variable	Coefficient	t-statistic
Main Mode Alternative-Specific Variables			
Car	Traveling in Group	0.557	8.1
	No Cars in Household	-0.899	-4.2
	Cars Less Than Workers	-0.649	-5.1
	Missing Income	0.024	0.2
	2005 Car Inertia	4.031	7.0
	2013-2014 Car Inertia	2.427	8.2
Air	ASC – RP	-2.236	-6.8
	ASC – 2005 SP	-4.862	-3.6
	ASC – 2013-2014 SP	0.447	0.9
	High-Income	0.492	3.6
	Commute	-0.399	-1.9
	2005 Air Inertia	6.100	4.9
	2013-2014 Air Inertia	1.890	4.1
HSR	ASC – 2005 SP	2.053	4.5
	ASC – 2013-2014 SP	2.420	9.7
	High-Income	0.233	1.9
	Commute	0.177	1.1
CVR	ASC – RP	-3.641	-11.0
	ASC – 2005 SP	-2.341	-2.4
	ASC – 2013-2014 SP	0.653	1.4
	Commute	0.627	5.9
	2005 CVR Inertia	2.363	3.0
	2013-2014 CVR Inertia	1.682	3.7
Access/Egress Mode Alternative-Specific Variables			
Drive-Park	ASC – Access	0.944	9.9
	Commute	0.460	4.9
	Cars Less Than Workers (Access Mode Choice Only)	-0.692	-5.1
	Low-Income	-1.177	-3.4
	Log (1 + Employment Density at Airport or Station – 2 mi buffer)[b]	-0.021	-2.3
Rental Car	ASC – Egress	0.269	5.3
	Commute	-0.612	-2.9
Serve Passenger	One person Household (Access Mode Choice Only)	-0.440	-3.7
Taxi	ASC – Access	-0.444	-4.0
	ASC – Egress	-0.008	-0.1
	Commute	-0.594	-6.1
	Log (1 + Employment Density at Airport or Station – 2 mi buffer)[b]	0.080	7.4
Transit	ASC – Access	-0.749	-4.4
	ASC – Egress	-0.076	-0.6
	Commute	0.398	4.0
	Cars Less Than Workers (Access Mode Choice Only)	0.896	5.3
	Log (1 + Employment Density at Airport or Station – 2 mi buffer)[b]	0.129	10.3
	Car Used in Transit Path	-0.324	-3.8
	Bus Used in Transit Path	-0.088	-0.9
Walk	ASC – Access and Egress	1.503	18.5

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

[b] Total employees per square mile within 2 miles of the main mode airport or station.

Source: Cambridge Systematics, Inc.

The recreation/other model estimation results have the following characteristics:

- All level-of-service and cost coefficients had correct signs and reasonable relationships. An exception was the low-income cost coefficient, which was removed from the final model.
- Values of travel time in 2005 dollars ranged from $9 per hour to $10 per hour. In 2014 dollars, the ranges were $11 per hour to $12 per hour.
- The access and egress time expressions that vary with origin-destination distance all have the correct negative sign. Long auto access times are more onerous than long non-auto access times.
- The nesting coefficient estimates for access and egress mode choices were 1.00 and 0.98, respectively, which were consistent with the business/commute model. The rail nesting coefficient was estimated to be 1.00, which also was consistent with the business/commute model.
- Main mode and access/egress alternative-specific variables had reasonable signs and magnitudes.
- The "traveling in group" variable (a variable that is 0 for travelers traveling alone and 1 for group travelers) specific to car main mode was estimated to be 2.17, which was equivalent to a reduction in cost for car travel of $92 for medium-income travelers. This value is larger than the value found for the business/commute model, which could be a result that the car mode is more attractive for group travelers when traveling for recreation/other purposes. Again, these utility contributions are in addition to the fact that car costs are divided by a party size of 2.5 for trips made by group travel.
- The SP inertia variables for each existing main mode and each SP dataset were positive and highly significant, suggesting that RP choices were very likely to be repeated in the SP experiments.

Table 5-4 Level-of-Service Variables and Model Fit – Recreation/Other Mode Choice Models

Modes	Variable	Units for Variable	Coefficient	t-statistic
LOS Variables				
MM and AE	IVT	Minutes	-0.0035	-9.6
	Cost	Dollars (in 2005$)	-0.0236	-21.1
	Cost – High-Income	Dollars (in 2005$)	0.0023	2.3
	Cost – Missing Income	Dollars (in 2005$)	-0.0025	-1.3
MM	Log (1+Headway/60)	(Headway in Minutes)	-0.8247	-12.0
	Reliability (excluding RP response for car)	Percent (0-100)	0.0125	4.0
AE	Taxi Cost per Mile	Miles	1.17	6.3
	OVT to IVT Ratio	–	2.00	Constrained
	AE Time to MM Time Ratio	–	1.00	Constrained
	AE Time / Car Distance – 0.2, Auto Modes	–	-4.038	-27.0
	AE Time / Car Distance – 0.2, Non-Auto	–	-0.880	-8.5
	AE Time / Car Distance – 0.2, 2013-2014 SP	–	-1.794	-3.7
Structural Parameters				
N/A	Scale – 2005 SP		0.402	-18.5[a]
	Scale – 2013-2014 SP		0.367	-19.2[a]
	Access Logsum		1.000	0.0[a]
	Egress Logsum		0.978	-0.4[a]
	Rail Nesting Coefficient		1.000	0.0[a]
Observations			34,969	
Log Likelihood – Constants Only			-23,291.1	
Log Likelihood at Convergence			-17,219.9	
Rho Squared			0.261	
			2005 Dollars per Hour	**2014 Dollars per Hour**
Main Mode Values of Time				
Low-Income			$8.81	$10.70
Medium-Income			$8.81	$10.70
High-Income			$9.76	$11.85

[a] t-statistic measured in relation to 1.0, not 0.0.

Source: Cambridge Systematics, Inc.

Table 5-5 Alternative-Specific Variables – Recreation/Other Mode Choice Models[a]

Modes	Variable	Coefficient	t-statistic
Main Mode Alternative-Specific Variables			
Car	Traveling in Group	2.166	23.2
	Household Size	-0.149	-6.4
	No Cars in Household	-1.042	-7.7
	Cars Less Than Workers	-0.929	-9.7
	2005 Car Inertia	4.072	7.5
	2013-2014 Car Inertia	3.535	7.4
Air	ASC – RP	-2.371	-8.4
	ASC – 2005 SP	-3.459	-3.8
	ASC – 2013-2014 SP	1.219	2.4
	Traveling in Group	0.749	7.5
	2005 Air Inertia	4.084	6.5
	2013-2014 Air Inertia	3.187	6.0
HSR	ASC – 2005 SP	2.379	5.6
	ASC – 2013-2014 SP	4.457	11.1
CVR	ASC – RP	-2.549	-8.2
	ASC – 2005 SP	-1.997	-2.9
	ASC – 2013-2014 SP	-0.366	-0.7
	Low-Income	0.468	4.0
	High-Income	-0.336	-5.0
	Missing Income	-1.014	-6.4
	2005 CVR Inertia	3.615	5.5
	2013-2014 CVR Inertia	4.494	6.8
Access/Egress Mode Alternative-Specific Variables			
Drive-Park	ASC – Access	0.036	0.5
	Cars Less Than Workers (Access only)	-0.903	-6.0
	Traveling in Group	0.529	5.0
Rental Car	ASC – Egress	0.182	2.4
	Low-Income	-0.483	-2.5
	Traveling in Group	-0.164	-1.4
Serve Passenger	One Person Household (Access only)	-0.421	-4.3
	Low-Income	0.219	2.8
Taxi	ASC – Access	-1.409	-9.5
	ASC – Egress	-1.784	-10.5
	Traveling in Group	0.623	6.8
	Log (1 + Employment Density at Airport or Station – 2 mi buffer)[b]	0.108	7.3
Transit	ASC – Access	0.060	0.4
	ASC – Egress	0.046	0.3
	Cars Less Than Workers (Access only)	0.633	5.1
	Log (1 + Employment Density at Airport or Station – 2 mi buffer)[b]	0.063	6.6
	Car Used in Transit Path	-0.911	-10.7
	Bus Used in Transit Path	-0.236	-2.2
Walk	ASC – Access	0.619	4.4
	ASC – Egress	0.205	1.7

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

[b] Total employees per square mile within 2 miles of the main mode airport or station.

Source: Cambridge Systematics, Inc.

5.2 Destination Choice Model Estimation

This section details the Version 2 destination choice model estimation process and results. The Version 2 model estimation was not updated for the BPM-V3 primarily because the issues noted with the Version 2 model related to mode choice (long access and egress trips for short travel times on main modes) and to take advantage of the new RP/SP data from the 2013-2014 RP/SP survey for mode choice model estimation. In addition:

- The Version 2 destination choice model produced reasonable flows between major regions; no concerns with model results had been noted;
- While the RP destination data from the 2013-2014 RP/SP survey would have provided additional observations, there was no reason to believe they would have reflected substantially different choice information from that collected in the 2012-2013 CSHTS Long-Distance Recall survey used for the Version 2 model estimation; and
- For purposes of the long-distance model, the input variables such as the straight-line distance from TAZ centroid to TAZ centroid and the destination size variables did not change.

One input variable used in the destination choice models that would have changed due to the re-estimation of the mode choice models was the mode choice logsum. This variable relies on specific estimated mode choice model parameters and structure. However, in the Version 2 model, the coefficients for the logsum variables were not statistically significant and were constrained to values of 0.05. Based on experience with the Version 2 model estimation, this result was not expected to change; the BPM-V3 continues to use the 0.05 coefficients but with the updated logsums from the mode choice models documented in Section 5.1.

For completeness and ensuring that the full model is described in one document, the remainder of this section describes the Version 2 model estimation results since they did not change for the BPM-V3. As with the Version 2 model, some of the model parameters were updated during calibration of the BPM-V3. Section 6.0 describes the final calibrated BPM-V3 destination choice model parameters.

Estimation Datasets

The destination choice models were estimated using data from two datasets:

1. The 2012-2013 Long-distance portion of the CSHTS.
2. The 2005 RP/SP Survey. Only the RP portion of the survey was used for destination choice model estimation.

Destination Choice Model Design

Compared to the Version 1 destination choice models, the general specifications for the Version 2 model and the BPM-V3 were altered in several ways and tested several variables as follows:

- Version 1 model included three distance variables (distance, distance squared, and distance cubed). In Version 2 and BPM-V3, a piecewise linear distance specifications with breakpoints every 50 miles was tested.

Land-use (area type) variables were revised. A revised intensity variable was generated using a two-mile buffer around each zone. Buffer distances were based on centroid-to-centroid distances, which resulted in a relatively straightforward calculation that could be easily coded for model application. The revised intensity variable was formulated as follows:

$$[Intensity]_{2i} = \frac{\sum_{j \in C_i}([HH]_j + [EMP]_j)}{\sum_{j \in C_i}[AREA]_j}$$

Here, C_i is the set of all zones with centroid-to-centroid distance of less than 2 miles. For completeness, intrazonal centroid-to-centroid distance is taken to be zero miles for all zones, thus ensuring zone *i* is always a member of C_i.

Using this intensity measure, thresholds were devised to categorize each zone into one of five area type definitions. Area types were defined as follows and units were expressed as households and workers per square mile:

- Rural: $[Intensity]_{2i} \leq 1000$
- Suburban: $1000 < [Intensity]_{2i} \leq 4000$
- Urban: $4000 < [Intensity]_{2i} \leq 7000$
- CBD Fringe: $7000 < [Intensity]_{2i} \leq 15000$
- CBD: $[Intensity]_{2i} > 15000$

The new area type definitions resulted in much ***more contiguous area types***, particularly for the densest area types. Area types remained largely the same for large zones, since large zones typically did not have neighboring zones with centroid-to-centroid distances less than two miles.

- County/regional indicator variables were not used, though regional-specific indicator variables were interacted with area type variables (e.g. a SCAG indicator was not used).
- Segmenting size variables by income was explored as an option.
- A more disaggregate set of employment variables in the size function was explored. The size function was defined as follows:

$$[Size]_i = ln\left(\sum_k \exp(\beta_k) \times Z_{ik}\right)$$

Here, β_k is a size parameter to be estimated and Z_{ik} is the k^{th} size variable for zone *i*. One size parameter must be constrained to zero for the model to be statistically identified. The exponent in the expression above ensures the each size variable has a nonnegative effect on the size function.

- Accessibility variables related to specific large attractors (e.g., Disneyland), especially for the recreation trip purpose were considered.

  – Accessibility measures were generated using the following formula:

$$Acc_{ij} = \frac{2}{\max\left(2, Distance_{ij}^2\right)}$$

  Here, accessibility is measured for zone *i* to large attractor *j* (where *j* is simply the zone corresponding to the large attractor), and the distance is the straight-line distance. The accessibility value takes values between 0 and 1, with locations close to the large attractor taking larger values.

Estimation Results

The estimated models for the business, commute, recreation, and other trip purposes are shown in Tables 5-6, 5-7, 5-8, and 5-9. Some general findings and notes made during model estimation include the following:

- **Travel Distance Variable.** For each of the four trip purposes, distance variables were tested. In each case, the distance measures were found to have a great deal more explanatory power than the mode choice logsum, resulting in very low (and sometimes negative) coefficient estimates on the logsum variable. Nonetheless, the RTAP made a strong argument that distance variables were needed. Thus, in each of the specifications presented below, the coefficient on mode choice logsum was constrained to be 0.05, a larger value than the values that were estimated.

- **Piecewise Linear Distance Variables**. For each of the four trip purposes, piecewise linear distance variables were tested with breakpoints every 50 miles, starting with the 100-mile breakpoint and ending with the 550-mile breakpoint. A base distance variable was also included. A general trend in each of the models was found with the following characteristics:

  – A substantial impact of distance on the utility of travel in the 50- to 200-mile range;

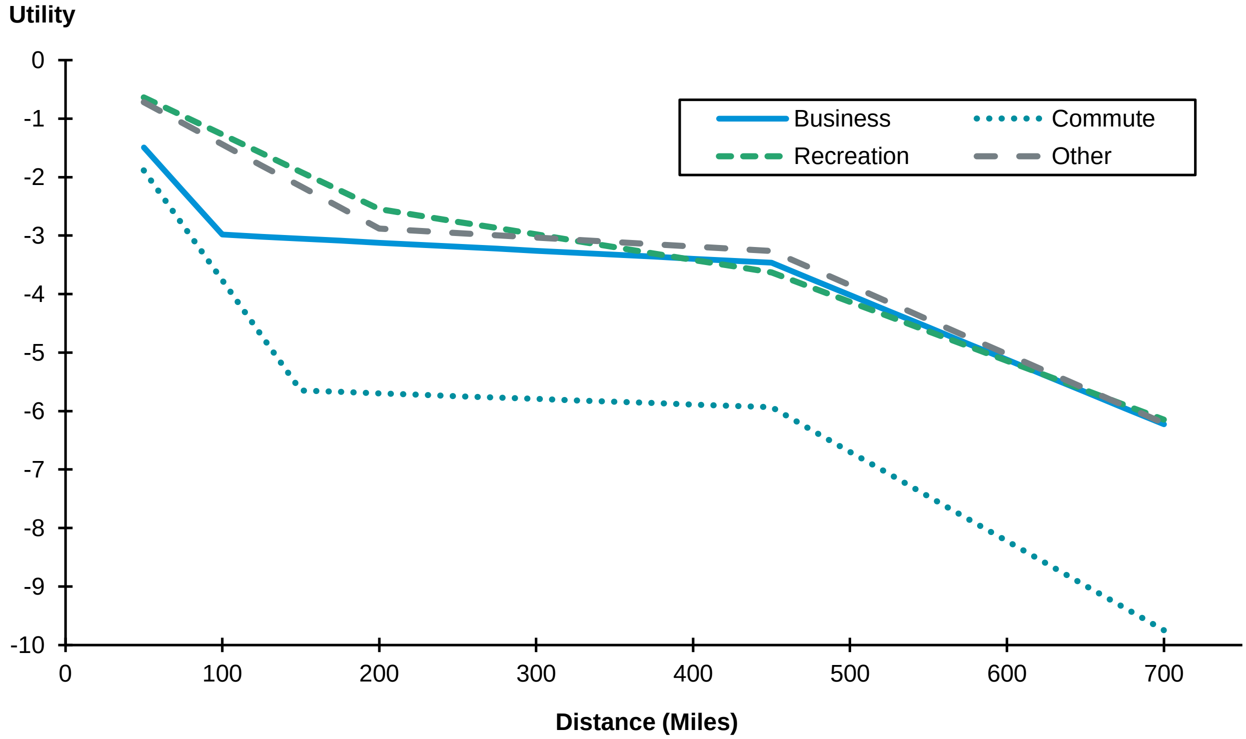
  – A subdued impact of distance on utility in the 300- to 450-mile range; and

  – Again a substantial impact on utility for distances greater than 450 miles.

  The minimal impact of distance on disutility is a result of the MTC-SCAG and SACOG-SCAG markets falling in this range. To ensure monotonic distance effects across the relevant distance range, all but two piecewise linear distance variables were dropped in the model for each trip purpose. The first breakpoint varied by trip purpose for the distance range from 100 to 200 miles, while the second breakpoint at 450 miles was found to work well for each purpose.

Figure 5-7 shows the impacts of distance on utilities for the four models using an observation that belongs to the high-income market segment.

Figure 5-7 Distance Utility Effect on High-Income Utility in Four Estimated Models



Source: Cambridge Systematics, Inc.

- **Size Variable Segmentation by Income**. A number of models tested that included segmentation of size variables by income produced mixed results in terms of the implied travel behavior. Therefore, income segmentation of size variables was removed from the model estimation.

- **Size Variable Statistics.** The tables with estimation results do not show t-statistics related to the size variables. The models are applied such that the exponent of the reported coefficient is multiplied by the size variable. Therefore, a coefficient of zero in the tables means that the actual coefficient is one. However, the t-statistic for a coefficient of zero would be zero, suggesting the coefficient is not significant, when, in fact, it may be highly significant. Therefore, in lieu of t-statistics, standard errors of the size coefficient estimates have been reported.

Business Purpose Destination Choice Model

Table 5-6 shows the estimation results for the business purpose destination choice model. A total of over 3,600 observations were used in estimation. The model includes a number of statistically significant effects and a good measure of fit was obtained.

Distance effects: There are strong distance effects for the ***"base" distance*** variable and some additional differentiation using piece-wise linear distance effects and differences by income.

The ***piecewise linear distance*** variables, "Max (0, Distance-100)" and "Max (0, Distance-450)" are additive to the base distance variable. The effect of the piecewise linear distance variable for "Max (0, Distance-100)" almost negates the base distance variable, suggesting that the increasing effect of distance is minimal in the 100- to 450-mile range (Figure 5-1).

Income effects are introduced by using the "Distance – Low-Income," "Distance – High-Income," and "Distance – Missing Income" variables which are also additive to the base distance variable. The negative coefficient on the low-income variable and positive coefficients on the high and missing income variables indicate that low-income individuals are less likely to travel longer distances for business trips compared to medium-income individuals. The reverse is true for high-income individuals and for those with missing income.

Land Use effects: The positive coefficients on the CBD area type variable and the ***additional CBD effects*** for SACOG, MTC, and SANDAG regions suggest that all else being equal, zones categorized as CBD are more attractive destinations.

The ***SACOG CBD*** and ***CBD Fringe*** are particularly attractive, over and above what is explained by accessibility and size variables. This is probably a function of the State Capitol and government offices at those locations.

Note that the variables specific to SACOG, MTC, and SANDAG regions are all additive to the base CBD variable. Also note that under the new area type definitions, no zones outside SACOG, MTC, SCAG, or SANDAG are categorized as CBD.

Size effects: For the business model, an assumption was that ***each job in a zone should contribute to the size variable*** for that zone. However, when separate coefficients were estimated for each employment category, wholesale trade and retail trade employment types resulted in highly negative coefficients, meaning they have no effect on the size function since they are exponentiated in application. Therefore, jobs of these employment categories were combined with the transportation employment category, with each job of these employment types contributing the same amount to the overall size variable for a zone.

Table 5-6 Destination Choice Coefficient Estimates – Business Purpose[a]

	Model B3	
Variables	**Coefficient**	**t-statistic**
Utility		
Mode Choice Logsum	0.0500	Constrained
Distance – All (per mile of straight line distances between TAZ centroids)	-0.0319	-22.8
Distance – Low-Income (additive to Distance – All)	-0.0052	-3.7
Distance – High-Income (additive to Distance – All)	0.0021	5.9
Distance – Missing Income (additive to Distance – All)	0.0032	6.0
Max (0, Distance-100 miles) (additive to Distance – All)	0.0285	18.8
Max (0, Distance-450 miles) (additive to Distance – All)	-0.0097	-4.7
CBD	0.156	1.9
CBD Fringe	-0.254	-4.2
Urban	-0.277	-5.1
Suburban	-0.259	-5.3
CBD or CBD Fringe – SACOG	1.71	18.8
CBD – MTC	0.813	8.4
CBD – SANDAG	1.13	9.5
Variables	**Coefficient**	**Standard Error**
Size		
Log Size Multiplier	1.00	b
Office Employment[a]	0.00	b
Primary Sector Employment[a]	-2.33	0.476
Education/Medical Employment[a]	-1.88	0.280
Leisure/Hospitality Employment[a]	1.54	0.098
Other Service Employment[a]	-0.483	0.513
Wholesale Trade + Transportation + Retail Trade Employment[a]	-0.750	0.205
Observations	3,633	
Log Likelihood at Zero	-30,057.5	
Log Likelihood at Convergence	-26,014.7	
Rho Squared	0.135	

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

[b] Size coefficients are exponentiated in the utility calculations. For example, the base office employment size coefficient of 0.0 is applied as exp(0.0) x office employment, or 1.0 x office employment.

Source: Cambridge Systematics, Inc.

Commute Purpose Destination Choice Model

Table 5-7 shows the estimation results for the commute purpose destination choice model. Despite a smaller sample size that reflects fewer long-distance commute trips, the model again provides statistically significant effects and good overall model fit.

Table 5-7 Destination Choice Coefficient Estimates – Commute Purpose[a]

	Model C3	
Variables	**Coefficient**	**t-statistic**
Utility		
Mode Choice Logsum	.0500	Constrained
Distance – All (per mile of straight line distances between TAZ centroids)	-0.0403	-23.0
Distance – Low-Income (additive to Distance – All)	-0.0026	-0.6
Distance – High-Income (additive to Distance – All)	0.0027	2.2
Distance – Missing Income (additive to Distance – All)	0.0031	1.8
Max (0, Distance-150 miles) (additive to Distance – All)	0.0367	17.8
Max (0, Distance-450 miles) (additive to Distance – All)	-0.0143	-1.7
CBD	-0.70	-5.4
CBD Fringe	-0.535	-6.0
Urban	-1.12	-12.7
Suburban	-1.18	-14.2
Variables	**Coefficient**	**Standard Error**
Size		
Log Size Multiplier	1.000	b
Office Employment[a]	0.000	b
Transportation Employment[a]	0.489	0.209
Education/Medical Employment[a]	-1.02	0.233
Leisure/Hospitality Employment[a]	0.103	0.225
Primary Sector + Wholesale Trade + Retail Trade + Other Service Employment[a]	-0.98	0.226
Observations	1,213	
Log Likelihood at Zero	-10,066.8	
Log Likelihood at Convergence	-8,214.3	
Rho Squared	0.184	

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

[b] Size coefficients are exponentiated in the utility calculations. For example, the base office employment size coefficient of 0.0 is applied as exp(0.0) x office employment, or 1.0 x office employment.

Source: Cambridge Systematics, Inc.

Distance effects: The ***"base" distance*** effect is again strong and significant.

The *piecewise linear distance* variables also dampen the effect of increasing distance in the middle distance range of 150 to 450 miles (Figure 5-6).

Similar to the business model, the commute model includes segmentation of the distance effect by *income level.* The estimated coefficients suggest that high and missing income individuals are more willing to travel longer distances.

Land Use effects: For the commute purpose, the area type indicators generally did not have significant impacts on the destination choice utilities and were removed.

Size effects: As with the business model, an initial assumption was that each job in a zone should contribute to the size variable for that zone in the commute model. Since ***several of the employment categories*** were found to not have significant individual impacts on the size function, those categories were combined (primary sector, wholesale trade, retail trade, and other service employment).

Recreation Purpose Destination Choice Model

Table 5-8 presents the destination choice model for the recreation trip purpose. A large sample size of over 6,600 observations for recreation travel was used in estimation. Strong statistically significant results were obtained for most explanatory variables. The best overall model fit among destination models was obtained.

Distance effects: Similar distance variable effects to those noted for the business and commute models can be noted in the model for recreational travel.

Land Use effects: The area type indicator variables suggest that, all else being equal, ***MTC and SANDAG CBDs*** are preferred for long-distance recreational travel. However, the negative coefficients on the base CBD variable and CBD fringe, urban, and suburban area type variables suggest that rural zones, in general, are also highly attractive for recreation trips. The attractiveness of rural zones varies based on accessibility effects and size variables. The ***SACOG CBD*** and ***CBD Fringe*** are attractive, over and above what is explained by the accessibility and size variables. This is probably a function of the State Capitol and other government offices at those locations.

Accessibility effects: A number of different location-specific accessibility variables were tested, but only accessibility to ***Disneyland*** and accessibility to ***Yosemite National Park*** were retained. Those two locations had the largest t-statistics of the various locations tested and are the two recreation locations most likely to attract travelers for the sole purpose of visiting that location. Other locations such as the Sea World, Fisherman's Wharf, the Lake Tahoe area (within California), or Big Sur are also popular tourist destinations. However, travel to those locations is often combined with visits to other tourist destinations in the regions such as the San Diego Zoo or the Golden Gate Bridge or lacked the necessary size and uniqueness to have significant location-specific accessibility variables. Therefore, the impacts of recreational sites other than Disneyland and Yosemite should generally be captured through the leisure employment size variables and region-specific area type variables.

Size effects: Unlike the business and commute models, the assumption that each job should necessarily have an impact on the size function for recreation purposes was not made. In this model, the size function features only the ***leisure/hospitality employment*** of the zone, ***transportation employment*** of the zone, and the ***zonal area***.

Table 5-8 Destination Choice Coefficient Estimates – Recreation Purpose[a]

Variables	Model R3 Coefficient	t-statistic
Utility		
Mode Choice Logsum	0.0500	Constrained
Distance – All (per mile of straight line distances between TAZ centroids)	-0.0129	-33.8
Distance – High-Income (additive to Distance – All)	0.0002	0.8
Distance – Missing Income (additive to Distance – All)	0.0004	0.8
Max (0, Distance-200 miles) (additive to Distance – All)	0.0084	14.1
Max (0, Distance-450 miles) (additive to Distance – All)	-.0057	-2.5
CBD	-0.81	-7.8
CBD Fringe	-1.02	-17.1
Urban	-1.25	-25.0
Suburban	-0.823	-21.8
Accessibility Disney[a]	2.17	26.9
Accessibility Yosemite[a]	1.83	19.8
CBD or CBD Fringe – SACOG	0.415	2.6
CBD – MTC	1.30	11.3
CBD – SANDAG	1.48	11.3
Variables	**Coefficient**	**Standard Error**
Size		
Log Size Multiplier	1.00	c
Leisure/Hospitality Employment[b]	0.00	c
Transportation Employment[b]	-2.14	0.130
Zonal Area (in square miles)	0.313	0.056
Observations	6,619	
Log Likelihood at Zero	-54,693.4	
Log Likelihood at Convergence	-42,736.2	
Rho Squared	0.219	

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

[b] Accessibility measures were generated using the following formula: $\mathrm{Acc}_{ij} = \frac{2}{\max\left(2, \mathrm{Distance}_{ij}^2\right)}$. Accessibility is measured for zone *i* to attractor *j*, and the distance is the straight-line distance in miles. The accessibility value takes values between 0 and 1, with locations close to the large attractor taking larger values.

[c] Size coefficients are exponentiated in the utility calculations. For example, the base office employment size coefficient of 0.0 is applied as exp(0.0) x office employment, or 1.0 x office employment.

Source: Cambridge Systematics, Inc.

Other Purpose Destination Choice Model

Table 5-9 shows coefficient estimates for the "all other purposes" destination choice model. This model has the largest sample size available for estimation (over 10,400 observations) but has the lower overall model fit in part reflecting the range of travel purposes that were considered together.

Table 5-9 Destination Choice Coefficient Estimates – Other Purpose[a]

	Model O3	
Variables	**Coefficient**	**t-statistic**
Utility		
Mode Choice Logsum	0.0500	Constrained
Distance – All (per mile of straight line distances between TAZ centroids)	-0.0157	-50.5
Distance – High-Income (additive to Distance – All)	0.0013	6.5
Distance – Missing Income (additive to Distance – All)	0.0019	5.3
Max (0, Distance-200 miles) (additive to Distance – All)	0.0129	25.5
Max (0, Distance-450 miles) (additive to Distance – All)	-0.0103	-7.0
CBD	-0.232	-3.3
CBD Fringe	-0.296	-7.7
Urban	-0.257	-8.4
Suburban	-0.184	-6.9
CBD or CBD Fringe – SACOG	0.942	10.3
CBD – MTC	0.340	3.8
CBD – SANDAG	0.677	5.5
	Coefficient	**Standard Error**
Size		
Log Size Multiplier	1.00	b
Leisure/Hospitality Employment[a]	0.00	b
Office Employment[a]	-2.79	0.151
Education/Medical Employment[a]	-2.48	0.101
Primary Sector + Wholesale Trade + Transportation + Retail Trade + Other Service Employment[a]	-4.16	0.246
Households[a]	-2.36	0.058
Zonal Area (in square miles) [a]	-0.852	0.126
Observations	10,464	
Log Likelihood at Zero	-86,829.4	
Log Likelihood at Convergence	-75,393.6	
Rho Squared	0.132	

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

[b] Size coefficients are exponentiated in the utility calculations. For example, the base office employment size coefficient of 0.0 is applied as exp(0.0) x office employment, or 1.0 x office employment.

Source: Cambridge Systematics, Inc.

This model is similar to the other models in terms of the **distance effects** and the **area** type effects.

Size effects: For this group of "other purposes," each job was assumed to be represented in the size function. The highly negative coefficient on the "catch all" employment category (including primary sector, wholesale trade, transportation, retail trade, and other service employment) implies that the impact of those employment types is quite low for destination choice. The size function also includes ***zonal area*** and ***number of households***.

5.3 Trip Frequency Model Estimation

This section details the Version 2 trip frequency model estimation process and results. The Version 2 model estimation was not updated for the BPM-V3. As described in the destination choice model section, the focus of the BPM-V3 updates were the mode choice model. In addition, no new data for trip frequency estimation were available since the 2013-2014 RP/SP survey focused on the current or most recent trip, not multiple trips made over a specified recall period.

For completeness and ensuring that the full model is described in one document, the remainder of this section describes the Version 2 model estimation results since they did not change for the BPM-V3. As with the Version 2 model, some of the model parameters were updated during calibration of the BPM-V3. Section 6.0 describes the final calibrated BPM-V3 trip frequency model parameters.

Model Estimation Data

The data used for trip frequency model estimation were derived from the 2012-2013 long-distance travel portion of the CSHTS. As discussed in detail in Section 2.2, a number of data issues were identified with the CSHTS long-distance data. Table 5-10 summarizes the survey design issues affecting the trip frequency model estimation, along with the methods used to correct the data.

Model Estimation Data Set Design

The CSHTS long-distance data set provided the information necessary to estimate control totals for the trip frequency model calibration. However, different data were required for model estimation. The CSHTS long-distance data set included one record for each "unique trip" reported by a member of the household. If multiple household members made the trip, that information was posted on the record but the trip record was not repeated for each household member. Further, accounting for, and taking advantage of, the fact the long-distance travel data included all long-distance trips made by a household over an eight-week period, not just a single day, was necessary.

Table 5-10 Trip Purpose Correspondence between Survey and Model

Issue Number	Survey Design Issue	Correction Method
1	Since completion of only the CSHTS Daily Diary was required for a survey to be considered to be complete, only about one-half of the respondent households completed the long-distance travel portion of the survey. Household characteristics and trip-making characteristics for households completing and households failing to complete the long-distance travel portion of the survey were different.	Responses from households completing the long-distance travel component were expanded based on household size, workers per household, number of vehicles, income group, and geographic area to estimates of 2010 households from the California Statewide Travel Model population synthesis.
2	The long-distance travel portion did not include a "repetition frequency" question, which would have allowed respondents who made multiple long-distance trips to the same location via the same travel mode to quickly report the repeated trips. An analysis of the responses along with the number of long-distance travel portions with exactly eight trips suggested that respondent fatigue coupled with a lack of understanding of the need for respondents to report all long-distance travel was an important issue.	An imputation process based on information collected in the 2011 Harris Panel Long-Distance Survey performed for the CHSRA was developed. Repeat factors were imputed based on trip purpose, income level, and trip distance.
3	The long-distance travel portion required respondents to remember and report travel completed as far back as eight weeks prior to their assigned travel day. The recall survey was subject to memory lapses resulting in underreporting of long-distance trips.	Adjustment factors by distance range were applied so that the total expanded long-distance trips by distance range (25-mile increments) matched the total long-distance trips by distance range estimated from the daily diary data.
4	Many respondents failed to record both directions of travel. On average, for every outbound trip, only 65 percent of return trips were recorded.	Information from only the outbound records was used and symmetry of trips was assumed.
5	The long-distance recall survey was not subject to the same rigorous process to make sure that all trips completed by all household members were reported by the survey respondent.	See correction method for Issue Number 3.

Source: Cambridge Systematics, Inc.

For model estimation, a data set was created that showed the number of days each person made 0 trips, 1 trip, or 2 or more trips during the eight-week, 56-day recall period. For example, during the 56-day recall period, for the business trip purpose, a single person might have had:

- 53 days with 0 trips;
- 2 days with 1 trip; and
- 1 day with 2 trips (i.e., one round-trip).

The information for that person was represented by three trip records, one for 0 trips with a weight of 53, one for 1 trip and a weight of 2, and one for 2 trips with a weight of 1.

A complicating factor with the development of the estimation data set was that only 65 percent of the outbound trips could be matched to a return inbound trip. As with the procedures used to develop the control totals for long-distance trips, only outbound trips were included in the model estimation data set base, and symmetry was assumed for the inbound trip. In order to include information on persons making one or two trips per day, it was necessary to know whether the symmetrical inbound trip was made on the same day as the outbound trip, or whether the inbound trip occurred on a subsequent day. Three options were considered to resolve this issue.

- **Option 1**: For the 65 percent of trips with both outbound and inbound trips reported, whether the inbound trip occurred on the same day could be directly found by comparing the dates on the two trips. For the remaining 35 percent of trips, this could be imputed based on trip lengths, number of household members traveling, and other information.

- **Option 2**: Since it had been determined that the Version 2 model (and by extension, the BPM-V3) would not model trip duration, the long-distance person days for trip frequency could simply be viewed as 0-1 variables for “did not make a long-distance trip” or “made a long-distance trip.” In effect, this simplified the trip frequency model from the Version 1 model multinomial model with choice options of 0, 1, or 2+ trips on a given day to a binary choice model. In the example above, the four business trips made by the individual (i.e., one roundtrip with the outbound and inbound trips occurring on different days and one roundtrip with the trips occurring on the same day) could be represented as two outbound trips in the dataset. Each of these trips would be assumed to have a symmetrical inbound trip. Thus, for the 56-day recall period, the four trips represented four person-days of travel and the remaining 52 days were no-travel days. While this would be in contrast to what actually occurred (53 no-travel days and three travel days, one of which included two trips), the correct number of person trips would be represented.

- **Option 3**: The decision-making unit could be changed to the household. Similar to Option 2, whether the inbound trip occurred on the same day or not would not be directly modeled. Instead, the total number of outbound long-distance trips for the entire household on a given day would be the dependent variable, and given a weight of two (to account for the return inbound trip). While this approach would simplify the creation of the estimation data set, it would complicate the trip frequency model, since the total number of possible trips generated in a day for a household would be equal to the household size.

Option 2 was used for a couple of reasons. First, Option 3 would have unnecessarily complicated the trip frequency model. Second, the simplicity of the binary choice model (make one trip or make no trips) was appealing. Further, the Version 1 model only differentiated the utility of 1-trip versus 2-trip alternatives via the alternative-specific constants. The available data did not offer much opportunity to improve upon that part of the Version 1 model; if the only difference would be a constant, it did not seem worth treating those choices differently. Finally, by moving to a choice of travel versus no travel, it was relatively simple to further distinguish the travel alternatives between traveling alone or in a group.

Another consideration in the decision to use Option 2 was that moving to a binary choice for a person-day would not preclude the later addition of a trip duration model. It could be argued that such a model should be partially dependent upon the distance traveled and, thus, applied after destination choice. It would not really change the number of trips modeled on a given day. Rather, it would simply add information regarding the duration of a trip that could then be used for the estimation of parking costs for mode choice.

Development of Final Trip Frequency Model Estimation Data Set

A family of data sets (one for each trip purpose) based on Option 2 was created for model estimation. The following adjustments were made:

- Only outbound production-attraction (PA) trips were included in the dataset. It was assumed that inbound attraction-production (AP) trips are symmetrical.
- Repeat factors found in the data were used to determine the total number of trips made by a household. Repeat factors indicated the number of times each unique trip record was made during the 56-day recall period. Since the repeat factors were not collected for the Long-Distance portion of the CSHTS, they were imputed using information from the 2011 Harris Long-distance survey.
- Each household was represented three separate times in the dataset for each trip purpose, once for the "No Travel" alternative, once for the "Travel Alone" alternative, and once for the "Group Travel" alternative. Representative weights for each of the three alternatives were based, in part, on the number of days during the recall period for which each alternative was chosen.
- Since, in keeping with the Version 1 and 2 models, the trip frequency model continued to be a person-based model, with household size being used to weight the data. For the example above, if the household had been a 2-person household with the second person accompanying the first person for all travel, 52 no travel days, 0 alone travel days, and 4 group travel days would have been recorded for the person.
- Group travel was determined by the existence of reported traveling companions, whether or not the companions were from the same household.
- Households reporting no trips for the 56-day recall period were included in the estimation data set as 56 no travel days for each of the four trip purposes, and zero alone and zero group travel days for each of the four trip purposes.

Based on the design of the data set, a multinomial choice model could be constructed for each trip purpose with the choices being: Make Zero Trips, Make One Trip Alone, and Make One Trip in a Group. The Make One Trip Alone and Make One Trip in a Group included alternative-specific constants that could be adjusted to match control totals for all intra-California long-distance trip-making on a given day.

Trip Frequency Model Estimation Data Set Summary Statistics

Table 5-11 summarizes the data and choices included in the trip frequency model estimation data set.

Table 5-11 Trip Frequency Model Estimation Dataset Statistics

Trip Purpose	Business	Commute	Recreation	Other
No Travel Days	53,070	52,979	52,640	52,461
Travel Alone Days	118	245	46	139
Travel in Group Days	132	95	633	719
Total Number of Person Days[a]	53,319	53,319	53,319	53,319
No Travel Days	99.53%	99.36%	98.73%	98.39%
Travel Alone Days	0.22%	0.46%	0.09%	0.26%
Travel in Group Days[a]	0.25%	0.18%	1.19%	1.35%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**

[a] Totals may not sum due to rounding.

Source: Cambridge Systematics, Inc.

Trip Frequency Model Design

The trip frequency model includes the following key features:

1. Trip frequency for each trip purpose (business, commute, recreation, and other) is handled in separate models. All trips greater than 50 miles (measured as straight-line distance from TAZ centroid-to-centroid) are considered long-distance trips.

2. The model choice set includes the decision to make 0 trips, 1 travel alone trip, and 1 travel in a group trip for each individual member of a household on a specific day. Since the trip frequency model will explicitly model group size, a separate group size submodel is not needed.

3. The formulation of the short-distance accessibility variable used in the latest models is shown below.

$$Acc_i = \ln\left(1 + \sum_{j \in B_i} \frac{(Emp\ or\ Emp + HHs)_j}{\exp\left(-2 \times \frac{Dst_{ij}}{Dst_{mean}}\right)}\right)$$

   This function reflects the characteristic that greater numbers of short-distance opportunities will result in individuals generating fewer long-distance trips to satisfy their activity needs. Dst in the denominator of the summation is the straight-line distance to ensure changes to the highway network will not affect the accessibility variable, which could potentially lead to undesired results when the model is applied. B_i represents the set of TAZs that are less than 50 miles (i.e., short-distance) from zone *i*.

4. Like the Version 1 and Version 2 models, destination choice logsums are included in the models reflecting the characteristic that increased accessibility to destinations more than 50 miles from a traveler's home will result in increased long-distance trip-making (or vice-versa). Changes in the destination choice logsum values can result from changes in travel impedances from the TAZ in question to all other TAZs in the State (e.g., due to the introduction of a high-speed rail system) or changes in households and employment throughout the State.

5. Household size, income level, number of workers, and auto availability socioeconomic variables have continued to be included in the Version 2 model (and, by extension, the BPM-V3).

Estimation Results

For each of the four trip purposes, the alternatives in the models are identical and include: no long-distance trips, 1 travel-alone long-distance trip, and 1 travel-in-group long-distance trip. The no-travel alternative represents the reference alternative and always has utility equal to zero. Nested logit models were tested for each trip purpose, where the nest in each case contained the two travel alternatives with the no-travel alternative outside the nest. In the case of commute and recreation models, the estimated nesting coefficients were not significantly different from 1.0 and/or greater than 1.0. In the other two models, the estimated nesting coefficients were reasonable, but did not improve the fit of either model significantly. Therefore, all recommended models shown below are multinomial logit models.

Table 5-12 shows the estimation results for the business and commute purpose models. For each of these two models, the zonal attribute used in computing the short-distance accessibility variables was the total employment. For the commute model, the initial, unconstrained coefficient estimate of the long-distance destination choice logsum was greater than 1.0. Since this was an illogical result, it was constrained to 1.0 for the final estimation of the model.

Overall, the two models have similar trends in the estimated coefficients. Most of the demographic variables have similar effects on the utilities of traveling alone or in a group. For instance, larger households were found to make fewer trips, in general, but were less likely to travel alone than in a group, though this effect is dampened for each worker in the household. Households with no workers are less likely to make business trips or, especially, commute trips.

Table 5-12 Business and Commute Trip Frequency Model Estimation Results[a]

	Business		Commute	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
Long-Distance Destination Choice Logsum – Business	0.799	4.3		
Long-Distance Destination Choice Logsum – Commute			1.00	
Short-Distance Accessibility (Total Employment) – All	-0.192	-4.9	-0.247	-6.6
ASC – Alone	-12.1	-5.3	-11.5	-17.8
Household Size – Alone	-0.582	-5.9	-0.382	-5.7
Cars less than Workers – Alone			-1.031	-2.3
ASC – Group	-12.7	-5.5	-12.7	-18.3
Household Size – Group	-0.329	-3.6	-0.302	-2.9
Cars less than Workers – Group	0.263	0.7		
High-Income – Alone/Group	0.209	1.4		
Workers – Alone/Group	0.217	1.5	0.337	2.8
No Workers in Household – Alone/Group	-0.468	-1.4	-1.28	-3.5
Observations	53,319		53,319	
Log Likelihood – Constants Only	-1,757.4		-22,61.4	
Log Likelihood at Convergence	-1,706.9		-21,69.9	
Rho-Squared	0.029		0.040	

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

Source: Cambridge Systematics, Inc.

Table 5-13 shows the estimated results for the recreation and other purpose models. Unlike the business and commute models, the short-distance accessibility variables for these two models are different. For the recreation model, leisure employment was used in the accessibility variable rather than total employment. For the other model, the average of accessibility variables computed for leisure employment and for households was used.

The effects of demographic variables in the recreation and other purpose models are similar, like the business and commute models. For instance, larger households are much less likely to generate trips traveling alone. In addition, low-income households are less likely to generate trips overall, while high-income households are more likely to generate trips.

The alternative-specific constants are relatively large for each of the four models. As noted by the RTAP, the large alternative-specific constants in the model are considered to be appropriate and reflect the fact that long-distance trips are infrequently made by people. Based on the expanded CSHTS data, residents of California make about 1/100th as many long-distance trips as short-distance, local trips on an average day.

Table 5-13 Recreation and Other Trip Frequency Model Estimation Results[a]

	Recreation		Other	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
Long-Distance Destination Choice Logsum – Recreation	0.478	3.0		
Long-Distance Destination Choice Logsum – Other			0.463	4.2
Short-Distance Leisure Employment Accessibility – All	-0.032	-1.2		
Short-Distance Accessibility (0.5*Leisure Emp. + 0.5*Households) – All			-0.186	-8.1
ASC – Alone	-9.9	-5.4	-6.20	-4.9
Household Size – Alone	-0.944	-5.7	-1.01	-10.1
ASC – Group	-9.7	-5.4	-6.90	-5.5
Household Size – Group			-0.0641	-1.6
Low-Income – Alone/Group	-0.570	-3.5	-0.226	-1.9
High-Income – Alone/Group	0.373	3.8	0.076	0.9
Missing Income – Alone/Group	0.135	0.8	-0.356	-2.2
No Cars – Alone/Group			-0.586	-1.9
Workers – Alone/Group			-0.129	-2.4
Observations	53,319		53,319	
Log Likelihood – Constants Only	-3,806.8		-4,773.1	
Log Likelihood at Convergence	-3,757.2		-4,661.8	
Rho-Squared	0.013		0.023	

[a] Estimated coefficients in this table were subject to modification in the model calibration process.

Source: Cambridge Systematics, Inc.

Model Application

The estimated models produce the probabilities of a single person in a household making one travel-alone long-distance trip and one travel-in-group long-distance trip on a given day. Since the PA trips were, in effect, doubled in the estimation data set to represent the symmetrical AP trips (see the example under the Option 2 discussion above), the probabilities represent the trips per person for each household type. The trips per person are multiplied by the household size and, then, by the number of households in the specific household size group to estimate the total person trips "generated."

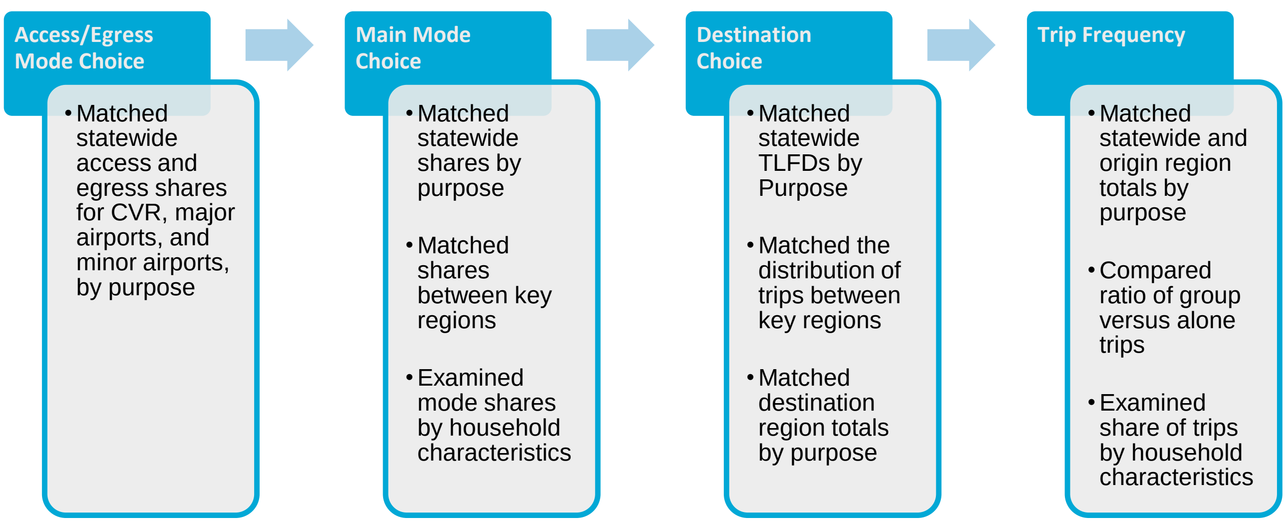
6.0 Long-Distance Model Calibration

6.1 Overview of Calibration Process

The BPM-V3 including trip frequency, destination choice, main mode choice, and access/egress mode choice, were calibrated to reproduce estimates of long-distance travel patterns of California travelers. The observed data were based on an expansion of the 2012-2013 CSHTS Daily Diary and Long-Distance survey data to match the socioeconomic characteristics of the 2010 California population. The expansion of 2012-2013 CSHTS data to year 2010 conditions has been documented in Section 2.2.

Since the model components pass logsum information "up" through the modeling process and trip information "down" through the process, the individual model components had to be calibrated in an iterative fashion. The initial step was calibration of the access/egress portion of the mode choice model followed by, and sometimes simultaneously with, the main mode portion of the mode choice model. Once calibration targets were reached for access/egress and main mode choice models, destination choice was calibrated, followed by trip frequency. The process was repeated, since individual adjustments to one model could affect others. Figure 6-1 illustrates this iterative process used for calibration and documents the targets for each model. The next several sections details the calibration results for each model.

Figure 6-1 Calibration Process



6.2 Access/Egress Mode Choice Model Calibration

Access/Egress Calibration Targets

Unlike most of the other calibration targets that will be discussed in Section 6.0, the access/egress target shares did not come from the CSHTS survey. Instead, target shares were developed from observed data from available sources.

Air access and egress shares were derived from two sources of data:

- MTC 2006 airline passenger survey tabulations of access and egress modes at Oakland and San Francisco airports; and
- 2005 RP/SP survey.

CVR access and egress shares were developed from three sources of data:

- 2007 Capitol Corridor Satisfaction Study;
- Summaries of ridership data for San Diego area conventional rail services; and
- 2005 RP/SP survey.

In addition to these data sources, professional judgment was used to develop the final access and egress mode share targets by trip purpose. Moreover, early on in examining these data sources, it became evident that access and egress mode shares were quite different at airports and CVR stations. Major and minor airports had starkly different access and egress modal shares as well. Because the model was not developed to allow for these sorts of differences explicitly, additional constants were added to the models. These constants allowed for calibration to separate CVR station targets, major airport targets, and minor airport targets.

Major airports include the following:

- Los Angeles International (LAX);
- John Wayne (SNA);
- Burbank (BUR);
- Ontario (ONT);
- Long Beach (LGB);
- San Diego (SAN);
- San Francisco (SFO);
- San Jose (SJC);
- Oakland (OAK); and
- Sacramento (SMF).

Minor airports include the following:

- Monterey (MRY);
- Oxnard (OXR);
- Palm Springs (PSP);
- Santa Barbara (SBA);
- Arcata (ACV);
- Bakersfield (BFL);
- Fresno (FAT); and
- Modesto (MOD).

Table 6-1, Table 6-2, and Table 6-3 show the calibration targets and final access and egress mode share for major airports, minor airports, and CVR stations, respectively. For the purposes of forecasting HSR ridership, the HSR modal access and egress models use the constants calibrated for CVR stations.

Table 6-1 Access and Egress Mode Shares to Major Airports by Aggregated Trip Purposes

	Target Mode Shares						Calibrated Model Mode Shares					
Region	Park	Rental Car	Drop-off/ Pick-up	Taxi	Transit	Walk/ Bike	Park	Rental Car	Drop-off/ Pick-up	Taxi	Transit	Walk/ Bike
Business/ Commute – Access	45%	0%	30%	15%	10%	0%	45%	0%	30%	15%	10%	0%
Business /Commute – Egress	0%	40%	15%	35%	10%	0%	0%	40%	15%	35%	10%	0%
Recreation/ Other – Access	25%	0%	45%	15%	15%	0%	25%	0%	45%	15%	15%	0%
Recreation/ Other – Egress	0%	25%	45%	20%	10%	0%	0%	25%	45%	20%	10%	0%

Source: Cambridge Systematics, Inc.

Table 6-2 Access and Egress Mode Shares to Minor Airports by Aggregated Trip Purposes

	Target Mode Shares						Calibrated Model Mode Shares					
Region	Park	Rental Car	Drop-off/ Pick-up	Taxi	Transit	Walk/ Bike	Park	Rental Car	Drop-off/ Pick-up	Taxi	Transit	Walk/ Bike
Business/ Commute – Access	80%	0%	15%	2%	3%	0%	80%	0%	15%	2%	3%	0%
Business/ Commute – Egress	0%	57%	20%	20%	3%	0%	0%	50%	19%	22%	9%	0%
Recreation/ Other – Access	45%	0%	50%	2%	3%	0%	45%	0%	50%	2%	3%	0%
Recreation/ Other – Egress	0%	20%	70%	5%	5%	0%	0%	28%	53%	11%	8%	0%

Source: Cambridge Systematics, Inc.

Table 6-3 Access and Egress Mode Shares to CVR Stations by Aggregated Trip Purposes

	Target Mode Shares						Calibrated Model Mode Shares					
Region	Park	Rental Car	Drop-off/ Pick-up	Taxi	Transit	Walk/ Bike	Park	Rental Car	Drop-off/ Pick-up	Taxi	Transit	Walk/ Bike
Business/ Commute – Access	75%	0%	10%	1%	9%	5%	75%	0%	10%	1%	9%	5%
Business/ Commute – Egress	0%	1%	10%	30%	50%	9%	0%	1%	10%	29%	50%	9%
Recreation/ Other – Access	35%	0%	33%	2%	10%	20%	32%	0%	31%	2%	17%	18%
Recreation/ Other – Egress	0%	2%	51%	5%	26%	16%	0%	2%	51%	5%	26%	16%

Source: Cambridge Systematics, Inc.

Access/Egress Calibration Results

The access/egress model constants were adjusted in order that the final 2010 model achieved results within a reasonable tolerance to the calibration targets, as described above. The final calibrated constants are shown in Table 6-4 and Table 6-5 for business/commute and recreation/other trip purposes, respectively. In each table, the initial constants developed during model estimation are shown alongside the calibrated constants. Also calculated is the value of the calibrated constants in terms of equivalent minutes of access/ egress travel time.[23]

For each access or egress mode, three constants were calibrated (except for walk), but only a single constant is shown for the initial model. This is because of the added constants representing the disparity between CVR stations, major airports, and minor airports. The base calibrated constant applies to all main mode options, while the added calibration constants apply only to major or minor airports. These added constants are additive. For instance, the actual major airport constant is reflected by the base constant, plus the major airport constant.

[23] Equivalent minutes of travel time" is estimated by dividing a constant or a variable by the coefficient associated with travel time. Equivalent minutes of travel time provides a convenient way to measure the magnitude of "unexplained variation" of a model constant using an understandable metric and to compare values among different models. Equivalent minutes of travel time is a derived measures that can be computed for any model variable. So, for example, a $72 HSR fare (2005 dollars) for an interchange in the recreation/other mode choice model would equate to 337 equivalent minutes of travel time while the implied equivalent minutes of travel time savings for group travel in an auto for the interchange would equate to a savings of 619 equivalent minutes of travel time. Note, however, these variables are important for their contributions to the mode choice utility function, not as direct measures of travel time.

The final set of calibrated constants shown in Table 6-4 and Table 6-5 result in the final model access/egress mode shares shown in Table 6-1, Table 6-2, and Table 6-3. In most cases, the targets and model shares are identical (to the whole percentage point) or are within only 1 or 2 percentage points.

Table 6-4 Access-Egress Mode Choice Model Constants – Business/Commute

Access/Egress Mode		Main Mode	Initial Constants	Calibrated Constants	Equivalent Minutes
Drive and Park	Access	All	0.944	2.016	-309
		Air – Major Airports		-1.212	186
		Air – Minor Airports		-0.110	17
Rental Car	Egress	All	0.269	0.292	-45
		Air – Major Airports		0.481	-74
		Air – Minor Airports		0.680	-104
Taxi	Access	All	-0.444	-2.292	351
		Air – Major Airports		1.234	-189
		Air – Minor Airports		0.121	-18
	Egress	All	-0.008	0.674	-103
		Air – Major Airports		-0.416	64
		Air – Minor Airports		-1.103	169
Transit	Access	All	-0.749	-0.644	99
		Air – Major Airports		0.296	-45
		Air – Minor Airports		1.478	-226
	Egress	All	-0.076	0.903	-138
		Air – Major Airports		-0.360	55
		Air – Minor Airports		-2.083	319
Walk	Both	CVR and HSR Only	1.503	1.643	-252

Source: Cambridge Systematics, Inc.

Table 6-5 Access-Egress Mode Choice Model Constants – Recreation/Other

Access/ Egress Mode		Main Mode	Initial Constants	Calibrated Constants	Equivalent Minutes
Drive and Park	Access	All	0.036	0.049	-14
		Air – Major Airports		-0.611	176
		Air – Minor Airports		-0.300	87
Rental Car	Egress	All	0.182	0.097	-28
		Air – Major Airports		-0.473	136
		Air – Minor Airports		-1.431	412
Taxi	Access	All	-1.409	-3.602	1038
		Air – Major Airports		1.570	-453
		Air – Minor Airports		-0.217	62
	Egress	All	-1.784	-3.013	868
		Air – Major Airports		1.291	-372
		Air – Minor Airports		-0.643	185
Transit	Access	All	0.060	-2.442	704
		Air – Major Airports		2.404	-693
		Air – Minor Airports		3.052	-880
	Egress	All	0.046	0.359	-104
		Air – Major Airports		-0.655	189
		Air – Minor Airports		-1.662	479
Walk	Access	CVR and HSR Only	0.619	2.085	-601
	Egress	CVR and HSR Only	0.205	1.398	-403

Source: Cambridge Systematics, Inc.

6.3 Main Mode Choice Model Calibration

Main Calibration Targets

For main mode choice model calibration, the key targets came from the CSHTS statewide modal shares by trip purpose. While the primary targets were statewide mode shares, origin region mode shares were also checked between the CSHTS targets and model. In most cases, the regional mode shares were close to targets, even if they did not match as well as statewide numbers. The origin region results are characterized by the region in which a trip originated.

Table 6-6, Table 6-7, Table 6-8, and Table 6-9 show the main mode calibration targets by origin region and the State for each trip purpose. In addition, calibrated model shares are shown in the table for comparison purposes. As illustrated in the tables, the model shares at the statewide level are nearly identical to the targets. At the origin region level, there is more variation with some regions matching targets better than others, but overall, even the regional model shares match targets relatively well.

Table 6-6 Main Mode Calibration Results – Daily Trips and Percent Differences by Origin Region – Business Purpose

Region Name	CSHTS				Calibrated Model				Percent Difference			
	Car	Air	CVR	Total	Car	Air	CVR	Total	Car	Air	CVR	Total
SACOG	6,595	545	230	7,369	6,746	490	136	7,372	2%	-10%	-41%	0%
SANDAG	9,030	654	264	9,948	8,799	958	194	9,951	-3%	46%	-27%	0%
MTC	24,886	3,959	615	29,460	26,386	2,741	341	29,469	6%	-31%	-44%	0%
SCAG	58,275	4,519	695	63,489	57,351	4,902	1,260	63,512	-2%	8%	81%	0%
San Joaquin Valley	21,709	290	121	22,120	21,312	624	192	22,127	-2%	115%	58%	0%
Other	14,385	639	89	15,112	14,493	553	77	15,122	1%	-14%	-14%	0%
Total	**134,881**	**10,606**	**2,014**	**147,500**	**135,088**	**10,266**	**2,199**	**147,553**	**0%**	**-3%**	**9%**	**0%**

Source: Cambridge Systematics, Inc.

Table 6-7 Main Mode Calibration Results – Daily Trips and Percent Differencesby Origin Region – Commute Purpose

Region Name	CSHTS				Calibrated Model				Percent Difference			
	Car	Air	CVR	Total	Car	Air	CVR	Total	Car	Air	CVR	Total
SACOG	10,678	15	547	11,240	11,049	20	175	11,244	3%	30%	-68%	0%
SANDAG	24,119	94	1,148	25,361	24,661	135	542	25,338	2%	44%	-53%	0%
MTC	49,608	167	110	49,886	49,205	142	546	49,894	-1%	-15%	395%	0%
SCAG	95,494	310	414	96,218	93,919	267	1,989	96,175	-2%	-14%	381%	0%
San Joaquin Valley	32,962	0	0	32,962	32,677	29	259	32,966	-1%	100%	100%	0%
Other	18,374	33	0	18,407	18,324	13	77	18,414	0%	-61%	100%	0%
Total	**231,235**	**620**	**2,219**	**234,074**	**229,836**	**606**	**3,589**	**234,030**	**-1%**	**-2%**	**62%**	**0%**

Source: Cambridge Systematics, Inc.

Table 6-8 Main Mode Calibration Results – Daily Trips and Percent Differences by Origin Region – Recreation Purpose

Region Name	CSHTS				Calibrated Model				Percent Difference			
	Car	Air	CVR	Total	Car	Air	CVR	Total	Car	Air	CVR	Total
SACOG	31,950	292	101	32,343	31,783	268	281	32,333	-1%	-8%	177%	0%
SANDAG	39,921	504	363	40,788	39,579	444	745	40,769	-1%	-12%	105%	0%
MTC	104,799	2,064	1,026	107,889	104,638	1,605	1,623	107,866	0%	-22%	58%	0%
SCAG	216,088	1,745	2,528	220,361	215,471	2,430	2,375	220,276	0%	39%	-6%	0%
San Joaquin Valley	70,633	137	278	71,048	70,212	244	538	70,995	-1%	78%	94%	0%
Other	30,607	234	175	31,017	30,822	117	73	31,012	1%	-50%	-58%	0%
Total	**493,999**	**4,976**	**4,471**	**503,446**	**492,506**	**5,108**	**5,636**	**503,250**	**0%**	**3%**	**26%**	**0%**

Source: Cambridge Systematics, Inc.

Table 6-9 Main Mode Calibration Results – Daily Trips and Percent Differences by Origin Region – Other Purpose

Region Name	CSHTS				Calibrated Model				Percent Difference			
	Car	Air	CVR	Total	Car	Air	CVR	Total	Car	Air	CVR	Total
SACOG	33,157	520	671	34,347	33,363	532	457	34,352	1%	2%	-32%	0%
SANDAG	41,917	1,604	776	44,297	42,309	995	988	44,292	1%	-38%	27%	0%
MTC	103,942	4,062	927	108,931	104,282	2,733	1,923	108,939	0%	-33%	107%	0%
SCAG	256,012	3,606	2,106	261,724	253,831	4,752	3,152	261,735	-1%	32%	50%	0%
San Joaquin Valley	99,624	210	1,665	101,500	99,947	401	1,130	101,479	0%	91%	-32%	0%
Other	65,821	217	1,013	67,051	66,390	467	218	67,075	1%	115%	-78%	0%
Total	**600,473**	**10,219**	**7,158**	**617,851**	**600,122**	**9,880**	**7,869**	**617,871**	**0%**	**-3%**	**10%**	**0%**

Source: Cambridge Systematics, Inc.

CVR Calibration

For the CVR mode, the final mode share targets were adjusted from the summarized CSHTS targets, because the initial assignments of CVR trips produced substantially lower CVR volumes than counts reported by operators for a number of key regional pairs. As a result, it was assumed that the observed long-distance CVR trips estimated using the CSHTS data were low. Table 6-10 shows the comparison of daily CVR ridership values between key regions.

The riders in Table 6-10 were summarized from ridership counts on specific routes. They include all trips crossing regional borders (e.g., SANDAG/SCAG). It was impossible to exclude trips less than 50 miles from these counts. The CSHTS data include only long-distance trips (to locations 50 miles or more from the tripmaker's home). The extended long-distance trips were assigned to the modeled network. Calibrated model results shown in Table 6-10 are from the final calibrated model and include only long-distance trips.

Table 6-10 Comparison of Average Daily Interregional CVR Ridership for 2010

Regions	Route(s)	Observed Riders[a]	CSHTS	Calibrated Model
SANDAG-SCAG	Pacific Surfliner	4,345	3,951	6,305
SACOG-MTC	Capitol Corridor	3,641	2,672	2,408
SJV-MTC	ACE, San Joaquin	2,418	232	1,033
MTC-SCAG	Coast Starliner	538	600	267
SJV-SACOG	San Joaquin	316	336	161
Total between Key Regions		11,259	7,790	10,168
Other Region Pairs			8,072	8,964
Total			**15,862**	**19,132**

[a] Includes both long-distance and short-distance riders.

Source: Cambridge Systematics, Inc.

Air Calibration

The initial modeled air mode shares for key region pairs were very low, including SCAG-to-MTC, SCAG-to-SACOG, and MTC-to-SANDAG. To correct for this issue, constants were added for access/egress to/from major airports. This ensured that the mode shares for these regional pairs matched targets reasonably well. The list of major airports is identical to the major airports identified in the access/egress mode choice calibration model. Table 6-11 shows the calibration targets and the calibrated model results for region-to-region pairs. Shaded lines are the region pairs of specific interest in the air market.

Final Calibrated Constants

Table 6-12 and Table 6-13 show the estimated model coefficients versus calibrated model coefficients for the business/commute and recreation/other models, respectively. In addition, equivalent minutes of travel time for the calibrated constants is shown as well (based on the in-vehicle time coefficient of the models).

The effects of constants are additive based on purpose, airport access, and airport egress combinations. For example, the business purpose constant for conventional rail is -6.564, while the commute purpose constants for conventional rail is -6.564 -0.433, or -6.997. As described above, additional constants were added to the model during calibration reflecting access or egress at major airports (rather than minor airports). Similar to the commute-specific constants, these constants are additive to the base air constant. For example, the business purpose constant for air travel between two minor airports is -6.133, for air travel from a major to a minor airport is -6.133 + 0.380, or -5.753, for air travel from a minor to a major airport is -6.133 + 2.318, or -3.815, and for air travel between two major airports is -6.133 + 0.380 + 2.318, or -3.435.

Table 6-11 Calibration Targets and Results for Region-to-Region Pairs

	CSHTS			Calibrated Model			Difference		
OD Major Flows	Auto	Air	CVR	Auto	Air	CVR	Auto	Air	CVR
Intra-SCAG	99%	0%	1%	99%	0%	1%	-1%	0%	1%
Intra-MTC	99%	0%	1%	98%	0%	2%	-2%	0%	2%
Intra-SJV	98%	0%	2%	98%	0%	2%	0%	0%	0%
Intra-SACOG	100%	0%	0%	100%	0%	0%	0%	0%	0%
Intra-SANDAG	100%	0%	0%	100%	0%	0%	0%	0%	0%
Intra-Other	99%	0%	0%	100%	0%	0%	0%	0%	0%
SCAG to SANDAG	98%	0%	2%	97%	0%	2%	-1%	0%	1%
SCAG to SJV	99%	1%	0%	98%	1%	0%	-1%	1%	0%
SCAG to MTC	69%	30%	1%	71%	28%	1%	3%	-2%	-1%
SCAG to SACOG	75%	24%	0%	77%	23%	0%	1%	-1%	0%
SCAG to Other	96%	1%	2%	96%	3%	1%	0%	2%	-2%
MTC to SANDAG	49%	49%	2%	60%	40%	0%	11%	-10%	-1%
MTC to SJV	99%	0%	1%	98%	1%	1%	0%	0%	0%
MTC to SACOG	98%	0%	2%	98%	0%	2%	0%	0%	0%
MTC to Other	99%	0%	1%	99%	0%	1%	0%	0%	0%
SJV to SANDAG	96%	3%	1%	93%	5%	2%	-3%	2%	1%
SJV to SACOG	99%	0%	1%	99%	0%	1%	1%	0%	-1%
SJV to Other	100%	0%	0%	100%	0%	0%	0%	0%	0%
SACOG to SANDAG	73%	27%	0%	65%	34%	0%	-8%	8%	0%
SACOG to Other	100%	0%	0%	100%	0%	0%	0%	0%	0%
SANDAG to Other	90%	5%	5%	90%	9%	1%	0%	4%	-4%
Total	**97%**	**2%**	**1%**	**97%**	**2%**	**1%**	**0%**	**0%**	**0%**

Source: Cambridge Systematics, Inc.

Table 6-12 Estimated and Calibrated Main Mode Choice Model Coefficients – Business/Commute

			Calibrated Model	
Mode	Purpose	Initial Constants	Constants	Equivalent Minutes
Air	Both purposes	-2.236	-6.133	944
	Commute	-0.399	-2.725	419
Conventional Rail	Both purposes	-3.641	-6.564	1,010
	Commute	0.627	-0.433	67
Air	Major Airport – Production – Both purposes	N/A	0.380	-58
	Major Airport – Attraction – Both purposes	N/A	2.318	-357

Source: Cambridge Systematics, Inc.

Table 6-13 Estimated and Calibrated Main Mode Choice Model Coefficients – Recreation/Other

Mode	Purpose	Initial Constants	Calibrated Model: Constants	Calibrated Model: Equivalent Minutes
Air	Both	-2.371	-5.595	1,599
Conventional Rail	Both	-2.549	-4.419	1,263
Air	Major Airport – Access – Both purposes	N/A	1.409	-403
	Major Airport – Egress – Both purposes	N/A	1.388	-397

Source: Cambridge Systematics, Inc.

6.4 Destination Choice Model Calibration

The destination choice model is a multinomial logit model, with alternatives defined as TAZs. The destination choice probability calculations are composed of two key components: the utility function (common to all of the choice models in the model system) and the size function. The size function measures the opportunity in an elemental zonal alternative (e.g., number of jobs), whereas the utility function measures the quality of the zonal alternative (e.g., accessibility). In model calibration, only utility function coefficients were adjusted.

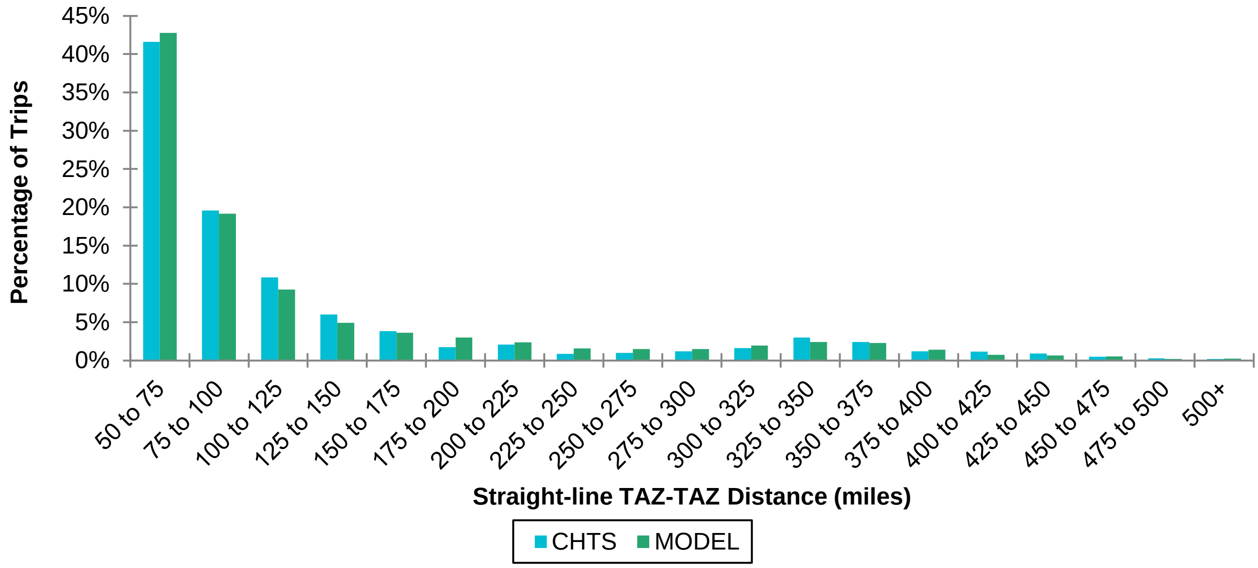
Trip Length Frequencies

Trip length frequency targets were generated from CSHTS data by trip purpose. Trip lengths were measured by straight-line distance from origin TAZ centroid to destination TAZ centroid. The destination choice models include a stepwise linear distance curve in the utility function, which allowed the marginal effect of one additional mile of travel to differ within different distance bands. The distance bands varied by trip purpose as follows:

- **Business purpose:**
  - 50 to 100 miles,
  - 100 to 450 miles, and
  - 450 or more miles.
- **Commute purpose:**
  - 50 to 150 miles,
  - 150 to 450 miles, and
  - 450 or more miles.
- **Recreation purpose:**
  - 50 to 200 miles,
  - 200 to 450 miles, and
  - 450 or more miles.
- **Other purpose:**
  - 50 to 200 miles,
  - 200 to 450 miles, and
  - 450 or more miles.

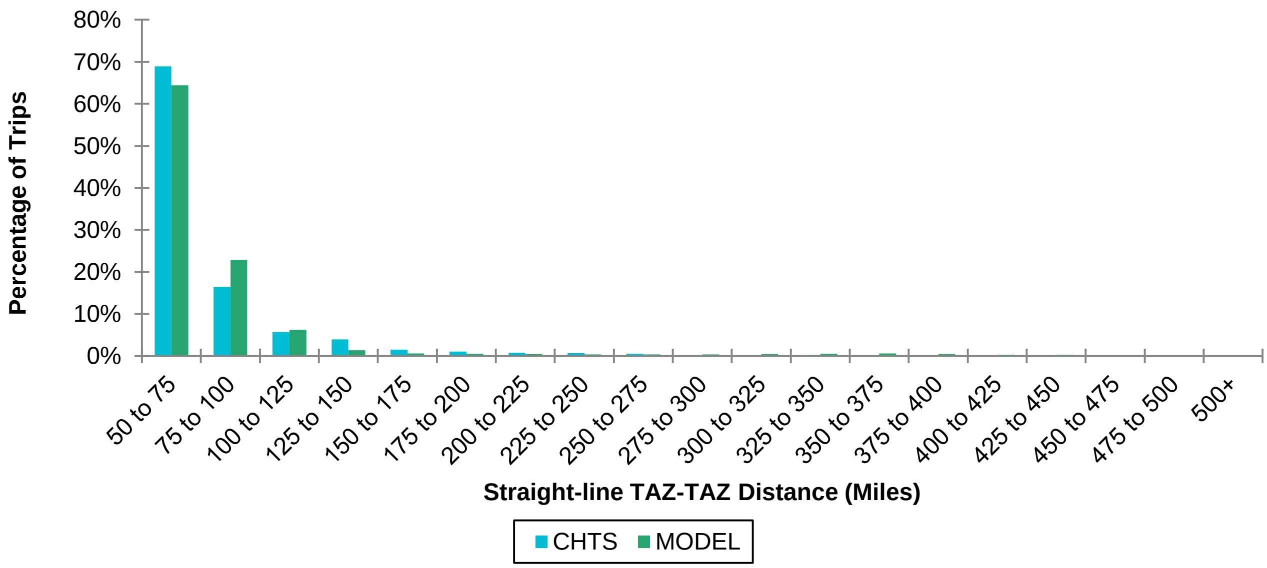
During calibration the coefficients were adjusted on these distance bands to match the CSHTS trip length frequency distributions. Figure 6-2, Figure 6-3, Figure 6-4, and Figure 6-5 show the trip length frequency comparisons between CSHTS targets and the final calibrated destination choice model for business, commute, recreation, and other trip purposes, respectively. In general, the trip length frequency distributions match quite well. Because the marginal utility contribution only varies across three travel distance ranges, distributions could not be matched exactly.

Figure 6-2 Trip Length Frequency Distribution Targets and Calibrated Model – Business Purpose



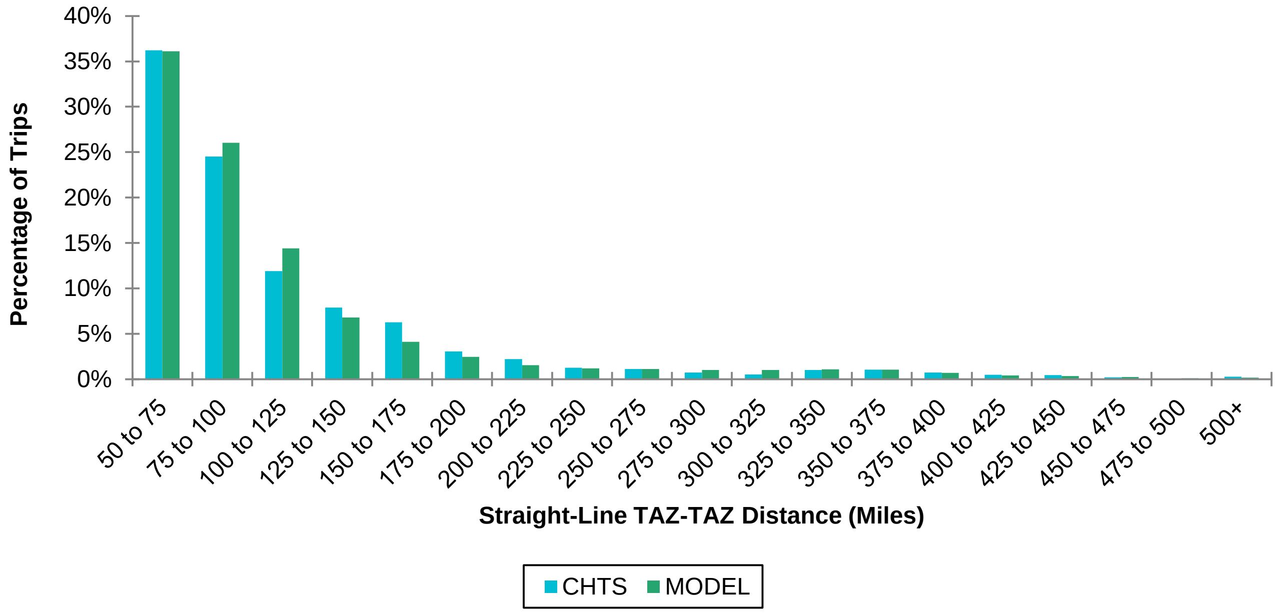
Source: Cambridge Systematics, Inc.

Figure 6-3 Trip Length Frequency Distribution Targets and Calibrated Model – Commute Purpose



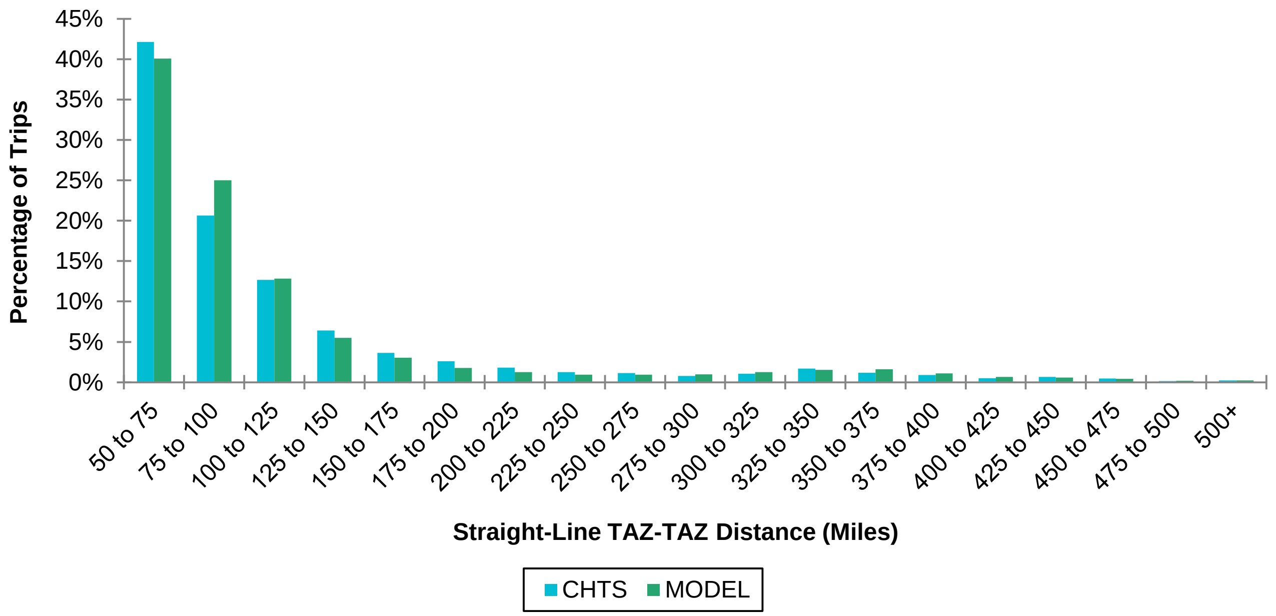
Source: Cambridge Systematics, Inc.

Figure 6-4 Trip Length Frequency Distribution Targets and Calibrated Model – Recreation Purpose



Source: Cambridge Systematics, Inc.

Figure 6-5 Trip Length Frequency Distribution Targets and Calibrated Model – Other Purpose



Source: Cambridge Systematics, Inc.

Region to Region Flows

While matching trip length frequencies is important, it was not enough to ensure flows between region pairs were accurate. Region flow targets were developed in two ways. First, overall trip totals by destination region by trip purpose were developed from CSHTS data. Second, region to region flows by trip purpose were also developed from CSHTS data. In order to match the CSHTS targets, new constants were added. Table 6-14 shows the calibrated region to region flows versus the region to region targets.

Table 6-14 Calibrated Region-to-Region Flows for All Modes

	CSHTS		Calibrated Model		Difference[a]	
Major Flows	Daily Long-Distance Trips	Percent of Total Long-Distance Trips	Daily Long-Distance Trips	Percent of Total Long-Distance Trips	Trips	Percent Difference
Intra-SCAG	349,900	23%	351,800	23%	1,900	1%
Intra-MTC	71,300	5%	79,200	5%	7,800	11%
Intra-SJV	55,700	4%	52,500	3%	-3,200	-6%
Intra-SACOG	9,400	1%	8,600	1%	-800	-9%
Intra-SANDAG	2,800	0%	2,200	0%	-600	-23%
Intra-Other	38,600	3%	52,300	3%	13,700	36%
SCAG to SANDAG	259,700	17%	269,100	18%	9400	4%
SCAG to SJV	85,700	6%	78,800	5%	-7,000	-8%
SCAG to MTC	45,600	3%	45,100	3%	-500	-1%
SCAG to SACOG	11,800	1%	14,900	1%	3,100	26%
SCAG to Other	80,500	5%	76,000	5%	-4,500	-6%
MTC to SANDAG	10,000	1%	7,400	0%	-2,500	-25%
MTC to SJV	80,000	5%	90,100	6%	10,100	13%
MTC to SACOG	116,500	8%	116,000	8%	-600	0%
MTC to Other	136,800	9%	114,700	8%	-22,100	-16%
SJV to SANDAG	7,800	1%	7,400	0%	-300	-4%
SJV to SACOG	25,500	2%	28,600	2%	3,100	12%
SJV to Other	60,200	4%	61,200	4%	1,100	2%
SACOG to SANDAG	2,500	0%	2,000	0%	-400	-18%
SACOG to Other	43,500	3%	38,100	3%	-5,400	-12%
SANDAG to Other	9,100	1%	6,500	0%	-2,600	-28%
Total	**1,502,900**	**–**	**1,502,700**	**–**	**-200**	**–**

[a] Differences may not match Calibrated Model – CSHTS due to rounding.

Source: Cambridge Systematics, Inc.

Destination Choice Calibrated Coefficients

Calibration was performed on the piecewise linear distance coefficients described above. Table 6-15 shows the estimated and final calibrated distance coefficients by trip purpose for the destination choice models. To better illustrate their effect on the utility function, Figure 6-6 plots the effect distance has on the utility function in the calibrated model for each trip purpose. The high-income segment is illustrated in Figure 6-6, since this segment has the flattest distance curves among income groups.

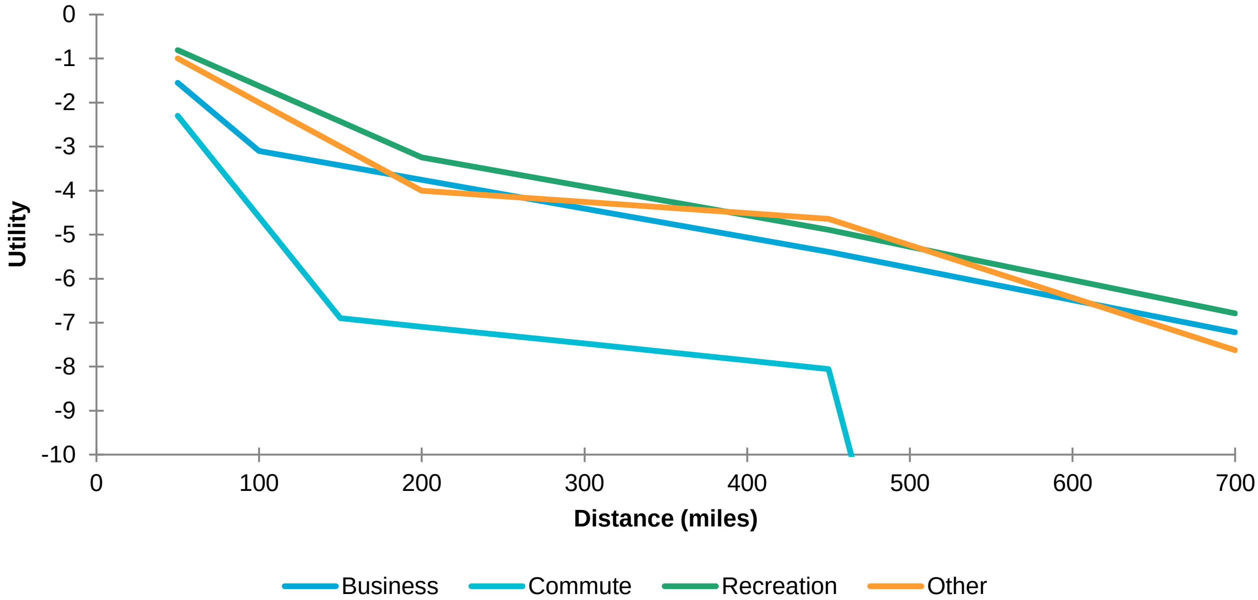
Table 6-15 Estimated and Calibrated Distance Coefficients by Trip Purpose[a]

Distance Coefficients	Estimated	Calibrated
Business Purpose		
Distance – All	-0.0319	-0.0310
Max(0, Distance – 100)	0.0285	0.0244
Max(0, Distance – 450)	-0.0097	-0.0008
Commute Purpose		
Distance – All	-0.0403	-0.0460
Max(0, Distance – 150)	0.0367	0.0422
Max(0, Distance – 450)	-0.0143	-0.1362
Recreation Purpose		
Distance – All	-0.0129	-0.0162
Max(0, Distance – 200)	0.0084	0.0096
Max(0, Distance – 450)	-0.0057	-0.0010
Other Purpose		
Distance – All	-0.0157	-0.0200
Max(0, Distance – 200)	0.0129	0.0174
Max(0, Distance – 450)	-0.0103	-0.0094

[a] Only the distance coefficients listed were modified for the calibration. All other destination choice model coefficients remain as documented in Tables 5-6 through 5-11.

Source: Cambridge Systematics, Inc.

Figure 6-6 Impact of Distance on Destination Choice Utility Function by Trip Purpose – High-Income Traveler Segment



Source: Cambridge Systematics, Inc.

In addition to the distance coefficients, the models include two sets of constants that were not part of the estimated models but were added to better fit observed data during the calibration process. The first set of constants relates to the destination super-region, taking a value of 1 if the TAZ is a member of the destination super-region. Six super-regions were identified: SACOG, MTC, SCAG, SANDAG, the San Joaquin Valley, and the rest of the State. Since the destination choice models are singly constrained (i.e. they do not ensure that trips attracted to specific zones or regions match predetermined numbers of attractions), the addition of destination super-region constants can be interpreted as increasing or decreasing the attractiveness of zones within a super-region as represented by size variables in relation to the attractiveness of zones in other super-regions.

Adding geographic-based constants such as these is not taken lightly due to the potential of "overfitting" a model. This was avoided by limiting the number and specificity of the super-region constants and applying the constants only to destinations. Overfitting the model by adding interchange specific constants was not considered. Table 6-16 presents the final calibrated super-region constants by trip purpose.

Table 6-16 Calibrated Destination Zone Super-Region Constants by Trip Purpose

Super-Region of Destination Zone	Trip Purpose			
	Business	Commute	Recreation	Other
SACOG	0.009	-0.029	-0.365	0.056
MTC	-0.538	-0.525	-0.737	-0.277
SCAG	-0.777	-1.099	-0.890	-0.643
SANDAG	-0.666	-0.554	-0.514	-0.430
San Joaquin Valley	-0.127	-0.559	-1.076	-0.375

Source: Cambridge Systematics, Inc.

The second set of constants was introduced because it was found that the model produced too few long-distance intraregional trips, as described earlier. These constants use the same super-region definitions above. Since intraregional trips in MTC and SCAG were considered to be most critical, individual calibration constants were used for those super-regions. Each of the other four super-regions have distinct constants as well, but the value of the constants for those super-regions were constrained to equal one another. Part of the reason for this was the sparseness of observed intraregional trip data across those four super-regions. Table 6-17 shows the final calibrated constants by trip purpose.

Table 6-17 Calibrated Constants for Trips with Both Trip Ends within a Single Super-Region

Super-Region	Trip Purpose			
	Business	Commute	Recreation	Other
SACOG	1.415	1.030	0.740	0.685
MTC	0.746	0.541	0.750	0.448
SCAG	0.477	0.258	0.199	0.249
SANDAG	1.415	1.030	0.740	0.685
San Joaquin Valley	1.415	1.030	0.740	0.685
Other	1.415	1.030	0.740	0.685

Source: Cambridge Systematics, Inc.

6.5 Trip Frequency Model Calibration

This section details the calibration process for the trip frequency model. There are four trip-frequency models – one for each trip purpose. The trip frequency models are multinomial logit models of daily person long-distance trips. Each trip frequency model has three choice alternatives: no travel, one long-distance trip traveling alone, and one long-distance trip traveling in a group.

Model Calibration Results

Statewide- and region-specific constants were adjusted within the trip frequency models to match origin region CSHTS trip totals. Constants were calibrated to minimize the percent differences between the estimated total trips from the CSHTS and the modeled total trips originating from each region. In addition, constants representing alone and group travel were also adjusted to meet targets developed from the CSHTS. Table 6-18 and Table 6-19 present the CSHTS target trip totals and final calibrated model trips by region and by trip purpose.

Table 6-18 Trip Frequency Model Calibration – Observed and Modeled Daily Trips by Region – Business and Commute Trip Purposes

	Business			Commute		
Region Name	CSHTS Daily Trips	Modeled Daily Trips	Percent Difference	CSHTS Daily Trips	Modeled Daily Trips	Percent Difference
SACOG	7,369	7,372	0%	11,240	11,244	0%
SANDAG	9,948	9,951	0%	25,361	25,338	0%
MTC	29,460	29,469	0%	49,886	49,894	0%
SCAG	63,489	63,512	0%	96,218	96,175	0%
San Joaquin Valley	22,120	22,127	0%	32,962	32,966	0%
Other	15,112	15,122	0%	18,407	18,414	0%
Total	**147,500**	**147,553**	**0%**	**234,074**	**234,030**	**0%**

Source: Cambridge Systematics, Inc.

Table 6-19 Trip Frequency Model Calibration – Observed and Modeled Daily Trips by Region – Recreation and Other Trip Purposes

	Recreation			Other		
Region Name	CSHTS Daily Trips	Modeled Daily Trips	Percent Difference	CSHTS Daily Trips	Modeled Daily Trips	Percent Difference
SACOG	32,343	32,333	0%	34,347	34,352	0%
SANDAG	40,788	40,769	0%	44,297	44,292	0%
MTC	107,889	107,866	0%	108,931	108,939	0%
SCAG	220,361	220,276	0%	261,724	261,735	0%
San Joaquin Valley	71,048	70,995	0%	101,500	101,479	0%
Other	31,017	31,012	0%	67,051	67,075	0%
Total	**503,446**	**503,250**	**0%**	**617,851**	**617,871**	**0%**

Source: Cambridge Systematics, Inc.

Table 6-20 shows trip frequency calibration results by party size for each trip purpose. The CSHTS and modeled percentages represent the share by purpose of alone trips versus group trips. As indicated by the table, modeled trips are generated at identical party size splits as observed CSHTS trips.

Table 6-20 Trip Frequency Calibrated Model Results by Party Size

Group Size	CSHTS	Model
Business		
Alone	61%	61%
Group	39%	39%
Commute		
Alone	76%	76%
Group	24%	24%
Recreation		
Alone	18%	18%
Group	82%	82%
Other		
Alone	25%	25%
Group	75%	75%

Source: Cambridge Systematics, Inc.

Trip Frequency Coefficient Calibration

Two calibration processes were used for trip frequency models. The first involved calibrating trips generated by region of origin. The second involved calibrating trips generated by whether those trips occurred as travel alone or group travel. The estimated trip frequency models did not include constants related to origin region of the trip. These constants were added to the models during the calibration process. Table 6-21 shows the estimated and final calibrated model coefficients for the trip frequency models by trip purpose.

Table 6-21 Impact of Calibration on Trip Frequency Model Coefficients

	Business		Commute		Recreation		Other	
	Initial	Calibrated	Initial	Calibrated	Initial	Calibrated	Initial	Calibrated
Travel Alone Constant – 1 Trip	-12.094	-11.623	-11.479	-10.796	-9.924	-8.765	-6.205	-5.257
Group Travel Constant – 1 Trip	-12.689	-12.768	-12.724	-12.276	-9.744	-9.732	-6.896	-6.537
SACOG – Alone or Group Travel		-0.345		-0.476		0.146		-0.421
MTC – Alone or Group Travel		0.096		0.102		0.268		-0.172
SCAG – Alone or Group Travel		0.194		0.333		0.214		-0.032
SANDAG – Alone or Group Travel		-0.098		0.674		0.200		-0.364
SJ Valley – Alone or Group Travel		0.132		0.200		0.558		0.184

[a] Only the coefficients listed were modified for the calibration. All other frequency choice model coefficients remain as documented in Tables 5-12 through 5-13.

Source: Cambridge Systematics, Inc.

6.6 Calibration of HSR Constant

As described in Section 5.1, since there was a substantial amount of RP data from the 2012-2013 CSHTS, the 2005 RP/SP survey, and the 2013-2014 RP/SP survey, constants for air and CVR could be determined with a reasonable degree of certainty while the auto mode served as the base. In addition, the constants for the existing modes, air and CVR, were calibrated to reproduce observed 2010 travel flow data, as described in Section 6.3. Since HSR does not exist in California today, the values of the HSR alternative-specific constants had to be asserted. Two approaches were devised to estimate the value of the HSR constants. The first is an offset approach that uses the estimated modal SP constants and calibrated air and CVR constants. The second approach was an averaging of the air and CVR constants. Both approaches were considered to be reasonable ways of estimating the constants by the RTAP. The two approaches are described in detail below after descriptions of the procedures necessary to estimate the "net" constants without the impacts of mode specific wait and terminal times.

Accounting for Mode-Specific Wait and Terminal Times in the Constants

The calibrated constants for model application include the disutilities resulting from mode-specific wait and terminal times. This approach was used since those components of disutility vary by mode rather than by alternative, route, line, or station.[24] The impacts of the wait and terminal times were also included in the constants estimated using FIML procedures rather than being explicitly included as separate components in the utility specifications. Table 6-22 shows the implicit disutilities of the mode-specific wait and terminal times included in the calibrated air and CVR constants. Table 6-22 also shows the implied contributions of the wait and terminal times for the HSR constants.

Development of Base RP and SP Constants for Asserting HSR Constants

RP and SP constants without the contributions of wait and terminal times were used to assert the HSR constants. Table 6-23 summarizes the development of the RP and SP constants. Section A of Table 6-23 shows the constants that were calibrated to reproduce observed mode shares for auto, air, and CVR when the main mode choice model was applied using 2010 input data. The constants estimated from the SP data included in the main mode/access-egress joint model estimation process are also shown in Section A.

Section B of the table shows the SP scale factors estimated from the SP data included in the main mode/access-egress joint model estimation process. In the joint RP/SP mode choice model estimation, the utility functions for SP choices included a scale value that, like the model coefficients, was estimated using FIML procedures. The scale on SP response utility functions accounted for the fact that the RP and SP choice exercises were systematically different, and thus, should not be assumed to have the same size residual errors. Since the terminal and wait times were implicitly included in the estimated SP coefficients, scaling of the SP constants and the contributions of the wait times and terminal times by the estimated SP scale factors was required prior to determining the offsets to the calibrated constants.

Section C of the table shows the scaled SP constants. The values in Section C are simply the Estimated SP Constants shown in Section A multiplied by the Scale Factors shown in Section B.

[24] This approach may be adjusted in future applications of the BPM-V3 without recalibrating the model. For example, wait times at airports changed due to increased security after the 9/11 terrorist attacks. Uncertainty in future wait and terminal times can also be considered in risk analyses through varying the magnitudes of the disutility added by those components in the overall model constants.

Section D of the table shows the contributions of the wait and terminal times included in the calibrated constants shown in Section A of the table or Section C of the table for the Estimated SP Constants. The contributions of the wait and terminal times for the various modes are based on the information summarized in Table 6-22.

Section E of the table shows the net constants without the contributions of the wait and terminal times. The information in Section E is used to estimate the HSR constants based on the SP offset method described below.

Table 6-22 Contributions of Mode-Specific Wait and Terminal Times to Constants

Modes Compared	Business	Commute	Recreation/Other
Air Constants			
Wait time (minutes)[a]	55	55	55
Terminal time (minutes)[a]	22	22	20
Coefficient of out-of-vehicle time[b]	-0.01632	-0.01632	-0.00694
Contribution of wait time to constant[b]	-0.90	-0.90	-0.38
Contribution of terminal time to constant[b]	-0.36	-0.36	-0.14
High-Speed Rail Constants			
Wait time (minutes)[c]	15	15	15
Terminal time (minutes)[c]	10	10	10
Coefficient of out-of-vehicle time[b]	-0.01632	-0.01632	-0.00694
Contribution of wait time to constant[b]	-0.24	-0.24	-0.10
Contribution of terminal time to constant[b]	-0.16	-0.16	-0.07
Conventional Rail Constants			
Wait time (minutes)[a]	15	15	15
Terminal time (minutes)[a]	3	3	3
Coefficient of out-of-vehicle time[b]	-0.01632	-0.01632	-0.00694
Contribution of wait time to constant[b]	-0.24	-0.24	-0.10
Contribution of terminal time to constant[b]	-0.05	-0.05	-0.02

[a] Air and conventional rail average wait times (from arrival at gate or platform to closing of cabin door or departure of the train) and terminal times (time from entering the airport to arrival at the gate or time from the curb to the train platform) were determined from the 2005 RP/SP survey.

[b] Wait and terminal times have been assumed to be "out-of-vehicle" travel time. In the joint main mode choice – access/egress mode choice model estimation, out-of-vehicle time was modeled as having 2.5 times the disutility of in-vehicle time for the business and commute trip purposes, and 2 times the in-vehicle time for the recreation/other trip purposes.

[c] Average wait time for HSR was asserted to be the same as for conventional rail; terminal times were asserted to be seven minutes greater than those for conventional rail to account for larger station sizes.

Source: Cambridge Systematics, Inc.

Table 6-23 Summary of 2013-2014 RP and SP CVR, Air, and HSR Constants

Table Section	Mode	Calibrated Constants[a] (Including Terminal and Wait Time Utilities) Business	Commute	Recreation/ Other	Estimated 2013-2014 SP Constants[b] (Including Terminal and Wait Time Utilities) Business	Commute	Recreation/ Other
A	Air[c]	-4.110	-6.835	-3.534	0.447	0.049	1.219
	HSR	–	–	–	2.420	2.598	4.457
	CVR	-6.564	-6.997	-4.419	0.653	1.280	-0.366
B	SP Scale Coefficient	–	–	–	0.839	0.839	0.367
					Scaled 2013-2014 SP Constants[b] (Including Terminal and Wait Time Utilities)		
C	Air	–	–	–	0.375	0.041	0.448
	HSR	–	–	–	2.030	2.178	1.637
	CVR	–	–	–	0.547	1.073	-0.134
		Utility Contribution of Wait and Terminal Times			Scaled Utility Contribution of Wait and Terminal Times		
D	Air	-1.256	-1.256	-0.520	-1.054	-1.054	-0.191
	HSR	-0.408	-0.408	-0.173	-0.342	-0.342	-0.063
	CVR	-0.294	-0.294	-0.125	-0.247	-0.247	-0.046
		Net Calibrated Constants[a] (Without Terminal and Wait Time Utilities)			Scaled 2013-2014 SP Constants[b] (Without Terminal and Wait Time Utilities)		
E	Air	-2.854	-5.579	-3.014	1.429	1.095	0.639
	HSR	–	–	–	2.372	2.520	1.700
	CVR	-6.270	-6.703	-4.294	0.794	1.320	0.088

[a] Constants shown have been calibrated to reproduce observed main mode share targets estimated using California Statewide Household Travel Survey Data.

[b] Estimated SP Constants and the SP Scale Coefficients are based on the maximum likelihood estimation of the joint main mode/access-egress mode choice model.

[c] The air constants shown are weighted averages of constants based on major-major, major-minor, minor-major, and minor-minor airport movements.

Source: Cambridge Systematics, Inc.

SP Offset Method

The SP offset method used the differences between estimated SP constants for air, CVR and HSR to determine offsets to be applied to the calibrated constants for air or CVR in order to assert HSR constants for model application. The approach results in four sets of constants, one each based on 2005 SP CVR constant, 2005 SP air constant, 2013-2014 SP CVR constant, and 2013-2014 SP air constant. Because the 2005 SP data may be too favorable to HSR in general (due to excitement about the project in that time period), the 2005 SP offsets were not used.

Even still, this method produced different results depending on whether the calibrated CVR constant or air constant was used as the basis for the offset. To address this issue, the asserted HSR constants were computed as averages of the results of the 2013-2014 SP offsets based on the CVR and air constants.

As an example, the SP constant offset for HSR from air for Business based on the information in Section E of Table 6-23 is 2.372 – 1.429, or 0.943. Applying this offset to the net, calibrated Air constant in Section E produces an estimated HSR constant of -2.854 + 0.943, or -1.911. Using a similar procedure for the HSR constant based on SP offsets from CVR produces an estimated HSR constant of -4.692. The average of the two offset estimates produces an HSR constant of -3.30.

Straight Average Method

The second approach for estimating the HSR constants was to use a straight average of the calibrated CVR and air constants. This approach has merit as well, since the HSR mode may be perceived similarly to these other common carrier modes. Using this approach produces an HSR constant estimate for Business trips of (-2.854 + -6.270)/2, or -4.56.

Chosen Method

Ultimately, it was decided that, since two reasonable estimates of the HSR constants were available, the best approach was to average the estimated constants resulting from the two. The logic here was with multiple reasonable estimates for the value of the HSR constants, the best prediction of the HSR constants was to average all of the reasonable estimates. Thus, the estimate HSR constant (without terminal and wait time components) for business trips is (-3.30 + -4.56)/2, or -3.93.

Calibrated HSR Constants

Table 6-24 summarizes the calibrated CVR and air constants as well as the asserted HSR constants based on the three different procedures. Figure 6-7 shows the relative values of the net constants without the contributions of wait and terminal times in relation to auto (the base, zero, “constant”).

The following observations can be made regarding the results for the HSR constants without the contributions of wait and terminal time utilities:

- The average of the SP offsets produced HSR constants that were less negative than the air constants for the commute and recreation/other trip purposes. The implication was that, all else being equal, travelers who responded to the RP/SP surveys preferred the use of HSR over air for those purposes.
- By design, the straight averaging method always produced HSR constants one-half way between the air and CVR constants.
- The asserted HSR constants were less negative than the CVR constants and, for the commute and recreation/other trip purposes, comparable to the air constant.

Table 6-24 Summary of CVR, Air, and HSR Constants

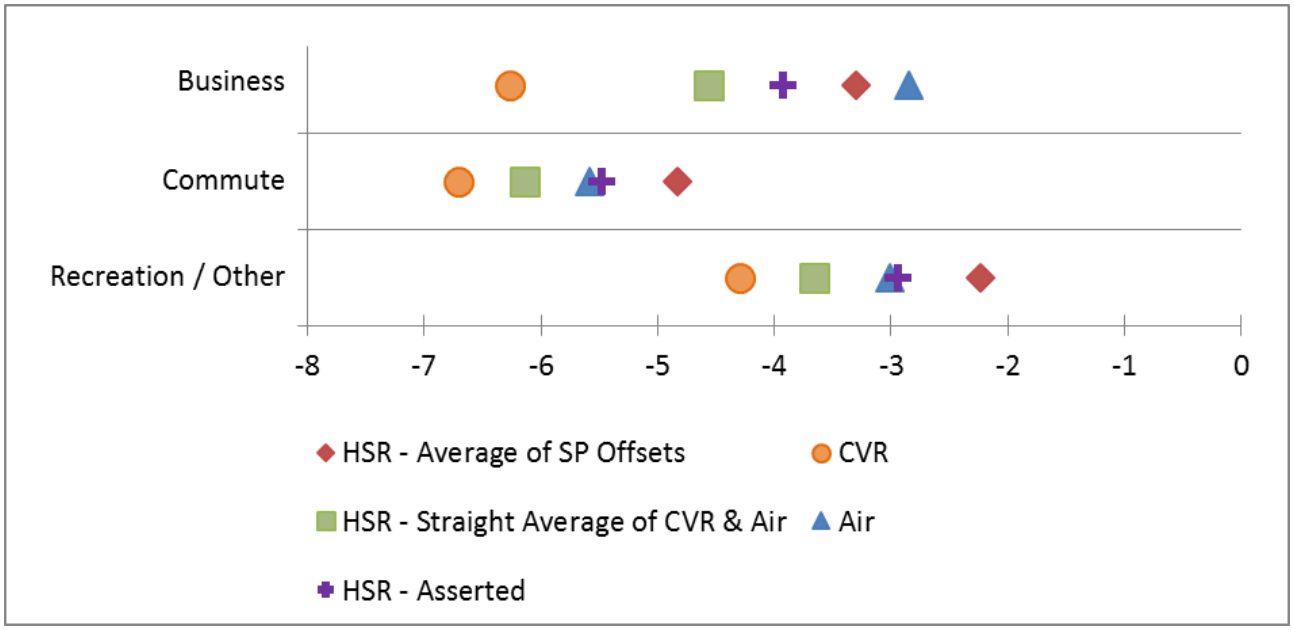
	Net Constants (Without Terminal and Wait Time Utilities)			Equivalent Minutes[b] of Net Constants (Without Terminal and Wait Time Utilities)		
Mode	**Business**	**Commute**	**Recreation/ Other**	**Business**	**Commute**	**Recreation/ Other**
Air[a]	-2.85	-5.58	-3.01	437	855	869
HSR						
Average of SP Offsets	-3.30	-4.83	-2.23	506	740	642
Straight Average Approach	-4.56	-6.14	-3.65	699	941	1,053
Asserted Values	-3.93	-5.49	-2.94	603	841	848
CVR	-6.27	-6.70	-4.29	961	1,027	1,238
	Constants (Including Terminal and Wait Time Utilities)			**Equivalent Minutes[b] of In-Vehicle Time (Including Terminal and Wait Time Utilities)**		
Air[a]	-4.11	-6.83	-3.53	630	1,047	1,019
HSR						
Average of SP Offsets	-3.71	-5.24	-2.40	568	802	692
Straight Average Approach	-4.97	-6.55	-3.83	761	1,003	1,103
Asserted Values	-4.34	-5.90	-3.12	665	903	898
CVR	-6.56	-7.00	-4.42	1,006	1,072	1,274

[a] The air constants shown are weighted averages of constants based on major-major, major-minor, minor-major, and minor-minor airport movements. See Section 6.3 for calibrated air constants and net air constants for major-major, minor-minor, major-minor, and minor-major airport travel.

[b] Equivalent minutes of travel time" is estimated by dividing a constant or a variable by the coefficient associated with travel time. Equivalent minutes of travel time provides a convenient way to measure the magnitude of "unexplained variation" of a model constant using an understandable metric and to compare values among different models. Equivalent minutes of travel time is a derived measures that can be computed for any model variable. So, for example, a $72 HSR fare (2005 dollars) for an interchange in the recreation/other mode choice model would equate to 337 equivalent minutes of travel time while the implied equivalent minutes of travel time savings for group travel in an auto for the interchange would equate to a savings of 619 equivalent minutes of travel time. Note, however, these variables are important for their contributions to the mode choice utility function, not as direct measures of travel time.

Source: Cambridge Systematics, Inc.

Figure 6-7 Values of CVR, Air, and HSR Constants Without Contribution of Wait and Terminal Time Utilities in Comparison to Auto



Source: Cambridge Systematics, Inc.

7.0 Intraregional Model Development and Calibration

7.1 Overview

Short-distance trips (less than 50 miles in length) that take place within the SCAG or MTC region are modeled with separate intraregional mode choice models. Although these trips are not a major market for HSR, they are evaluated to get a more complete picture of travel within the state that may be attracted to and served by the HSR system. Both the SCAG and MTC intraregional mode choice models are based on a refined version of the MTC BAYCAST model. The models use static trip tables adopted from the SCAG and MTC regional models.[25] In addition, the models use transportation LOS characteristics and household characteristics developed specifically for the HSR model system. This section begins by discussing the mode choice model structure. Next, the inputs that were developed for the SCAG and MTC mode choice models, including development of the skims, socioeconomic data, and trip tables, are reported. Finally, the process and results of model calibration for both SCAG and MTC are provided. During application, the models are run for all trips (both less than and greater than 50 miles in length), and then the long-distance trips (greater than or equal to 50 miles in length) are removed from the results. Thus, the model results presented in this section encompass all trip lengths.

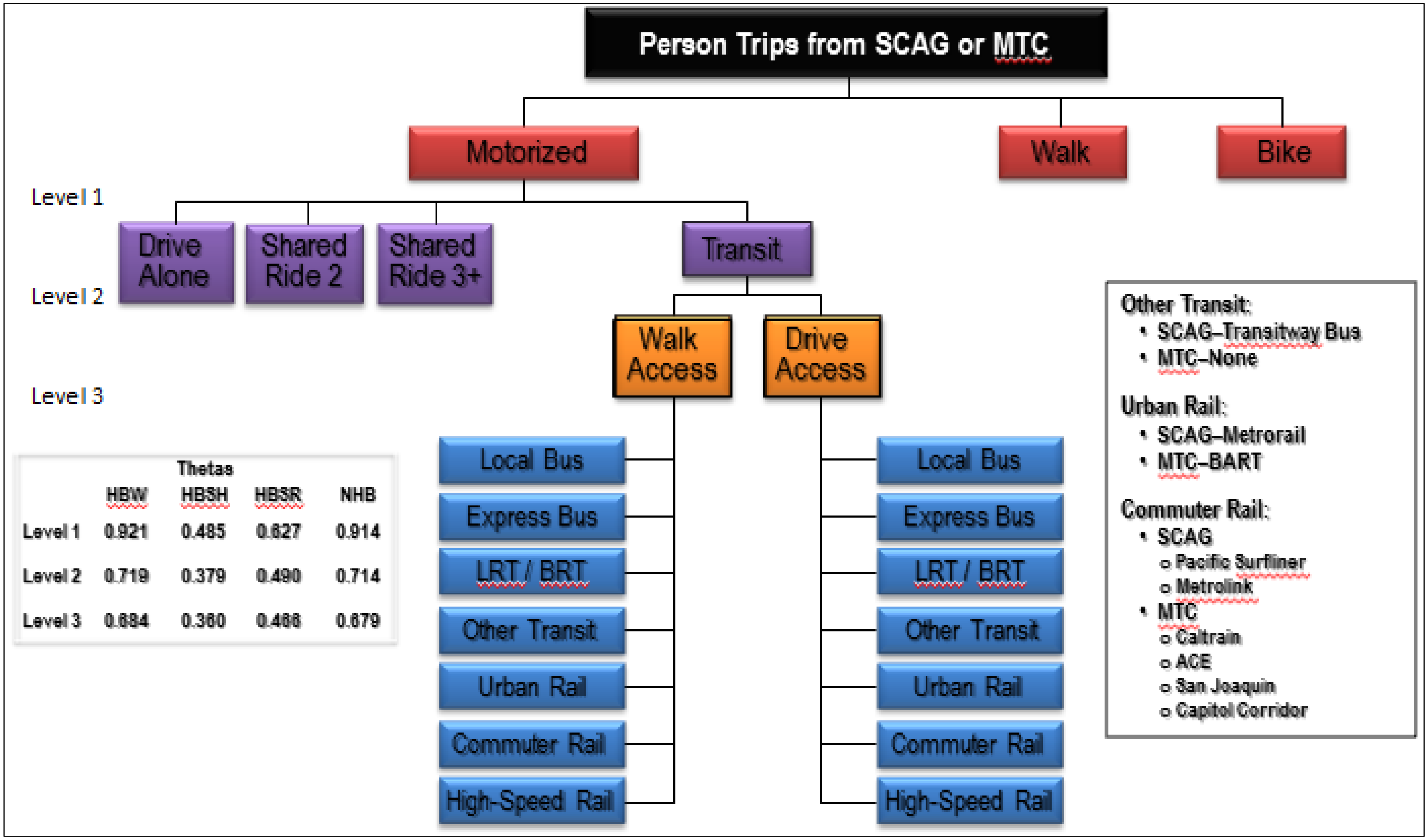
7.2 Mode Choice Model Structure

Overview

The SCAG and MTC intraregional mode choice models use a nested logit model structure, as shown in Figure 7-1, which is based on the MTC Baycast model. The models are stratified by trip purpose and market segmentation:

[25] Southern California Association of Governments, *SCAG Regional Travel Demand Model and 2008 Model Validation*, June 2012; and Metropolitan Transportation Commission, *Travel Model Development: Calibration and Validation*, May 2012.

Figure 7-1 Mode Choice Model Structure



Thetas

	HBW	HBSH	HBSR	NHB
Level 1	0.921	0.485	0.627	0.914
Level 2	0.719	0.379	0.490	0.714
Level 3	0.684	0.360	0.466	0.679

- Home-based work:
  - Zero auto households;
  - Auto < workers households;
  - Auto > worker, low-income households;
  - Auto > worker, medium-income households; and
  - Auto > worker, high-income households.
- Home-based shop.
- Home-based recreation/other.
- Nonhome-based work.
- Nonhome-based other.

The mode choice model considers the following modes:

- **Auto Modes:**
  - Drive alone,
  - Shared ride 2, and
  - Shared ride 3.
- **Nonmotorized Modes:**
  - Walk, and
  - Bike.
- **Transit Modes:**
  - Local bus;
  - Express bus;
  - Light rail, bus rapid transit (BRT), and ferry;
  - Other transit (i.e. fixed guideway, "Transitway Bus," for SCAG, none for MTC);
  - Urban rail (e.g., BART, Metrorail);
  - Commuter rail (e.g. Caltrain, ACE, Metrolink, Pacific Surfliner); and
  - HRS.

Value-of-Time Adjustment

In order to account for the market segmentations, the cost coefficients were adjusted so that the value-of-time for each income group was 37 percent of the average wage rate. The 37 percent average wage rate value comes from an average of the MTC (34 percent) and SCAG (41 percent) percentage of average wage rate found using the original coefficients and average regional income. Table 7-1 shows the average wage rate for each market segmentation in the Intra-SCAG mode choice model.

Table 7-1 Average Wage Rate for Each Market Segmentation in Intra-SCAG Mode Choice Model

SCAG Model Breakpoints (1999 Dollars)	SCAG Model Breakpoints (2005 Dollars)	Average Income (2005 Dollars)	Average Wage Rate (2005 Dollars)	Implied VOT from Adjusted Coefficients (2005 Dollars)
0 Vehicle HH	0 Vehicle HH	$30,067	$14.46	$5.38
Worker > Veh	Worker > Veh	$68,842	$33.10	$12.33
Less than $25K	Less than $30K	$15,961	$7.67	$2.86
$25K to $50K	$30K to $60K	$44,310	$21.30	$7.93
Greater than $50K	Greater than $60K	$134,868	$64.84	$24.15

Source: Cambridge Systematics, Inc.

Model Coefficients

The model coefficients and structure for the home-based work, home-based shop/other, home-based social/recreation, and nonhome Intraregional Mode Choice models are shown in Table 7-2 through Table 7-5, respectively.

Table 7-2 Home-Based Work Intraregional Mode Choice Model

Included In Utility								CHSRA Intraregional Models (All Dollar-Related Information in 2005 Dollars)				
Drive Alone	Shared Ride 2	Shared Ride 3+	Drive to Transit	Walk to Transit	Bike	Walk	Variable	0 Auto Hholds	Wrkrs < Autos	$0K to $25K	$25K to $50K	$50K or more
					✓		Constant	See Calibration Section				
					✓		LnEmpDi	0.3522	0.3522	0.3522	0.3522	0.3522
			✓	✓			LnEmpDj	0.3929	0.3929	0.3929	0.3929	0.3929
						✓	LnEmpDj	0.154	0.154	0.154	0.154	0.154
✓							Veh/HH	0.8805	0.8805	0.8805	0.8805	0.8805
	✓						Veh/HH	0.6491	0.6491	0.6491	0.6491	0.6491
		✓					Veh/HH	0.6731	0.6731	0.6731	0.6731	0.6731
			✓				Veh/HH	0.4098	0.4098	0.4098	0.4098	0.4098
	✓						Single VHH	0.6021	0.6021	0.6021	0.6021	0.6021
				✓			No VHH	0.3957	0.3957	0.3957	0.3957	0.3957
✓							Wrkr/HH	-0.1765	-0.1765	-0.1765	-0.1765	-0.1765
	✓						Multi-Wrkr/HH	-0.6688	-0.6688	-0.6688	-0.6688	-0.6688
✓							Pers/HH	-0.2229	-0.2229	-0.2229	-0.2229	-0.2229
✓							IncomeLeg1	0.0000280	0.0000280	0.0000280	0.0000280	0.0000280
	✓	✓					IncomeLeg1	0.0000241	0.0000241	0.0000241	0.0000241	0.0000241
✓	✓	✓					IVTT	} -0.02393	} -0.02393	} -0.02393	} -0.02393	} -0.02393
			✓	✓			IVTT					
					✓		IVTT	-0.03612	-0.03612	-0.03612	-0.03612	-0.03612
			✓	✓			Wait	-0.03765	-0.03765	-0.03765	-0.03765	-0.03765
✓	✓	✓					Walk (PTT + ATTj)	} -0.06694	} -0.06694	} -0.06694	} -0.06694	} -0.06694
			✓	✓			Walk					
						✓	LnWalkTime	-2.321	-2.321	-2.321	-2.321	-2.321
✓	✓	✓					Cost	} -0.00266722	} -0.0011649	} -0.00502444	} -0.00180985	} -0.00059462
			✓	✓			Cost					
					✓		Stanfordj	2.27	2.27	2.27	2.27	2.27
					✓		PaloAltoj	1.72	1.72	1.72	1.72	1.72
					✓		Berkeleyj	1.097	1.097	1.097	1.097	1.097
□							Corej	-0.781	-0.781	-0.781	-0.781	-0.781
			✓				Corej	0.825	0.825	0.825	0.825	0.825
✓	✓	✓	✓	✓			Motorized Theta	0.9208	0.9208	0.9208	0.9208	0.9208
(✓)	(✓)	(✓)	✓	✓			Transit Theta	0.7194	0.7194	0.7194	0.7194	0.7194
							Submode Theta	0.6835	0.6835	0.6835	0.6835	0.6835

Source: Cambridge Systematics, Inc.

Table 7-3 Home-Based Shop/Other Intraregional Mode Choice Model

Included In Utility								
Drive Alone	Shared Ride 2	Shared Ride 3+	Drive to Transit	Walk to Transit	Bike	Walk	Variable	CHSRA Generic Intraregional Models (All Dollar-Related Information in 2005 Dollars)
							Constant	See Calibration Section
	✓						LnPHH	0.6635
		✓					LnPHH	2.236
			✓	✓			Veh/HH	-0.3352
✓							LnIncome	0.1753
	✓						LnIncome	0.1004
✓	✓	✓	✓	✓			Time (Total)	-0.05815
					✓	✓	Time (Total)	-0.11997
✓	✓	✓	✓	✓			LnCost	-0.2037
			✓	✓			Corej	2.375
✓	✓	✓					LnAreaDeni	-0.4701
					✓		Stanfordj	5.133
					✓		Berkeleyj	3.363
					✓		PaloAltoj	2.841
✓							Zero WHH	-0.2273
			✓	✓			Zero VHH	3.291
						✓	Zero VHH	3.5795
✓	✓	✓	✓	✓			Motorized Theta	0.4847
							Transit Access Theta	-0.03612
							Submode Theta	-0.03765

Source: Cambridge Systematics, Inc.

Table 7-4 Home-Based Social/Recreational Intraregional Mode Choice Model

Included In Utility								
Drive Alone	Shared Ride 2	Shared Ride 3+	Drive to Transit	Walk to Transit	Bike	Walk	Variable	CHSRA Generic Intraregional Models (All Dollar-Related Information in 2005 Dollars)
							Constant	See Calibration Section
		✓					LnPHH	1.834
			✓	✓			Veh/HH	-0.7475
	✓						LnIncome	0.2070
					✓		Income	-0.0094
✓							IVTT	-0.02745
	✓	✓	✓	✓			IVTT	-0.02745
					✓		IVTT	-0.04377
✓							OVTT	-0.06806
	✓	✓	✓	✓			OVTT	-0.06806
						✓	OVTT	-0.10853
✓							LnCost	-1.0516
	✓	✓	✓	✓			LnCost	-1.0516
			✓	✓			Corej	0.9694
			✓	✓			LnAreaDeni	0.3217
					✓		Stanfordj	3.5226
(✓)	✓	✓	✓	✓			Motorized Theta	0.6271
							Transit Access Theta	0.4899
							Submode Theta	-0.03612

Source: Cambridge Systematics, Inc.

Table 7-5 Nonhome-Based Work and Nonhome-Based Other Intraregional Mode Choice Model

Included In Utility						Variable	CHSRA Generic Intraregional Models (All Dollar-Related Information in 2005 Dollars)
Auto Driver	Auto Passenger	Drive to Transit	Walk to Transit	Bike	Walk		
✓						Constant	See Calibration Section
✓						AreaDeni	-0.0005277
					✓	AreaDeni	0.0004566
✓	✓	✓	✓			IVTT	-0.03232
				✓		IVTT	-0.03535
		✓	✓			Wait	-0.07836
✓	✓	✓	✓			Walk	-0.07583
					✓	Walk	-0.08293
✓	✓	✓	✓			LnCost	-0.8939
		✓	✓			Motorized Theta	0.9144
						Transit Access Theta	0.7144
						Submode Theta	0.6787

Source: Cambridge Systematics, Inc.

7.3 Inputs to Mode Choice Model

Transit Skims

Transit skims for the SCAG and MTC models are developed by importing the transit skimming input files from each respective regional model system. The SCAG transit skimming process is performed using Cube, but the SCAG Regional Model is in TransCAD. Input files, such as highway network, park-and-ride stations, transit routes, transit run time, and transit fare, were converted from TransCAD into Cube format for use in the SCAG intraregional skimming process.

The MTC Regional Model uses the Cube transportation modeling software and has an identical zonal structure to the CAHSR MTC intraregional model. Therefore, it was straightforward to transfer the skim input files from the regional model to the CAHSR MTC intraregional model.

Both models have separate skims for each of three trip purpose combinations:

1. Home-based work.
2. Home-based shopping.
3. Home-based social/recreation and nonhome-based and transit mode: local bus; express bus; light rail, BRT, and ferry; other transit (i.e., Transitway Bus for SCAG, none for MTC); urban rail (e.g., BART, Metrorail); commuter rail (e.g., Caltrain, ACE, Metrolink, Pacific Surfliner); and HSR.

This results in a total of 21 separate skims for the SCAG region and 18 separate skims for the MTC region.

The transit skimming process extracts the LOS matrices of total trip costs and their components into a zone-to-zone matrix. Transit route evaluation identifies a single best path (BESTPATHONLY=TRUE) between each origin-destination (OD) pair. In addition, the "MustUseMode" factor is used to ensure that a desired mode is included on the best path for a specific skim. The transit skims use path-building weights consistent with mode choice, as shown in Table 7-6.

Table 7-6 Final Path-Building Weights in SCAG Skims

	HBW	HBSH+O	HBSR, NHB
In-vehicle time	1	1	1
Walk time	2.8	1	2.4
Wait time	1.6	1	2.4
Transfer penalty	5	5	5
Transfer factor	1	1	1
Boarding penalty	0	0	0

Source: Cambridge Systematics, Inc.

Auto and Nonmotorized Skims

Auto skims for SCAG intraregional model were imported from SCAG's Regional Model for year 2008. These skims were used in the intraregional mode choice models. Walk and bike travel times were calculated using the distances from the auto skims. A speed of 3 mph was assumed for walking and 12 mph for bicycling.

Auto skims and walk and bike skims for the MTC intraregional model were imported from the MTC Regional Model for year 2010. These skims were used as is in the intraregional mode choice models. Travel times for bicycling and walking were obtained by converting walk and bike distances from the MTC skims into time. A speed of 3 mph was assumed for walking and 12 mph for bicycling.

Socioeconomic Datasets

The formats of the socioeconomic dataset for both the SCAG and MTC intraregional model are identical and are based on required inputs for the MTC Baycast Mode Choice Model, as shown in Table 7-7. SCAG's Regional Model socioeconomic dataset for year 2008 and MTC's Regional Model socioeconomic dataset for year 2010 were converted into this format to create the intraregional model socioeconomic dataset for each region.

Table 7-7 Intraregional Socioeconomic Dataset Variables

Column Number	Column Header	Description
1	TAZ	Intraregional TAZ
2	MHHINC	Median HH income
3	TOTHH	Total Households
4	TOTPOP	Total Population
5	EMPRES	Number of Employed Residents
6	AUTOS	Total Number of HH autos
7-21		Decimal Percent of Workers (0, 1, 1+) in HHs by Market Segmentation (0 Auto HHs, Worker > Auto HH, Auto Sufficient Low-Income HHs, Auto Sufficient Middle Income HHs, Auto Sufficient High-Income HHs)
22-36		Decimal Percent of Vehicles (0, 1, 1+) in HHs by Market Segmentation (0 Auto HHs, Worker > Auto HH, Auto Sufficient Low-Income HHs, Auto Sufficient Middle Income HHs, Auto Sufficient High-Income HHs)
37-39		Decimal Percent of Workers (0, 1, 1+) in all HHs
40-42		Decimal Percent of Vehicles (0, 1, 1+) in all HHs
43-47		Total HHs in each Market Segmentation (0 Auto HHs, Worker > Auto HH, Auto Sufficient Low-Income HHs, Auto Sufficient Middle Income HHs, Auto Sufficient High-Income HHs)
48	VHH	Average Vehicles per HH
52	TEMP	Total Employment
53	TACRES	Total Acreage
54	DLPKG	Daily Parking Cost (year 2005 cents)
55	HRPKG	Hourly Parking Cost (year 2005 cents)
56	AREATYPE	Area Type

Source: Cambridge Systematics, Inc.

Trip Tables

Since the SCAG Regional Model is a traditional trip-based model and the MTC Regional Model is an activity-based model, different methodologies were used to develop the trip tables for each respective intraregional model.

SCAG Trip Table Development

The SCAG regional model includes trip tables for the following trip purposes:

- Home-based work (HBW),
- Home-based shopping (HBSH),
- Home-based social/recreational (HBSR),
- Home-based other (HBO),

- Nonhome-based work (NHBW), and
- Nonhome-based non-work (NHBNW).

These trip tables are available for peak and off-peak periods. In addition, the SCAG Regional Model also includes home-based school (HBSC) trips and home-based serve passenger (HBSP) trips, but they are assumed to not use HSR and are not included in the mode choice model. Each of the home-based trip tables is segmented by household type:

- Zero-vehicle households;
- Auto deficient households (workers > vehicles, vehicles > 0);
- Auto sufficient households, low income (less than $25,000);
- Auto sufficient households, medium income ($25,000 to $50,000); and
- Auto sufficient households, high income (more than $50,000).

The above trip purposes and household segmentations are retained for the SCAG intraregional model. Therefore, the year 2008 SCAG Regional Model Trip Tables were used directly in the SCAG Intraregional Model without further processing.

MTC Trip Table Development

The year 2010 trip tables were developed from the MTC activity-based model (ABM) trip roster data.[26] The total number of households, persons, and trips is shown in Table 7-8. Individual trips from the roster data were used "as is." Joint trips were converted from the joint trip data by enumerating one trip per participant for each joint trip. For example, one joint trip with three participants generates three individual trips in the conversion process.

Table 7-8 Total Households, Persons, and Trips in MTC Trip Roster Data for Year 2010

Households	Persons	Trips		
		Individual	Joint	Total
2,732,722	7,053,334	22,872,096	1,424,946	24,297,042

Source: Cambridge Systematics, Inc.

Market segments were identified as shown in Table 7-9. This segmentation is identical to the SCAG intraregional model, and distinguishes among households based on vehicle ownership, auto deficiency (based on whether the number of workers exceeds the number of autos), and household income level. Income was converted to year 2010 dollars from year 2000 dollars before segmenting the population.

[26] Trip roster data from an ABM mimics household and person travel data from a household travel survey. The roster information can easily be processed to create trip matrices.

Table 7-10 lists each activity in the MTC trip roster data and shows the corresponding CAHSR intraregional model purpose.

The trip-end activities were used to assign each trip to a specific trip purpose, as shown in Table 7-11. If either end involves escorting, then the trip is considered a Serve Passenger trip. Otherwise, if one trip end is at home, then the purpose is Home-Based; if neither end is at home, then the trip is nonhome-based.

Table 7-9 Total Households by Intraregional Market Segmentation for Year 2010

Market Segmentation	Households	Percent Households
All households with zero autos	255,243	9.3%
All households with autos ≥1 and workers > autos	171,776	6.3%
All households with autos ≥1 and autos ≥ workers		
Income (2010) < $25,000	373,956	13.7%
$25,000 ≤ Income (2010) < $50,000	399,630	14.6%
Income (2010) ≥ $50,000	1,532,117	56.1%

Source: Cambridge Systematics, Inc.

Table 7-10 Correspondence between Trip Purposes in MTC ABM Model and Intraregional Model

MTC Model	Intraregional Model
Home	Home
Work	Work
atwork	Work
work	Work
eatout	Shop/Other
othdiscr	Shop/Other
othmaint	Shop/Other
shopping	Shop/Other
social	Social/Recreation
school	School
escort	Serve Passenger
university	University

Source: Cambridge Systematics, Inc.

Table 7-11 Determination of Home-Based versus Non-Home-Based Trip Purposes

One end at Home, the other at…		If neither end is at Home…	
...Work	HB Work	…& one end is at Work	NHBW
...Shop/Other	HB Shop/Other	…& neither end is at Work:	NHBO
...Soc/Rec	HB Soc/Rec		
...School	HB School		
...Univ	HB University		
If either end involves escorting (serve passenger):			
	Serve		

Source: Cambridge Systematics, Inc.

Table 7-12 shows the resulting number of trips by purpose. Table 7-13 shows additional detail on HBW trips by market segment and time of day.

Table 7-12 Total Trips by MTC Intraregional Trip Purpose for Year 2010

Trip Purpose	Frequency	Percent	Cumulative Percent
Model Purposes			
HBW	4,026,249	16.6	16.6
HBSH & HBO	8,163,632	33.6	50.2
HBSR	825,608	3.4	53.6
NHBW	2,646,460	10.9	64.5
NHBNW	2,476,458	10.2	74.7
Nonmodeled Purposes			
HBSC	1,749,077	7.2	81.9
HBSC	4,005,268	16.5	98.3
HB University	404,290	1.7	100.0
Total	**23,892,752**	**100.0**	

Source: Cambridge Systematics, Inc.

Table 7-13 HBW Trips by Market Segment and Time of Day for Year 2010

Market Segment	Peak	Off-Peak	Total
All households with zero autos	139,105	46,839	185,944
All households with autos ≥1 and workers > autos	446,206	173,267	619,473
All households with autos ≥1 and autos ≥workers			
Income (2010) < $25,000	112,526	49,129	161,655
$25,000 ≤ Income (2010) < $50,000	282,755	113,618	396,373
Income (2010) ≥ $50,000	1,939,807	722,997	2,662,804
Total	**2,920,399**	**1,105,850**	**4,026,249**

Source: Cambridge Systematics, Inc.

The raw trip roster data are in OD format. The data were converted into production-attraction format as follows:

- If one of the trip ends was at home, then the home end was considered the production end;
- Otherwise, if one trip end was at work, then the work end was considered the production end; and
- Otherwise, the origin was considered to be the production end.

7.4 Mode Choice Calibration

Calibration targets for the intraregional SCAG and MTC models were set to the mode choice output from the year 2008 SCAG and year 2010 MTC Regional Models.

A concern in model calibration is of overfitting the model and making it insensitive to network changes in forecast years. Although there are no formally adopted rules or standards to guide regional mode choice model calibration, informal guidelines have emerged from best practices over the years. The following guidelines were developed for use in this model calibration based on the informal guidelines:

- The absolute value of ASC should generally not exceed 5.0.
- In-vehicle time is weighted equally across all modes, except in cases where the transit-mode operates on a fixed guideway, has well defined and visible service, and/or station and car amenities.
- Transit mode-specific constants are constrained across market segments.
- Transit access constants are calibrated to represent the difference in utility generically across all transit modes. Transit mode-specific constants across access modes are constrained within each trip purpose and time period (i.e., the transit mode constants are the same within the drive-transit and the walk-transit nests).
- Constants for fixed guideway transit modes (BRT, LRT, urban rail, and CVR) are constrained to be greater than or equal to the Local Bus constant.

During calibration, it became clear that changes needed to be made to the input trip tables and target mode shares in order to successfully match the calibration targets and observed transit boarding data. These adjustments are discussed first, followed by details of the calibration process and results.

Adjustments to Trip Table Inputs

The trip tables and target mode shares from the existing regional models for MTC and SCAG were used as starting points for the HSR intraregional models, as described in Section 7.3. Initial calibration work concluded that, in general, the numbers of intercounty trips were too low and, in particular, within the SCAG region, there were too few intercounty trips to downtown Los Angeles. To resolve these issues, the 2012-2013 CSHTS data weighted to 2010 households, described in Section 2.2, were used to factor the input trip table at the county level.

Table 7-14 and Table 7-15 compare the county-level trips across all purposes from the regional model to the CSHTS for SCAG and MTC. Note that downtown Los Angeles, where the area type is urban CBD, is identified as a separate "county." There are substantial differences in the trip rates by county for both regions. In the SCAG region, the model trip rates are consistently higher than the CSHTS trip rates, while in the MTC region, the model trip rates are lower than the CSHTS rates, except in Napa County. The regional models predict similar aggregate trips rates per capita, but the CSHTS trip rates show that the MTC region has a significantly higher trip rate per capita than the SCAG region.

Table 7-14 SCAG Regional Model to CSHTS Trip Rate by County Comparison

	SCAG Regional Model			CSHTS Regional Model			Percentage Difference in SCAG vs. CSHTS Trips per Capita
County	2010 Total Population	Production-Based Trips	Trips per Capita	2010 Total Population	Production-Based Trips	Trips per Capita	
Imperial	170,003	427,602	2.515	174,529	412,318	2.362	6.5%
Los Angeles	9,526,514	32,596,941	3.422	9,573,476	28,098,160	2.935	16.6%
Los Angeles – Downtown	244,737	968,141	3.956	241,155	880,744	3.652	8.3%
Orange	2,995,637	11,297,302	3.771	3,009,932	8,971,303	2.981	26.5%
Riverside	2,128,305	6,623,134	3.112	2,189,710	5,956,955	2.720	14.4%
San Bernardino	2,009,652	6,470,560	3.220	2,035,295	5,086,790	2.499	28.8%
Ventura	813,037	2,836,387	3.489	823,340	2,407,939	2.925	19.3%
Total	**17,887,885**	**61,220,067**	**3.422**	**18,047,437**	**51,814,209**	**2.871**	**19.2%**

Source: Cambridge Systematics, Inc.

Table 7-15 MTC Regional Model to CSHTS Trip Rate by County Comparison

	MTC Regional Model			CSHTS Regional Model			Percentage Difference in MTC vs. CSHTS Trips per Capita
County	2010 Total Population	Production-Based Trips	Trips per Capita	2010 Total Population	Production-Based Trips	Trips per Capita	
Alameda	1,500,589	4,721,664	3.147	1,509,263	5,937,052	3.934	-20.0%
Contra Costa	1,026,444	2,890,908	2.816	1,049,445	3,752,415	3.576	-21.2%
Marin	252,526	778,503	3.083	252,459	985,012	3.902	-21.0%
Napa	136,026	404,308	2.972	136,473	367,704	2.694	10.3%
San Francisco	797,674	3,849,035	4.825	805,208	3,976,590	4.939	-2.3%
San Mateo	707,400	2,583,982	3.653	718,306	2,628,389	3.659	-0.2%
Santa Clara	1,750,925	6,482,318	3.702	1,781,826	6,767,198	3.798	-2.5%
Solano	401,662	1,164,584	2.899	413,611	1,242,115	3.003	-3.5%
Sonoma	480,088	1,421,751	2.961	483,866	1,623,960	3.356	-11.8%
Total	**7,053,334**	**24,297,053**	**3.445**	**7,150,457**	**27,280,435**	**3.815**	**-9.7%**

Source: Cambridge Systematics, Inc.

The CSHTS trip rates are expected to be more accurate than the regional model rates at the county level, so intercounty factors have been calculated from the ratio of CSHTS data to regional model county-to-county trips. This approach is used to provide a consistency across both regions since their modeling procedures are inherently different and because, as noted above, initial calibration results suggested that the long-distance intercounty trips estimated from the existing regional models were too low.

The factors are constrained to be between 0.25 and 4.00. A factor greater than 1 increases the number of modeled trips on the county to county interchange to better match the CSHTS data; less than 1 decreases the number of modeled trips. The factor matrices are symmetrical, so only the top one-half is shown in Table 7-16 and Table 7-17. The net effect of the factors is that total MTC trips are increased by 12 percent and total SCAG trips are decreased by 15 percent relative to the modeled regional trips in the unfactored trip tables.

Table 7-16 SCAG County-to-County Input Trip Table Factors

County-to-County Factors	Imperial	Los Angeles	Los Angeles – Downtown	Orange	Riverside	San Bernardino	Ventura
Imperial	0.87	4.00	0.25	4.00	3.65	4.00	0.25
Los Angeles		0.90	0.72	0.43	0.48	0.62	0.50
Los Angeles –Downtown			1.33	0.42	1.03	1.25	0.87
Orange				0.86	0.53	0.41	0.54
Riverside					0.93	0.50	0.35
San Bernardino						0.83	0.31
Ventura							0.88

Source: Cambridge Systematics, Inc.

Table 7-17 MTC County-to-County Input Trip Table Factors

County-to-County Factors	Alameda	Contra Costa	Marin	Napa	San Francisco	San Mateo	Santa Clara	Solano	Sonoma
Alameda	1.31	0.86	0.72	1.53	0.81	0.51	0.52	1.13	1.66
Contra Costa		1.21	0.80	0.46	0.69	0.97	0.76	0.66	0.92
Marin			1.26	0.52	0.75	0.35	1.20	0.74	1.01
Napa				1.00	0.47	1.25	3.75	0.52	0.62
San Francisco					1.48	0.56	2.59	0.75	0.56
San Mateo						1.19	0.81	2.08	1.14
Santa Clara							1.10	2.67	4.00
Solano								0.94	1.10
Sonoma									1.08

Source: Cambridge Systematics, Inc.

Adjustments to Target Shares

The commuter rail and urban rail regional model mode share results were reviewed against boarding data for validity. The MTC model calibration and validation report[27] showed that the modeled commuter rail boardings for the MTC regional model were only about 17,300, or about 50 percent lower than the observed boardings. The MTC regional model mode choice results were revised to increase the total number of intraregional CVR trips to 36,800, which improved the modeled boardings. The revised CVR trip target was developed from the process, as shown in Table 7-18.

[27] MTC with Parsons Brinkerhoff, *Travel Model Development: Calibration and Validation, Technical Report – Draft*, May 17, 2012, Table 72.

Table 7-18 MTC Revised CVR Target Trips

	Estimated Intraregional Trips (Based on January 2010 Boarding Count Data)
Caltrain	36,800
ACE	1,000
Amtrak	1,200
CVR-CVR transfers (remove double-counting)	-200
Remove School & Serve Passenger Purpose Trips	-2,000
Revised CVR Target Trips	**36,800**

Source: Cambridge Systematics, Inc.

Adjustments to Skimming Process

Transit Path Search

Initial calibration revealed that CVR and Urban Rail transit modes have a time-advantage over Local Bus because the ASCs for CVR and URBR are positive relative to Local Bus. However, insufficient paths were found for CVR and URBR because the default path search constraints were too restrictive. The calibrated model and expectations are that the CVR and URBR paths will be preferred to Local Bus, even if the path time is longer, because of increased vehicle and station amenities, service reliability, and service visibility. The path search constraints (in Cube, these are defined as a "Spread Factor") were modified to increase the number of available paths for CVR and Urban Rail.

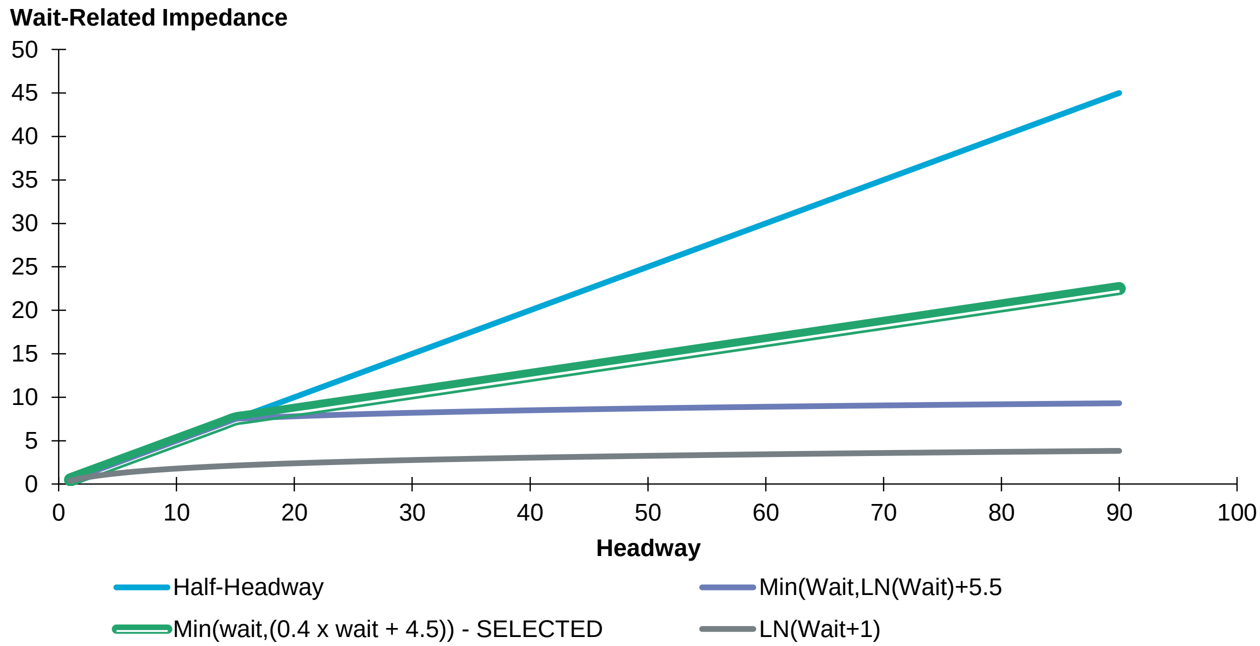
Drive-Access Time Weighting

The MTC mode choice model structure weights the drive-access time equal to in-vehicle time. While this is not an unreasonable assumption on its own, skimming with equal drive-access and in-vehicle time weights can lead to unreasonable drive-transit paths. If there is a high parking cost in the destination zone, for example, the shortest generalized cost path with equal drive-access and in-vehicle time weights may result in a long drive-access time with a very short transit trip at the end. Initial calibration found that many of the drive-transit paths had very short transit in-vehicle times. To reduce the number of imbalanced paths, a weight was added to drive-access links in the skim procedure. The mode choice utility functions were not changed.

Transit Initial Wait Time Adjustment

The regional models estimate initial transit wait time as one-half the headway, which assumes random passenger arrivals and regular service. This is appropriate for high-frequency service. Commuter rail service cannot be considered high frequency, and it is not reasonable to assume that passengers arrive randomly for a commuter train with a well-published schedule and vehicle arrival notifications. However, it is important to distinguish between high- and low-frequency service, and the alternative utility should decrease as headway increases. The initial wait time curves considered are shown in Figure 7-2. The selected curve is in yellow.

Figure 7-2 Initial Wait Time Curve Comparison



Source: Cambridge Systematics, Inc.

The selected initial wait time curve $\text{MIN}(\frac{h}{2}, 0.4 \times \frac{h}{2} + 4.5)$ was chosen because it assumes random arrivals for headways up to 15 minutes. For headways greater than 15 minutes, the wait time impedance increases more slowly than one-half the headway, but faster than the log formulations. The mode share for Commuter Rail increased with the revised initial wait time impedance function.

Transit In-Vehicle Time Discounts

In accordance with the FTA guidelines, the in-vehicle time of fixed guideway transit service with station and vehicle amenities and visible, reliable service may be discounted by as much as 25 percent. The commuter rail service in both MTC and SCAG regions meets most of these criteria. Accordingly, a 10-percent discount was applied to the Commuter Rail in-vehicle time in both the skimming procedure and the mode choice model. The in-vehicle time discount increased commuter rail mode share and increased the proportion of commuter rail time in the transit path.

Shadow Pricing at Key Park-and-Ride Facilities

The mode choice model does not support a fixed capacity to limit the number of trips using a particular park-and-ride facility. Instead, a shadow price was added to the parking cost to deter use of the facility when it was near the real capacity. The shadow price was set through an iterative process between mode choice and assignment.

Process for Calibrating the ASCs

The general procedure to calibrate the ASCs is as follows:

- Calculate mode shares using original ASCs.
- Compare the calculated shares with the target shares:
  - If the calculated shares exceed the target shares: decrease the associated ASC; and
  - Otherwise, increase the associated ASC.
- Recalculate mode shares using the updated ASCs.

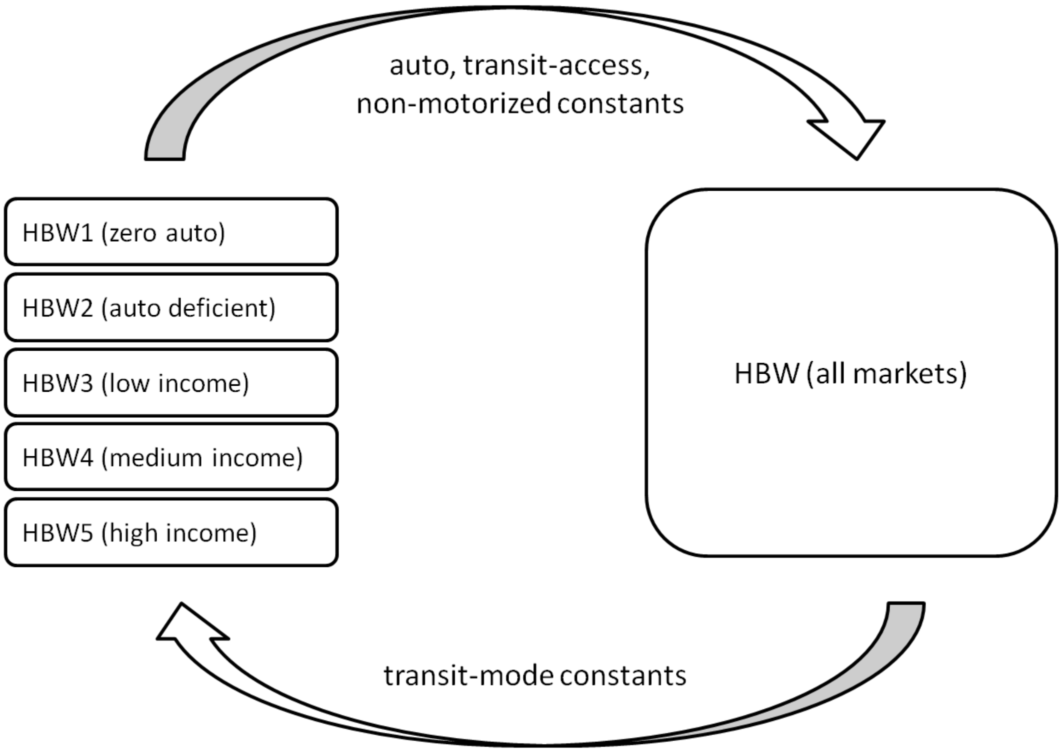
The generally accepted practice is to adjust the constant by adding the log of the ratio of target share to calculated share.[28] Let β_j^0 be the ASC, S_j the target share, and $\widehat{S_j^0}$ the estimated share for alternative *j* in the initial iteration. The ASC for the next iteration (β_j^1) is calculated as follows:

$$\beta_j^1 = \beta_j^0 + \ln\left(S_j / \widehat{S_j^0}\right)$$

To avoid overfitting the HBW market segments, the transit-mode ASCs are calibrated across all market segments while the transit access, auto occupancy, and nonmotorized mode constants are calibrated for each market segment. To completely calibrate the model, an iterative process is necessary where the transit-mode constants are fixed and the transit access constants are calibrated. Then, the transit access constants are fixed and the transit-mode constants are calibrated. Figure 7-3 shows the calibration process for HBW market segments. Each block represents a calibration phase. Note that only the transit-mode constants are calibrated in the HBW *(*all markets*)* block; and only the auto, transit-access, and nonmotorized constants are calibrated in each of the individual market segment blocks on the left.

[28] Train, Kenneth, 2009, *Discrete Choice Methods with Simulation*, Cambridge University Press, page 33.

Figure 7-3 Home-Based Work Calibration Process



For the home-based nonwork and nonhome-based trip purposes, auto, transit-access, nonmotorized, and transit-mode constants are calibrated independently across the trip purposes.

Intra-SCAG Calibration Results

Table 7-19 and Table 7-20 show the mode share targets and model results, respectively for the SCAG region. The transit-mode shares shown are the share of transit trips across both access modes. Model results (Table 7-20) are highlighted in yellow, where the model is more than one percentage point different from the target share. The model could not be calibrated to fit the target BRT share for HBW off-peak. This was due to the BRT constant being constrained to be less than or equal to the CVR constant.

Table 7-21 shows the calibrated ASCs at the motorized nest level. Constants with an absolute magnitude greater than 5 are highlighted in yellow.[29] Several HBW medium- and high-income drive-transit alternative constants are less than -5, but their absolute magnitudes are less than 7.

Table 7-22 shows the effective constants for each transit-mode by access mode at the motorized nest level. Effective constants are the composite constants that result from applying calibrated constants shown in Table 7-21 for modes and submodes at their various nesting levels. In Table 7-23, the constants are converted into IVTT equivalent units. For comparison, Local Bus is normalized to zero for each access-mode. Auto and nonmotorized modes are compared to the Local Bus Walk alternative. Drive to transit alternatives are compared to the Local Bus Drive alternative.

[29] Limiting mode specific ASCs to the range -5 to 5 is a good rule of thumb for mode choice models for urban areas.

Table 7-19 Intra-SCAG Mode Choice Targets

	Mode Share							Share of Transit Trips					
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk	Bike	Local Bus	Express Bus	Transit-way Bus	BRT/ LRT	Urban Rail	CVR
Peak													
HBW1 – 0 Auto	2.84%	12.98%	8.55%	55.30%	10.10%	6.60%	3.63%	66.78%	4.21%	3.82%	0.88%	17.13%	7.17%
HBW2 – Autos < Workers	35.62%	18.57%	9.90%	26.22%	1.95%	6.89%	0.84%						
HBW3 – Low Income	60.68%	7.22%	3.85%	22.73%	2.04%	3.07%	0.39%						
HBW4 – Middle Income	83.65%	6.79%	3.74%	2.51%	0.43%	2.59%	0.29%						
HBW5 – High Income	92.49%	4.09%	1.04%	0.42%	0.58%	1.25%	0.13%						
HBSH+O	38.06%	20.93%	26.97%	2.60%	0.18%	10.40 %	0.87%	68.42%	3.09%	4.23%	0.85%	21.22%	2.19%
HBSR	27.78%	32.87%	27.86%	1.43%	0.18%	8.99%	0.88%	67.27%	2.76%	4.87%	1.61%	21.19%	2.30%
NHB-W	84.23%		7.69%	2.01%	0.32%	2.82%	2.94%	69.30%	3.33%	3.14%	0.71%	21.71%	1.81%
NHB-O	56.68%		35.57%	0.49%	0.03%	6.76%	0.48%	73.68%	2.41%	3.46%	0.41%	19.10%	0.94%
Off-Peak													
HBW1 – 0 Auto	3.25%	9.13%	9.14%	59.02%	6.37%	9.38%	3.70%	71.18%	2.37%	3.13%	3.31%	19.42%	0.59%
HBW2 – Autos < Workers	38.75%	19.47%	10.33%	20.10%	2.17%	8.22%	0.95%						
HBW3 – Low Income	63.85%	7.26%	3.68%	18.47%	2.51%	3.80%	0.43%						
HBW4 – Middle Income	84.09%	6.61%	3.56%	2.24%	0.33%	2.84%	0.31%						
HBW5 – High Income	92.67%	3.92%	0.98%	0.46%	0.50%	1.34%	0.14%						
HBSH+O	41.83%	20.19%	25.20%	1.95%	0.14%	9.64%	1.05%	82.28%	5.32%	2.57%	0.64%	8.69%	0.50%
HBSR	27.64%	32.85%	27.66%	0.81%	0.13%	10.00 %	0.91%	80.70%	2.89%	4.14%	1.64%	10.08%	0.55%
NHB-W	82.55%		8.35%	1.53%	0.22%	6.26%	1.09%	85.27%	4.24%	3.17%	1.14%	5.68%	0.50%
NHB-O	66.77%		25.97%	0.34%	0.04%	6.37%	0.51%	89.21%	2.40%	1.64%	0.96%	5.46%	0.32%

Source: Cambridge Systematics, Inc.

Table 7-20 SCAG Mode Choice Results

	Mode Share							Share of Transit Trips					
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk	Bike	Local Bus	Express Bus	Transit-way Bus	BRT/ LRT	Urban Rail	CVR
Peak													
HBW1 – 0 Auto	6.39%	12.89%	8.49%	54.69%	10.06%	3.86%	3.61%	67.11%	4.18%	3.80%	0.88%	16.99%	7.03%
HBW2 – Autos < Workers	38.87%	18.53%	9.88%	26.19%	1.97%	3.72%	0.84%						
HBW3 – Low Income	61.19%	7.19%	3.83%	22.34%	2.02%	3.05%	0.39%						
HBW4 – Middle Income	84.76%	6.79%	3.74%	2.52%	0.43%	1.47%	0.29%						
HBW5 – High Income	92.47%	4.09%	1.04%	0.42%	0.60%	1.25%	0.13%						
HBSH+O	37.26%	20.92%	26.96%	2.58%	0.18%	10.39%	1.70%	68.46%	3.09%	4.23%	0.85%	21.19%	2.18%
HBSR	27.76%	32.88%	27.87%	1.44%	0.18%	8.99%	0.88%	67.39%	2.75%	4.86%	1.60%	21.11%	2.29%
NHB-W	84.22%	0.00%	7.69%	2.01%	0.33%	2.82%	2.94%	69.41%	3.32%	3.14%	0.70%	21.63%	1.80%
NHB-O	56.68%	0.00%	35.57%	0.49%	0.03%	6.76%	0.48%	73.77%	2.41%	3.45%	0.41%	19.02%	0.93%
Off-Peak													
HBW1 – 0 Auto	7.90%	9.12%	9.14%	58.93%	6.38%	4.84%	3.70%	73.56%	2.36%	3.12%	1.03%	19.34%	0.59%
HBW2 – Autos < Workers	42.87%	19.41%	10.30%	19.99%	2.17%	4.32%	0.94%						
HBW3 – Low Income	64.27%	7.23%	3.66%	18.17%	2.47%	3.77%	0.43%						
HBW4 – Middle Income	84.10%	6.61%	3.56%	2.24%	0.34%	2.84%	0.31%						
HBW5 – High Income	92.66%	3.92%	0.98%	0.46%	0.50%	1.34%	0.14%						
HBSH+O	41.10%	20.19%	25.19%	1.93%	0.14%	9.64%	1.82%	82.29%	5.31%	2.57%	0.64%	8.68%	0.50%
HBSR	27.63%	32.85%	27.66%	0.81%	0.13%	10.01%	0.91%	80.72%	2.88%	4.14%	1.63%	10.08%	0.55%
NHB-W	82.57%	0.00%	8.35%	1.52%	0.22%	6.25%	1.09%	85.22%	4.27%	3.18%	1.14%	5.70%	0.51%
NHB-O	66.77%	0.00%	25.97%	0.34%	0.04%	6.37%	0.51%	89.21%	2.40%	1.63%	0.96%	5.47%	0.33%

Source: Cambridge Systematics, Inc.

Table 7-21 SCAG Alternative Constants at the Motorized Nest Level

	Auto			Transit-Access		Nonmotorized		Transit-Mode					
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk	Bike	Local Bus	Express Bus	Transit-way Bus	BRT/ LRT	Urban Rail	CVR
Peak													
HBW1 – 0 Auto	0.00	0.07	-0.58	4.27	1.92	7.00	0.23	0.00	-0.14	-0.30	0.36	0.35	1.34
HBW2 – Autos < Workers	0.00	-1.07	-2.15	1.48	-2.51	7.00	-2.80	0.00	-0.14	-0.30	0.36	0.35	1.34
HBW3 – Low Income	0.00	-3.64	-4.45	0.46	-3.04	6.11	-4.83	0.00	-0.14	-0.30	0.36	0.35	1.34
HBW4 – Middle Income	0.00	-3.45	-4.28	-2.59	-6.13	5.00	-5.02	0.00	-0.14	-0.30	0.36	0.35	1.34
HBW5 – High Income	0.00	-3.49	-5.29	-3.98	-6.35	5.42	-5.41	0.00	-0.14	-0.30	0.36	0.35	1.34
HBSH+O	0.00	-1.28	-2.56	4.30	1.55	-0.53	-7.00	0.00	0.05	0.03	0.32	0.24	0.44
HBSR	0.00	-0.33	-0.96	1.10	-2.33	2.16	-4.67	0.00	0.10	0.18	0.48	0.46	0.71
NHB-W	0.00	0.00	-2.58	0.18	-2.88	-1.99	-4.00	0.00	-0.08	-0.17	0.32	0.71	0.81
NHB-O	0.00	0.00	-0.59	-2.59	-6.00	-0.57	-5.58	0.00	0.45	-0.08	0.84	0.09	1.04
Off-Peak													
HBW1 – 0 Auto	0.00	-0.47	-0.68	-3.70	-5.84	7.00	0.05	0.00	0.00	-0.35	0.76	0.44	0.76
HBW2 – Autos < Workers	0.00	-1.09	-2.17	-1.09	-2.84	7.00	-2.83	0.00	0.00	-0.35	0.76	0.44	0.76
HBW3 – Low Income	0.00	-3.61	-4.39	-0.18	-2.24	6.27	-4.80	0.00	0.00	-0.35	0.76	0.44	0.76
HBW4 – Middle Income	0.00	-3.38	-4.19	-1.60	-2.78	6.04	-4.94	0.00	0.00	-0.35	0.76	0.44	0.76
HBW5 – High Income	0.00	-3.45	-5.26	-0.55	-2.23	5.39	-5.37	0.00	0.00	-0.35	0.76	0.44	0.76
HBSH+O	0.00	-1.38	-2.70	-2.02	-4.10	-0.90	-7.00	0.00	0.21	-0.04	0.34	0.10	0.44
HBSR	0.00	-0.32	-0.95	-2.92	-5.87	2.42	-4.55	0.00	0.32	0.15	0.66	0.23	0.67
NHB-W	0.00	0.00	-2.47	-2.13	-3.97	-1.19	-5.08	0.00	-0.13	-0.01	0.12	0.90	0.97
NHB-O	0.00	0.00	-1.09	-3.25	-5.23	-0.93	-5.73	0.00	0.19	-0.32	0.70	0.23	1.02

Source: Cambridge Systematics, Inc.

Table 7-22 SCAG Alternative Constants – Effective Constants at the Motorized Nest Level

	Auto			Local Bus		Express Bus		Transitway Bus		BRT/LRT		Urban Rail		Commuter Rail		Nonmotorized	
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk	Bicycle
Peak																	
HBW1 – 0 Auto	0.00	0.07	-0.58	4.27	1.92	4.13	1.78	3.97	1.62	4.63	2.28	4.62	2.27	5.60	3.25	7.00	0.23
HBW2 – Autos < Workers	0.00	-1.07	-2.15	1.48	-2.51	1.34	-2.65	1.18	-2.81	1.84	-2.15	1.83	-2.16	2.81	-1.18	7.00	-2.80
HBW3 – Low Income	0.00	-3.64	-4.45	0.46	-3.04	0.32	-3.17	0.15	-3.34	0.82	-2.67	0.81	-2.68	1.79	-1.70	6.11	-4.83
HBW4 – Middle Income	0.00	-3.45	-4.28	-2.59	-6.13	-2.72	-6.26	-2.89	-6.43	-2.22	-5.76	-2.23	-5.77	-1.25	-4.79	5.00	-5.02
HBW5 – High Income	0.00	-3.49	-5.29	-3.98	-6.35	-4.12	-6.48	-4.28	-6.65	-3.62	-5.98	-3.63	-5.99	-2.65	-5.01	5.42	-5.41
HBSH+O	0.00	-1.28	-2.56	-1.09	-2.84	-1.04	-2.78	-1.06	-2.80	-0.77	-2.52	-0.86	-2.60	-0.65	-2.39	-0.53	-7.00
HBSR	0.00	-0.33	-0.96	-0.18	-2.24	-0.08	-2.14	0.00	-2.06	0.30	-1.76	0.28	-1.79	0.53	-1.53	2.16	-4.67
NHB-W	0.00		-2.58	-2.02	-4.10	-2.10	-4.19	-2.19	-4.27	-1.70	-3.79	-1.31	-3.40	-1.21	-3.29	-1.99	-4.00
NHB-O	0.00		-0.59	-2.92	-5.87	-3.05	-6.00	-2.92	-5.88	-2.79	-5.75	-2.02	-4.97	-1.94	-4.90	-0.57	-5.58
Off-Peak																	
HBW1 – 0 Auto	0.00	-0.47	-0.68	4.30	1.55	4.30	1.55	3.94	1.19	5.06	2.31	4.74	1.99	5.06	2.31	7.00	0.05
HBW2 – Autos < Workers	0.00	-1.09	-2.17	1.10	-2.33	1.10	-2.33	0.74	-2.68	1.86	-1.57	1.54	-1.89	1.86	-1.57	7.00	-2.83
HBW3 – Low Income	0.00	-3.61	-4.39	0.18	-2.88	0.18	-2.88	-0.18	-3.24	0.94	-2.12	0.62	-2.44	0.94	-2.12	6.27	-4.80
HBW4 – Middle Income	0.00	-3.38	-4.19	-2.59	-6.00	-2.59	-5.99	-2.95	-6.35	-1.83	-5.23	-2.15	-5.55	-1.83	-5.23	6.04	-4.94
HBW5 – High Income	0.00	-3.45	-5.26	-3.70	-5.84	-3.70	-5.84	-4.05	-6.20	-2.94	-5.08	-3.26	-5.40	-2.94	-5.08	5.39	-5.37
HBSH+O	0.00	-1.38	-2.70	-1.60	-2.78	-1.39	-2.58	-1.64	-2.82	-1.26	-2.44	-1.50	-2.68	-1.16	-2.35	-0.90	-7.00
HBSR	0.00	-0.32	-0.95	-0.55	-2.23	-0.23	-1.91	-0.40	-2.08	0.11	-1.57	-0.32	-2.00	0.12	-1.56	2.42	-4.55
NHB-W	0.00		-2.47	-2.13	-3.97	-1.68	-3.52	-2.21	-4.05	-1.28	-3.12	-2.03	-3.88	-1.08	-2.93	-1.19	-5.08
NHB-O	0.00		-1.09	-3.25	-5.23	-3.06	-5.04	-3.57	-5.55	-2.56	-4.53	-3.03	-5.00	-2.23	-4.21	-0.93	-5.73

Source: Cambridge Systematics, Inc.

Table 7-23 SCAG Alternative Constant Effect in IVTT Normalized to Local Bus by Access Mode

	Auto			Local Bus		Express Bus		Transitway Bus		BRT / LRT		Urban Rail		Commuter Rail		Nonmotorized	
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk	Bicycle
Peak																	
HBW1 – 0 Auto	178	175	202	0	0	6	6	13	13	-15	-15	-15	-15	-56	-56	-114	169
HBW2 – Autos < Workers	62	107	152	0	0	6	6	13	13	-15	-15	-15	-15	-56	-56	-231	179
HBW3 – Low Income	19	171	205	0	0	6	6	13	13	-15	-15	-15	-15	-56	-56	-236	221
HBW4 – Middle Income	-108	36	71	0	0	6	6	13	13	-15	-15	-15	-15	-56	-56	-317	102
HBW5 – High Income	-166	-21	55	0	0	6	6	13	13	-15	-15	-15	-15	-56	-56	-393	60
HBSH+O	-19	3	25	0	0	-1	-1	-1	-1	-5	-5	-4	-4	-8	-8	-10	102
HBSR	-6	6	29	0	0	-4	-4	-7	-7	-17	-17	-17	-17	-26	-26	-85	164
NHB-W	-62	-62	17	0	0	3	3	5	5	-10	-10	-22	-22	-25	-25	-1	61
NHB-O	-90	-90	-72	0	0	4	4	0	0	-4	-4	-28	-28	-30	-30	-73	82
Off-Peak																	
HBW1 – 0 Auto	180	199	208	0	0	0	0	15	15	-32	-32	-18	-18	-32	-32	-113	177
HBW2 – Autos < Workers	46	91	136	0	0	0	0	15	15	-32	-32	-18	-18	-32	-32	-247	164
HBW3 – Low Income	8	158	191	0	0	0	0	15	15	-32	-32	-18	-18	-32	-32	-255	208
HBW4 – Middle Income	-108	33	67	0	0	0	0	15	15	-32	-32	-18	-18	-32	-32	-361	98
HBW5 – High Income	-155	-10	65	0	0	0	0	15	15	-32	-32	-18	-18	-32	-32	-380	70
HBSH+O	-28	-4	19	0	0	-4	-4	1	1	-6	-6	-2	-2	-8	-8	-12	93
HBSR	-20	-8	15	0	0	-12	-12	-5	-5	-24	-24	-8	-8	-24	-24	-108	146
NHB-W	-66	-66	11	0	0	-14	-14	2	2	-26	-26	-3	-3	-32	-32	-29	92
NHB-O	-101	-101	-67	0	0	-6	-6	10	10	-22	-22	-7	-7	-32	-32	-72	77

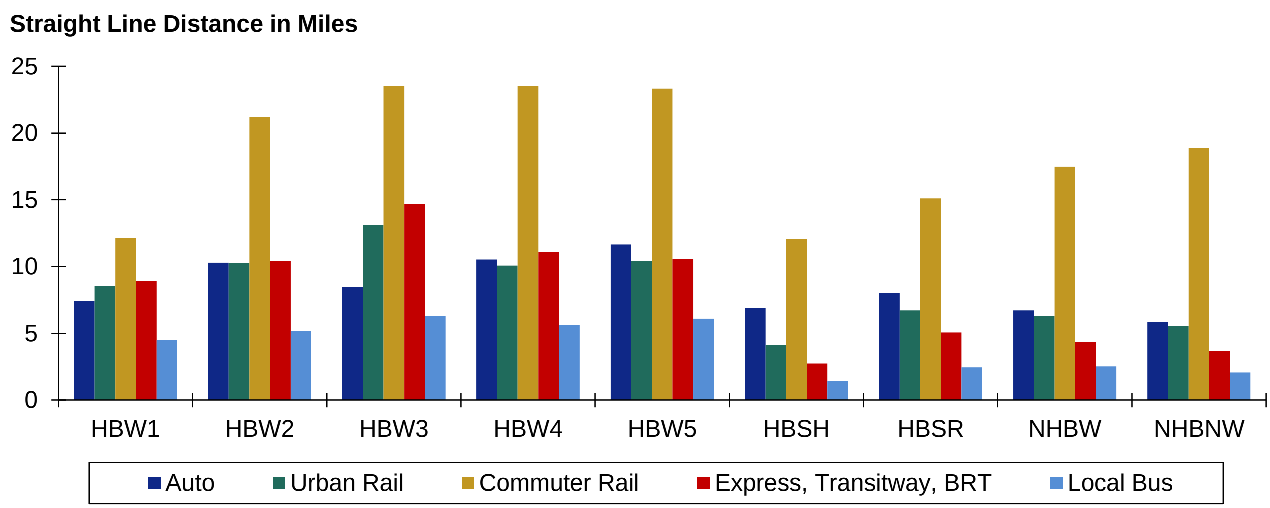
Source: Cambridge Systematics, Inc.

Average Trip Length

Two primary reasonableness checks (that the model is behaving logically) were conducted on the mode choice results: 1) average trip length by mode and 2) mode share by distances. Transit assignment boardings were also examined as discussed in Section 8.2.

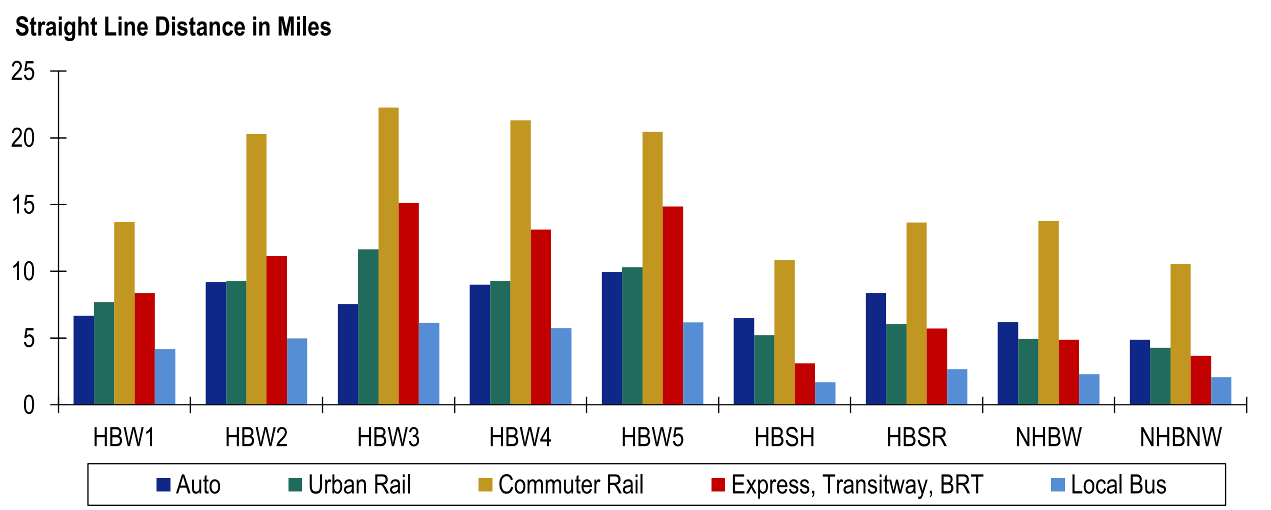
Figure 7-4 and Figure 7-5 show the average trip length by mode and trip purpose (HBW1-HBW5 are as defined in Table 7-23) for the peak and off-peak periods, respectively. As expected, Commuter Rail has the longest average trip length.

Figure 7-4 Intra-SCAG Average Trip Length – Peak



Source: Cambridge Systematics, Inc.

Figure 7-5 Intra-SCAG Average Trip Length – Off-Peak

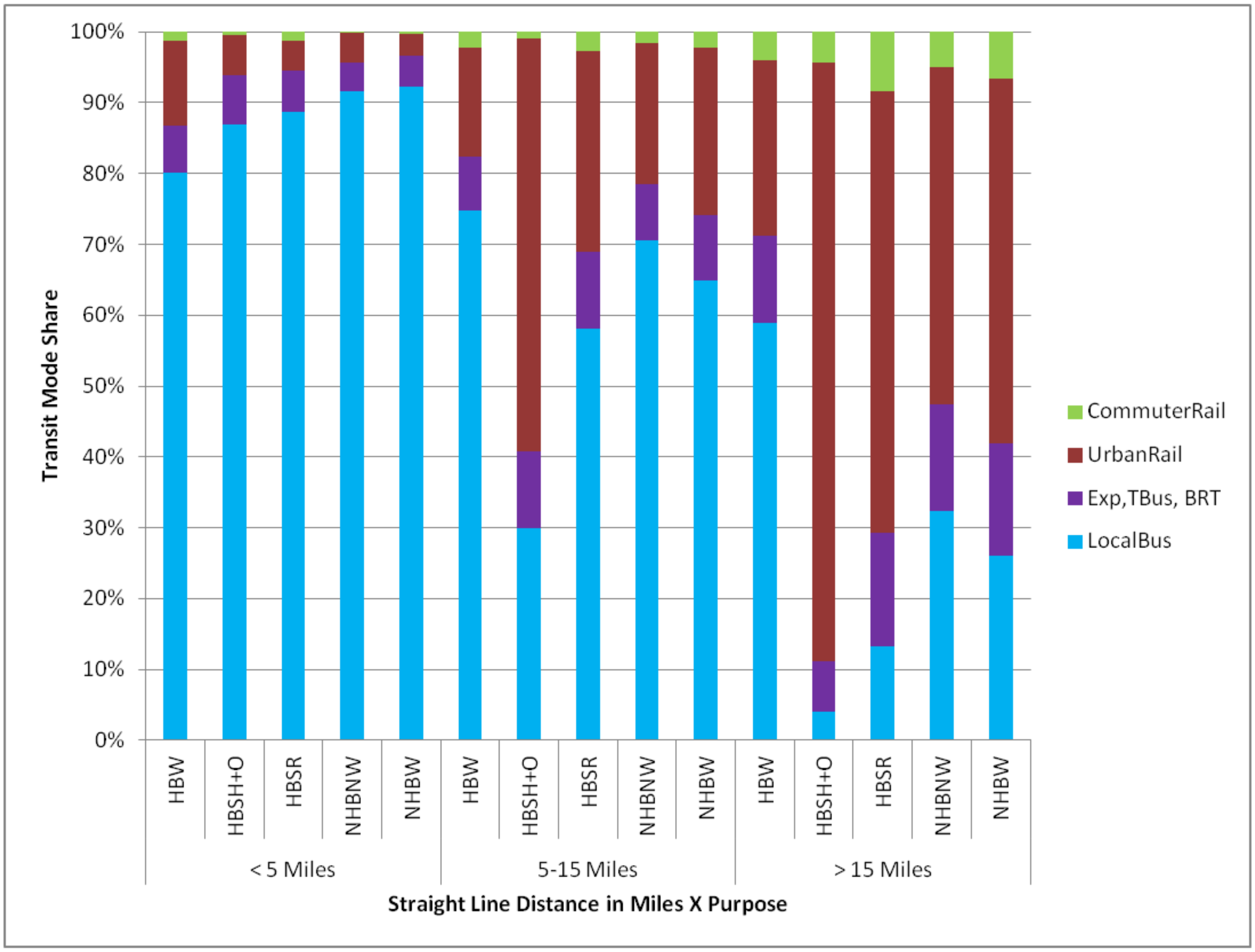


Source: Cambridge Systematics, Inc.

Mode Share by Distance

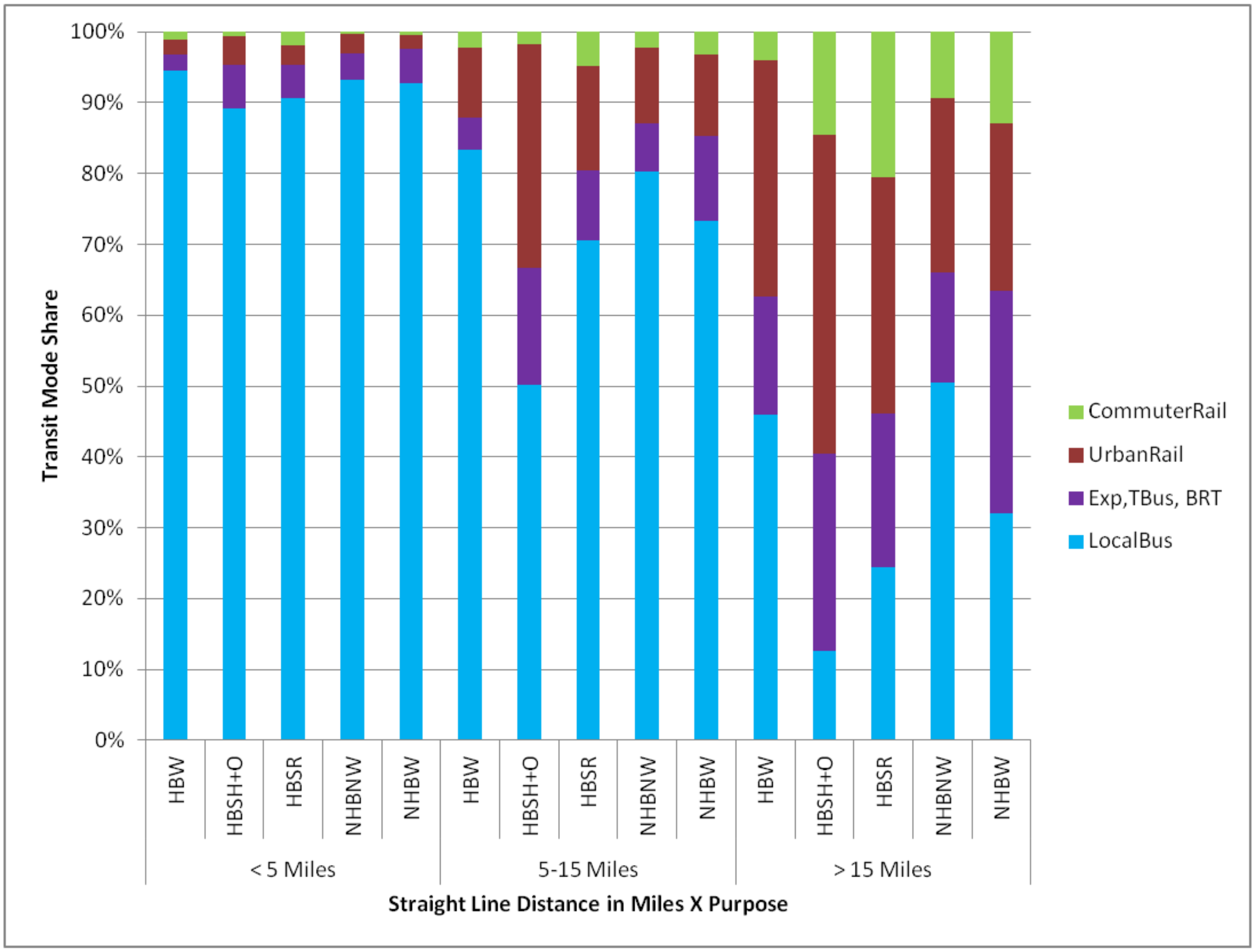
Figure 7-6 and Figure 7-7 show the transit mode shares by three distance ranges: less than 5 miles, between 5 and 15 miles, and greater than 15 miles. Across all purposes, local bus is the dominant transit mode for shorter trips; and urban rail, express bus, and commuter rail are used more on longer trips. This pattern is consistent in the peak and off-peak.

Figure 7-6 Intra-SCAG Transit Mode Share by Distance – Peak



Source: Cambridge Systematics, Inc.

Figure 7-7 Intra-SCAG Transit Mode Share by Distance – Off-Peak



Source: Cambridge Systematics, Inc.

Intra-MTC Calibration Results

Table 7-24 and Table 7-25 show the mode share targets and model results, respectively for the MTC region. The transit-mode shares shown are the share of transit trips across both access modes. Model results (Table 7-25) are highlighted in yellow where the model is more than 1 percentage point different from the target share.

Table 7-26 shows the calibrated ASCs at the motorized nest level. Constants with an absolute magnitude greater than 5 are highlighted in yellow. These are almost exclusively nonmotorized mode constants. While this may make the model less sensitive for these types of trips, it will not impact the area of interest for HSR study, which has much longer trip distances than either walk or bike.

Table 7-27 shows the effective constants for each transit-mode by access mode at the motorized nest level. Effective constants are the composite constants that result from applying calibrated constants shown in Table 7-26 for modes and submodes at their various nesting levels. In Table 7-28, the constants are converted into IVTT equivalent units. For comparison, Local Bus is normalized to zero for each access mode. Auto and nonmotorized modes are compared to the Local Bus Walk alternative. Drive to transit alternatives are compared to the Local Bus Drive alternative.

Table 7-24 MTC Mode Choice Targets

	Mode Share							Share of Transit Trips				
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk	Bike	Local Bus	Express Bus	LRT	Urban Rail	CVR
Peak												
HBW1 – 0 Auto	0.00%	9.43%	4.21%	53.99%	0.00%	26.18%	6.19%	32.96%	4.40%	16.28%	40.41%	5.46%
HBW2 – Autos < Workers	47.55%	13.48%	5.63%	13.68%	6.99%	8.44%	4.23%					
HBW3 – Low Income	72.43%	6.59%	3.41%	5.17%	4.72%	5.62%	2.05%					
HBW4 – Middle Income	72.15%	7.24%	3.65%	5.41%	5.04%	4.69%	1.82%					
HBW5 – High Income	72.85%	8.46%	4.16%	4.56%	6.49%	2.37%	1.12%					
HBSH+O	46.88%	19.43%	20.66%	2.40%	0.27%	9.26%	1.09%	58.84%	4.56%	16.08%	19.09%	1.24%
HBSR	37.67%	20.55%	24.27%	3.14%	0.46%	12.78%	1.13%	56.71%	5.38%	15.28%	21.08%	1.34%
NHB-W	75.55%		10.02%	3.27%	0.00%	10.48%	0.68%	60.33%	1.90%	16.27%	18.62%	2.59%
NHB-O	61.45%		27.19%	2.73%	0.00%	8.16%	0.47%	75.21%	0.83%	17.11%	6.60%	0.21%
Off-Peak												
HBW1 – 0 Auto	0.00%	9.94%	4.08%	47.86%	0.00%	30.51%	7.62%	30.86%	3.47%	16.55%	44.09%	4.60%
HBW2 – Autos < Workers	48.92%	13.42%	5.38%	11.81%	6.83%	9.11%	4.54%					
HBW3 – Low Income	73.26%	6.67%	3.11%	4.36%	4.59%	5.74%	2.27%					
HBW4 – Middle Income	73.54%	7.24%	3.35%	4.47%	4.68%	4.82%	1.90%					
HBW5 – High Income	73.79%	8.33%	3.83%	3.78%	6.55%	2.52%	1.21%					
HBSH+O	50.44%	19.21%	16.95%	2.16%	0.28%	9.79%	1.18%	56.75%	4.12%	17.42%	20.49%	1.06%
HBSR	41.45%	20.10%	20.22%	2.97%	0.50%	13.51%	1.26%	54.61%	4.89%	16.41%	23.00%	0.94%
NHB-W	61.45%		14.22%	1.40%	0.00%	22.15%	0.79%	60.62%	2.06%	19.91%	15.91%	1.28%
NHB-O	66.59%		23.65%	1.91%	0.00%	7.41%	0.43%	74.01%	0.94%	18.04%	6.82%	0.16%

Source: Cambridge Systematics, Inc.

Table 7-25 MTC Mode Choice Results

	Mode Share							Share of Transit Trips				
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk	Bike	Local Bus	Express Bus	LRT	Urban Rail	CVR
Peak												
HBW1 – 0 Auto	16.20%	9.39%	4.19%	54.08%	0.03%	9.95%	6.15%	34.01%	4.36%	16.12%	40.10%	5.41%
HBW2 – Autos < Workers	49.22%	13.46%	5.62%	13.85%	7.14%	6.50%	4.21%					
HBW3 – Low Income	72.43%	6.58%	3.40%	5.18%	4.76%	5.61%	2.04%					
HBW4 – Middle Income	72.04%	7.23%	3.64%	5.47%	5.12%	4.69%	1.81%					
HBW5 – High Income	72.63%	8.44%	4.15%	4.63%	6.65%	2.37%	1.12%					
HBSH+O	45.45%	19.43%	20.66%	2.42%	0.27%	9.27%	2.49%	59.17%	4.54%	15.98%	19.06%	1.24%
HBSR	37.63%	20.56%	24.27%	3.16%	0.47%	12.78%	1.13%	57.05%	5.36%	15.19%	21.06%	1.34%
NHBW	75.47%		10.02%	3.29%	0.05%	10.49%	0.68%	60.71%	1.90%	16.22%	18.59%	2.58%
NHBNW	61.39%		27.20%	2.74%	0.04%	8.16%	0.47%	68.16%	0.83%	17.06%	13.63%	0.33%
Off-Peak												
HBW1 – 0 Auto	16.59%	9.90%	4.06%	48.00%	0.04%	13.84%	7.58%	31.99%	3.43%	16.36%	43.67%	4.55%
HBW2 – Autos < Workers	50.51%	13.39%	5.36%	11.97%	6.99%	7.25%	4.52%					
HBW3 – Low Income	73.28%	6.66%	3.11%	4.36%	4.61%	5.72%	2.25%					
HBW4 – Middle Income	73.43%	7.23%	3.34%	4.53%	4.77%	4.82%	1.89%					
HBW5 – High Income	73.56%	8.31%	3.82%	3.84%	6.74%	2.52%	1.21%					
HBSH+O	49.02%	19.22%	16.95%	2.18%	0.28%	9.79%	2.57%	57.13%	4.11%	17.26%	20.45%	1.05%
HBSR	41.40%	20.10%	20.22%	2.99%	0.50%	13.52%	1.26%	54.98%	4.87%	16.27%	22.96%	0.93%
NHBW	61.39%		14.22%	1.41%	0.04%	22.16%	0.79%	60.98%	2.06%	19.80%	15.88%	1.29%
NHBNW	66.55%		23.66%	1.92%	0.03%	7.42%	0.43%	67.16%	0.93%	17.99%	13.76%	0.16%

Source: Cambridge Systematics, Inc.

Table 7-26 MTC Alternative Constants at the Motorized Nest Level

	Auto			Transit-Access		Nonmotorized		Transit-Mode				
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk	Bike	Local Bus	Express Bus	LRT	Urban Rail	CVR
Peak												
HBW1 – 0 Auto	0.00	-1.18	-2.29	1.03	-4.64	7.00	-1.40	0.00	-0.26	0.63	0.36	0.57
HBW2 – Autos < Workers	0.00	-1.59	-2.96	-0.72	-2.16	7.00	-1.92	0.00	-0.26	0.63	0.36	0.57
HBW3 – Low Income	0.00	-3.83	-4.75	-2.68	-3.29	5.41	-4.12	0.00	-0.26	0.63	0.36	0.57
HBW4 – Middle Income	0.00	-3.16	-3.91	-2.17	-3.19	6.00	-3.36	0.00	-0.26	0.63	0.36	0.57
HBW5 – High Income	0.00	-2.48	-3.49	-1.58	-2.78	6.32	-3.08	0.00	-0.26	0.63	0.36	0.57
HBSH+O	0.00	-1.38	-2.57	-4.04	-3.49	-1.04	-7.00	0.00	0.29	0.18	0.05	0.35
HBSR	0.00	-1.07	-1.26	-0.96	-2.04	1.93	-4.95	0.00	0.28	0.36	0.10	0.32
NHB-W	0.00	0.00	-2.21	-1.31	-4.70	-0.17	-5.46	0.00	-0.22	0.51	0.01	0.57
NHB-O	0.00	0.00	-1.65	-2.05	-5.03	0.47	-5.26	0.00	0.51	0.65	0.02	1.46
Off-Peak												
HBW1 – 0 Auto	0.00	-1.14	-2.30	0.56	-4.64	7.00	-1.49	0.00	-0.14	0.64	0.38	0.98
HBW2 – Autos < Workers	0.00	-1.61	-3.00	-0.90	-2.20	7.00	-1.92	0.00	-0.14	0.64	0.38	0.98
HBW3 – Low Income	0.00	-3.82	-4.73	-3.04	-3.43	5.19	-4.19	0.00	-0.14	0.64	0.38	0.98
HBW4 – Middle Income	0.00	-3.17	-3.97	-2.42	-3.31	5.94	-3.38	0.00	-0.14	0.64	0.38	0.98
HBW5 – High Income	0.00	-2.50	-3.54	-1.69	-2.71	6.31	-3.03	0.00	-0.14	0.64	0.38	0.98
HBSH+O	0.00	-1.46	-2.82	-4.23	-3.56	-1.00	-7.00	0.00	0.40	0.19	0.05	0.55
HBSR	0.00	-1.21	-1.50	-1.20	-2.22	1.90	-4.90	0.00	0.52	0.42	0.11	0.54
NHB-W	0.00	0.00	-0.94	-1.27	-4.57	-0.38	-5.81	0.00	-0.40	0.67	0.00	0.00
NHB-O	0.00	0.00	-1.18	-1.72	-4.96	-0.64	-6.01	0.00	0.24	0.68	0.00	0.54

Source: Cambridge Systematics, Inc.

Table 7-27 MTC Alternative Constants – Effective Constants at the Motorized Nest Level

	Auto			Local Bus		Express Bus		LRT		Urban Rail		Commuter Rail		Nonmotorized	
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk	Bicycle
Peak															
HBW1 – 0 Auto	0.00	-1.18	-2.29	1.03	-4.64	0.77	-4.89	1.66	-4.01	1.39	-4.28	1.60	-4.07	7.00	-1.40
HBW2 – Autos < Workers	0.00	-1.59	-2.96	-0.72	-2.16	-0.98	-2.42	-0.09	-1.53	-0.36	-1.80	-0.15	-1.59	7.00	-1.92
HBW3 – Low Income	0.00	-3.83	-4.75	-2.68	-3.29	-2.93	-3.54	-2.05	-2.66	-2.32	-2.93	-2.10	-2.71	5.41	-4.12
HBW4 – Middle Income	0.00	-3.16	-3.91	-2.17	-3.19	-2.42	-3.44	-1.54	-2.56	-1.81	-2.83	-1.60	-2.62	6.00	-3.36
HBW5 – High Income	0.00	-2.48	-3.49	-1.58	-2.78	-1.84	-3.04	-0.95	-2.15	-1.22	-2.42	-1.01	-2.21	6.32	-3.08
HBSH+O	0.00	-1.38	-2.57	-4.04	-3.49	-3.75	-3.21	-3.86	-3.31	-3.99	-3.44	-3.68	-3.14	-1.04	-7.00
HBSR	0.00	-1.07	-1.26	-0.96	-2.04	-0.69	-1.77	-0.60	-1.68	-0.87	-1.95	-0.65	-1.73	1.93	-4.95
NHB-W	0.00		-2.21	-1.31	-4.70	-1.52	-4.92	-0.79	-4.19	-1.30	-4.69	-0.74	-4.13	-0.17	-5.46
NHB-O	0.00		-0.94	-1.27	-4.57	-1.67	-4.97	-0.60	-3.90	-1.27	-4.57	-1.27	-4.57	-0.38	-5.81
Off-Peak															
HBW1 – 0 Auto	0.00	-1.14	-2.30	0.56	-4.64	0.42	-4.77	1.20	-4.00	0.93	-4.26	1.54	-3.66	7.00	-1.49
HBW2 – Autos < Workers	0.00	-1.61	-3.00	-0.90	-2.20	-1.04	-2.34	-0.26	-1.56	-0.53	-1.83	0.08	-1.22	7.00	-1.92
HBW3 – Low Income	0.00	-3.82	-4.73	-3.04	-3.43	-3.18	-3.57	-2.40	-2.79	-2.66	-3.06	-2.06	-2.46	5.19	-4.19
HBW4 – Middle Income	0.00	-3.17	-3.97	-2.42	-3.31	-2.55	-3.44	-1.78	-2.67	-2.04	-2.93	-1.44	-2.33	5.94	-3.38
HBW5 – High Income	0.00	-2.50	-3.54	-1.69	-2.71	-1.83	-2.85	-1.05	-2.07	-1.32	-2.34	-0.71	-1.73	6.31	-3.03
HBSH+O	0.00	-1.46	-2.82	-4.23	-3.56	-3.82	-3.16	-4.03	-3.36	-4.18	-3.51	-3.68	-3.01	-1.00	-7.00
HBSR	0.00	-1.21	-1.50	-1.20	-2.22	-0.67	-1.70	-0.77	-1.80	-1.08	-2.11	-0.66	-1.68	1.90	-4.90
NHB-W	0.00		-1.65	-2.05	-5.03	-1.53	-4.52	-1.40	-4.38	-2.03	-5.01	-0.58	-3.57	0.47	-5.26
NHB-O	0.00		-1.18	-1.72	-4.96	-1.48	-4.73	-1.04	-4.29	-1.72	-4.96	-1.17	-4.42	-0.64	-6.01

Source: Cambridge Systematics, Inc.

Table 7-28 MTC Alternative Constant Effect in IVTT Normalized to Local Bus by Access Mode

	Auto			Local Bus		Express Bus		LRT		Urban Rail		Commuter Rail		Nonmotorized	
	Drive Alone	Shared Ride 2	Shared Ride 3+	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk to Transit	Drive to Transit	Walk	Bicycle
Peak															
HBW1 – 0 Auto	43	92	139	0	0	11	11	-26	-26	-15	-15	-24	-24	-250	101
HBW2 – Autos < Workers	-30	36	93	0	0	11	11	-26	-26	-15	-15	-24	-24	-323	50
HBW3 – Low Income	-112	48	87	0	0	11	11	-26	-26	-15	-15	-24	-24	-338	60
HBW4 – Middle Income	-91	41	73	0	0	11	11	-26	-26	-15	-15	-24	-24	-341	50
HBW5 – High Income	-66	38	80	0	0	11	11	-26	-26	-15	-15	-24	-24	-330	63
HBSH+O	-69	-46	-25	0	0	-5	-5	-3	-3	-1	-1	-6	-6	-52	51
HBSR	-35	4	11	0	0	-10	-10	-13	-13	-3	-3	-12	-12	-105	145
NHB-W	-40	-40	28	0	0	7	7	-16	-16	0	0	-18	-18	-35	129
NHB-O	-39	-39	-10	0	0	12	12	-21	-21	0	0	0	0	-28	140
Off-Peak															
HBW1 – 0 Auto	23	71	119	0	0	6	6	-27	-27	-16	-16	-41	-41	-269	86
HBW2 – Autos < Workers	-38	30	87	0	0	6	6	-27	-27	-16	-16	-41	-41	-330	43
HBW3 – Low Income	-127	32	71	0	0	6	6	-27	-27	-16	-16	-41	-41	-344	48
HBW4 – Middle Income	-101	31	65	0	0	6	6	-27	-27	-16	-16	-41	-41	-349	40
HBW5 – High Income	-71	34	77	0	0	6	6	-27	-27	-16	-16	-41	-41	-334	56
HBSH+O	-73	-48	-24	0	0	-7	-7	-3	-3	-1	-1	-9	-9	-55	48
HBSR	-44	0	11	0	0	-19	-19	-15	-15	-4	-4	-20	-20	-113	135
NHB-W	-63	-63	-12	0	0	-16	-16	-20	-20	-1	-1	-45	-45	-78	99
NHB-O	-53	-53	-17	0	0	-7	-7	-21	-21	0	0	-17	-17	-33	133

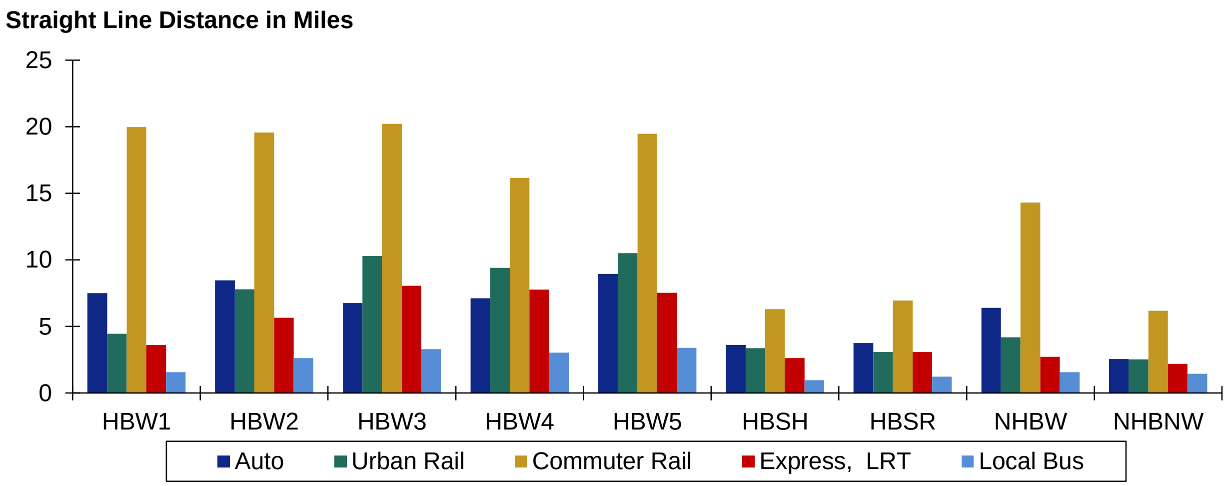
Source: Cambridge Systematics, Inc.

Average Trip Length

Two primary reasonableness checks were conducted on the mode choice results: 1) average trip length by mode and 2) mode shares by distance. Reasonableness tests are not comparisons against observed data but, rather, summaries to check that the model is behaving logically. Transit assignment boardings also were examined, as discussed in Section 8.2.

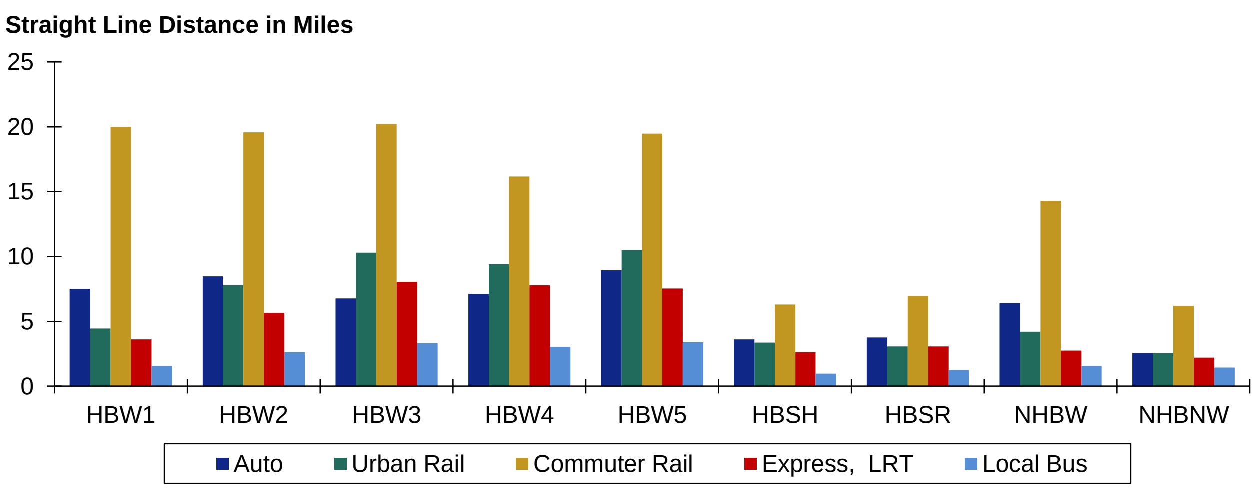
Figure 7-8 and Figure 7-9 show the average trip length by mode and trip purpose for the peak and off-peak periods, respectively. As expected, Commuter Rail has the longest average trip length followed by Urban Rail and LRT, with Local Bus having the shortest average trip length.

Figure 7-8 Intra-MTC Average Trip Length – Peak



Source: Cambridge Systematics, Inc.

Figure 7-9 Intra-MTC Average Trip Length – Off-Peak

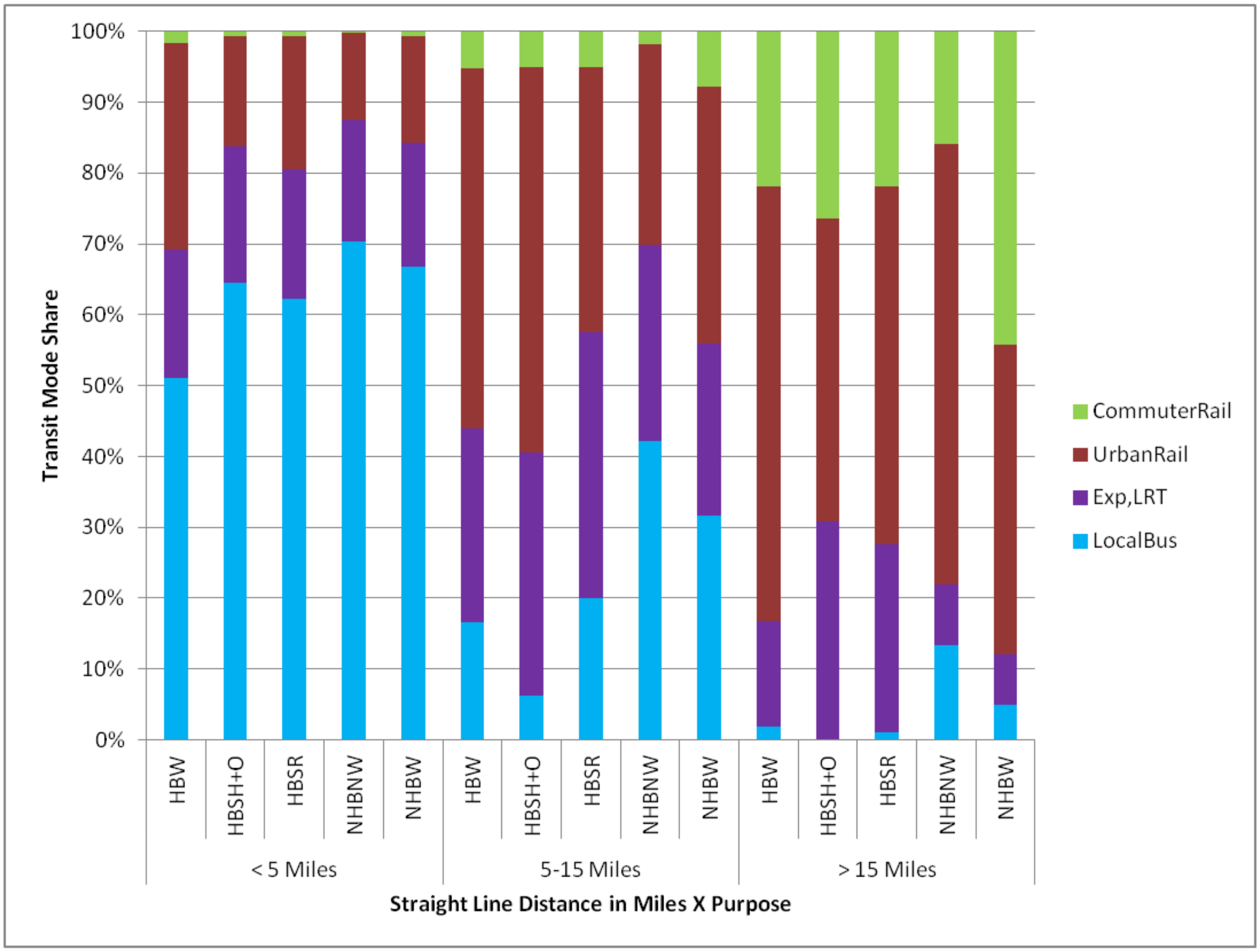


Source: Cambridge Systematics, Inc.

Mode Share by Distance

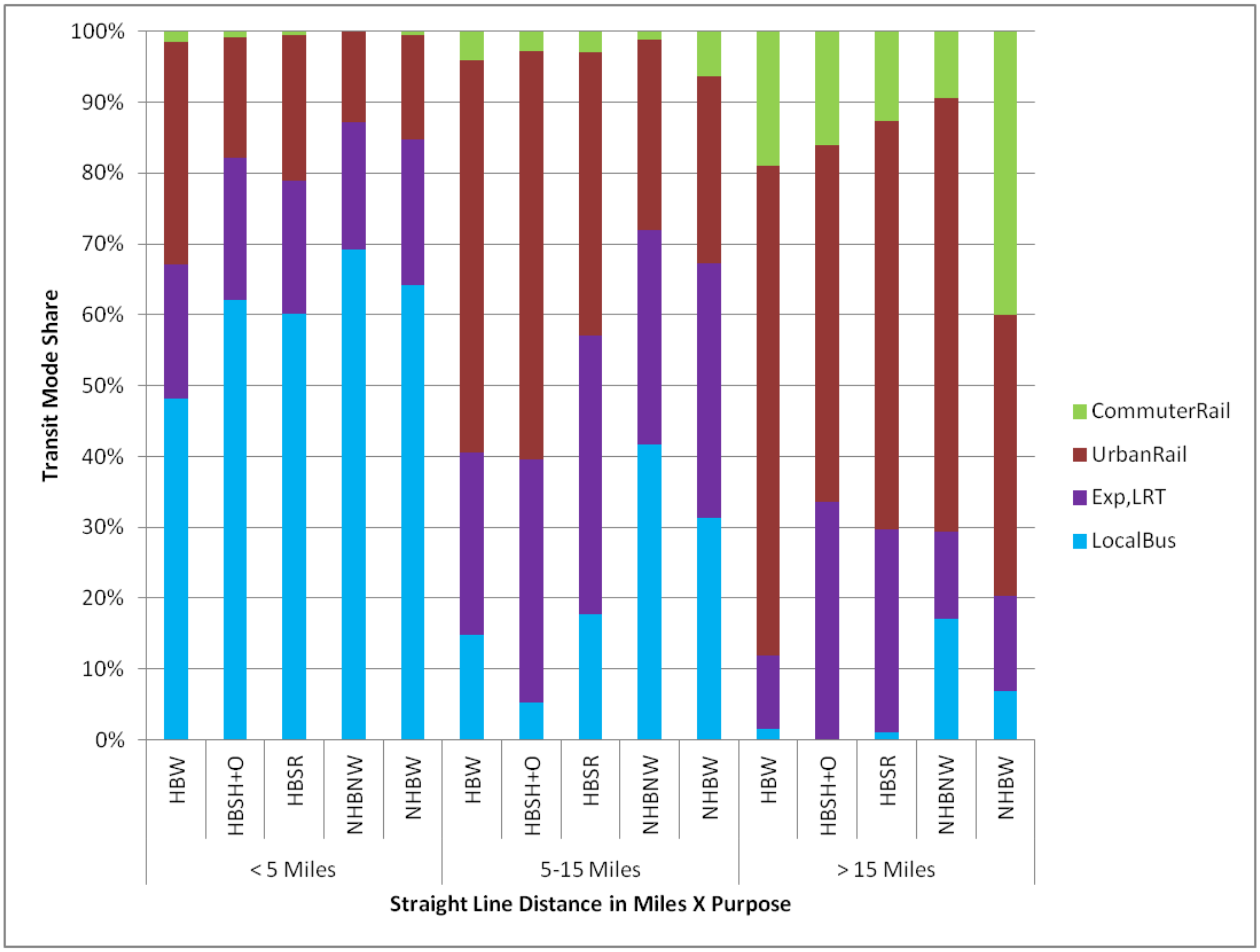
Figure 7-10 and Figure 7-11 show the transit mode shares by three distance ranges: less than 5 miles, between 5 and 15 miles, and greater than 15 miles. Across all purposes, local bus is the dominant transit mode for shorter trips; and urban rail, express bus, and commuter rail are used more on longer trips. This pattern is consistent in the peak and off-peak.

Figure 7-10 Intra-MTC Transit Mode Share by Distance – Peak



Source: Cambridge Systematics, Inc.

Figure 7-11 Intra-MTC Transit Mode Share by Distance – Off-Peak



Source: Cambridge Systematics, Inc.

8.0 Validation and Sensitivity Testing

8.1 Overview

After the model was calibrated, it was validated in three ways:

1. Model outcomes were compared to the observed data used for calibration that were not directly affected by the calibrated constants. This included examining mode shares by distance, and mode shares by household characteristics.

2. CVR and AIR assignment results were compared to observed boarding, segment volume, and origin-destination data collected from transit operators and the Bureau of Transpiration Statistics (BTS).

3. The model was run for a different year (2000) to validate the model's ability to be used for forecasting a different year. This is sometimes called a "backcast."

It should be noted, that the concepts of model calibration and validation are often confused. After model constants have been adjusted so that modeled shares match observed shares for specified variables for a base year, the model is often labeled as being validated. This is really model calibration.

On the other hand, there is a component of model validation, or, at least, improved comfort with the veracity of the model, when modeled results reasonably match observed data for summaries not directly affected by the calibrated constants. Note that this is not independent data from those used to calibrate the model, just pieces of that data which did not directly affect the calibrated parameters.

A second type of validation compares model results for the base year with independently collected data. This is the more traditional definition of model validation. In this chapter, both types of validation are used with year 2010 data, as listed under number one and two, above.

In addition to validation, a number of model runs for Year 2010 were performed to assess the model's sensitivity to various changes in level-of-service characteristics for different modes. This sensitivity testing included evaluating a high-speed rail system that has similar level-of-service characteristics as the Northeast Corridor and evaluating self- and cross-elasticities of level-of-service variables by adjusting one input variable at a time.

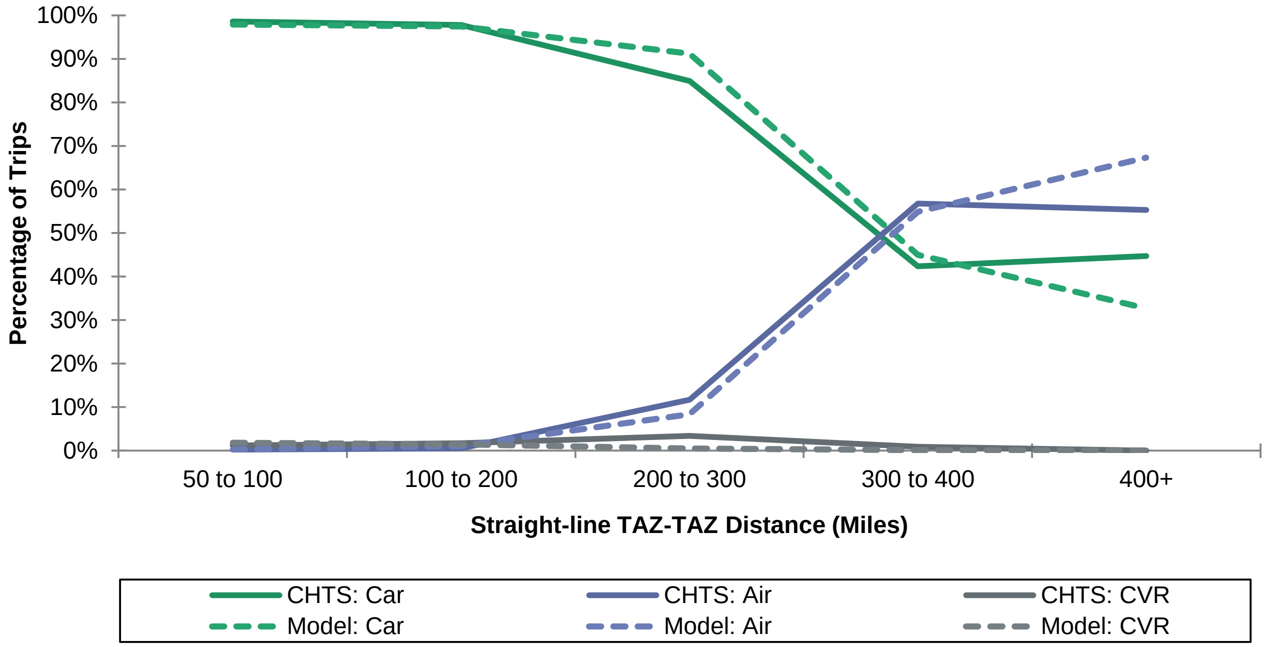
8.2 Validation Against Year 2010 Observed Data

Model outcomes were compared to the observed CSHTS data used for calibration that were not directly affected by the calibrated constants. This included examining mode shares by distance, and mode shares by household characteristics.

Mode Shares by Distance

The first test was the model's forecast of main mode choice by travel distance compared to observed data. This travel characteristic was not addressed by the mode choice or trip distribution models. Figure 8-1 shows the CSHTS and modeled mode shares by distance range for business trips. The modeled distributions match the observed CSHTS distributions very well.

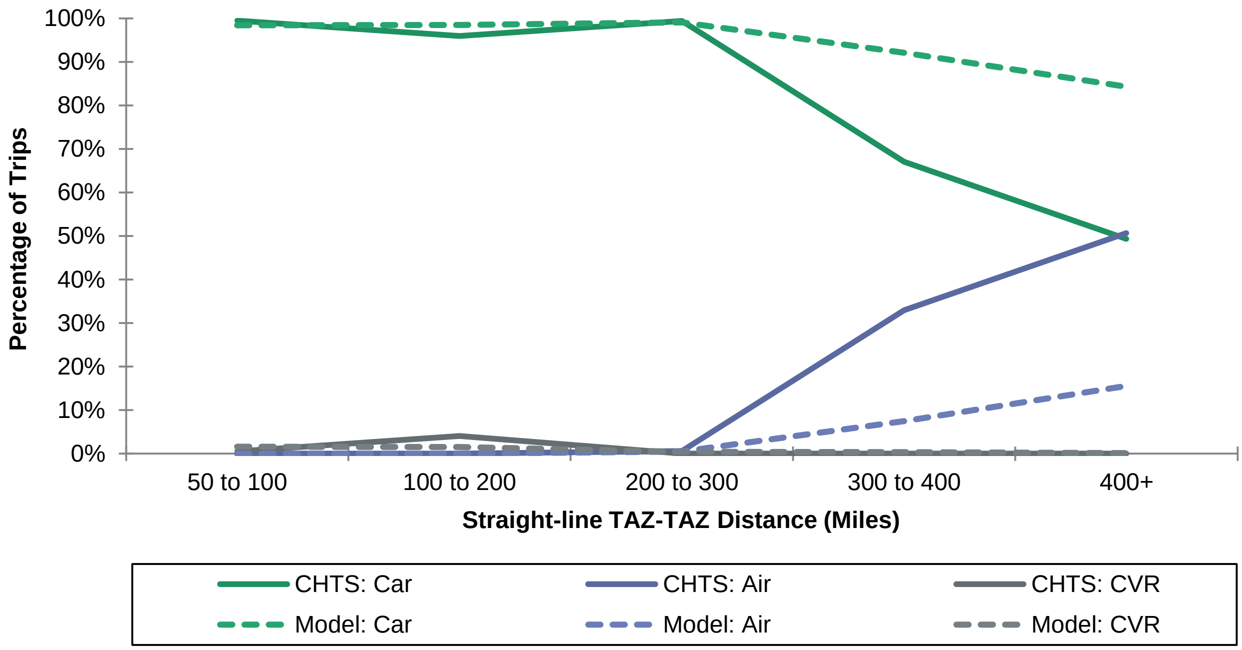
Figure 8-1 Mode Share by Distance Range Summary – Business



Source: Cambridge Systematics, Inc.

Commute purpose summaries for CSHTS and the calibrated model, shown in Figure 8-2, indicate the mode shares by distance range match reasonably well for shorter distance commuter trips. Mode shares for longer distance commute trips look a bit worse in comparison to observed data primarily due to the lack of sufficient observed data in long-distance ranges for the commute purpose. Moreover, due to the low number of commute trips predicted to be in such long-distance ranges, matching CSHTS is less critical for those trips.

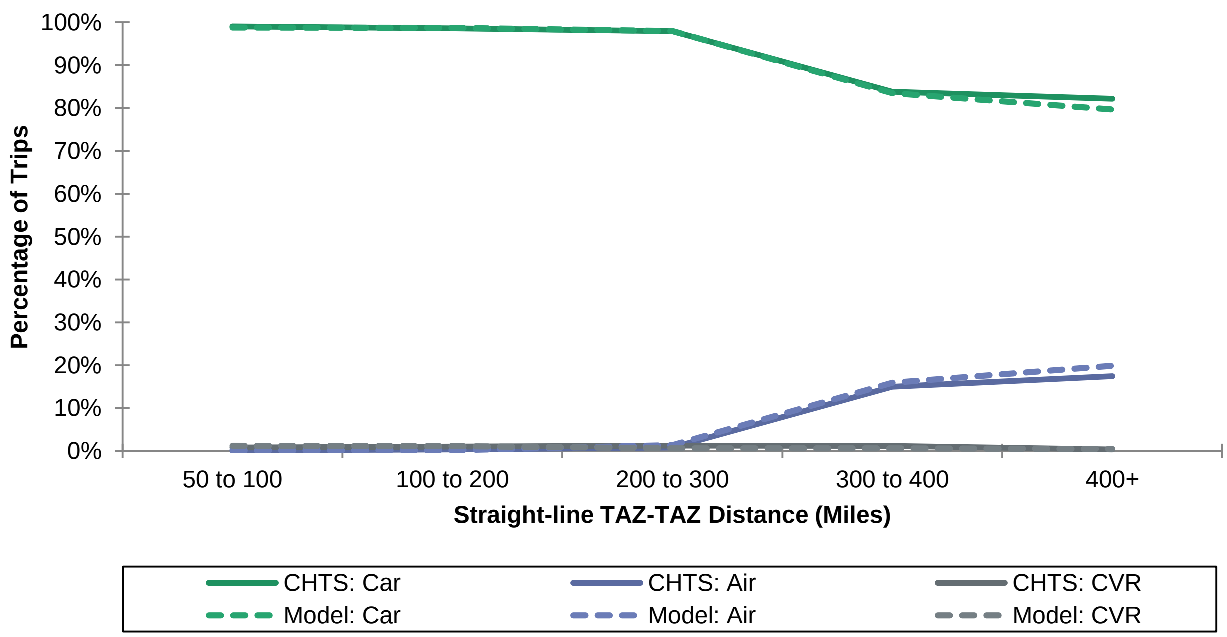
Figure 8-2 Mode Share by Distance Range Summary – Commute



Source: Cambridge Systematics, Inc.

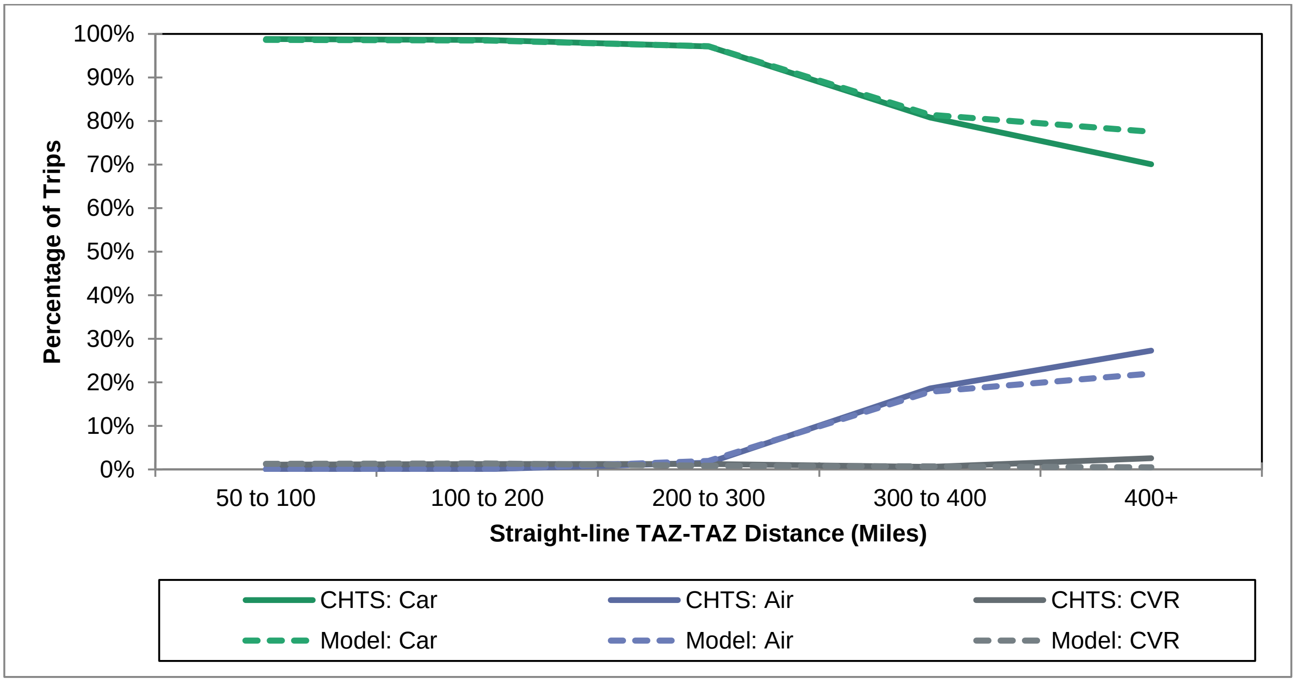
Figure 8-3 and Figure 8-4 show mode shares by distance for CSHTS and the calibrated model for recreation and other trips, respectively. Similar to the business trip purpose, recreation and other trip mode shares appear to match observed data reasonably well for all distance ranges.

Figure 8-3 Mode Share by Distance Range Summary – Recreation



Source: Cambridge Systematics, Inc.

Figure 8-4 Mode Share by Distance Range Summary – Other



Source: Cambridge Systematics, Inc.

Overall, the modeled distributions for each trip purpose shown in the figures demonstrate that the distribution and mode choice models are producing reasonable results. The modeled average trip lengths by mode and purpose are also encouraging, as shown in Table 8-1. While the model generally underpredicted the average trip lengths of CVR trips, the observed average trip lengths for that mode were based on relatively few observations.

Table 8-1 Average Trip Lengths (in Miles) by Mode and Purpose

Average Trip Length (Miles)	CSHTS				Calibrated Model				Difference				Percent Difference			
	Car	Air	CVR	Total	Car	Air	CVR	Total	Car	Air	CVR	Total	Car	Air	CVR	Total
Business	110	355	121	128	111	353	88	128	1	-2	-33	0	1%	-1%	-27%	0%
Commute	80	365	91	81	83	372	75	84	4	8	-16	4	5%	2%	-17%	4%
Recreation	113	328	132	116	111	354	100	114	-2	26	-32	-2	-2%	8%	-24%	-2%
Other	112	368	121	116	112	366	102	116	0	-2	-19	0	0%	0%	-16%	0%

Source: Cambridge Systematics, Inc.

Trips by Household Attributes and Mode

Model results for trip frequency, destination choice, and mode choice models by household attributes and mode were evaluated. Since the trip frequency models forecast only total trips by purpose, summarizing the numbers of trips by mode and purpose for various household strata demonstrates the reasonableness of the overall modeling process.

Table 8-2, Table 8-3, Table 8-4, and Table 8-5 detail the summaries by trip purpose. The model results were compared to the CSHTS data summaries. CSHTS results are not shown explicitly in the tables, but the percent difference of model results to CSHTS is shown. While the summaries show some rather large differences between modeled and observed trips by mode for the various strata, the largest differences tend to occur for socioeconomic strata with relatively few trips and, by implication, households. When there are relatively few households, there is more likelihood of larger sampling errors in the observed data. In general, the greater the number of trips, the closer the model reproduces the observed data. This is not surprising, since the greater the number of trips, the more reflective that population segment is of the overall average, and the models replicate average behaviors quite well. Due to the impacts of sampling error on the observed data, it is probably better to focus on the marginal distributions (e.g. total trips by household size, number of workers, or income group, or total trips by mode) in Tables 8-2 through 8-5.

Table 8-2 Total Average Daily Household Trips by Household Attributes and Mode – Business

	Model				Percent Difference from CSHTS			
	Car	Air	CVR	Total	Car	Air	CVR	Total
Household Size								
One	19,015	1,202	320	20,538	14%	-42%	-30%	7%
Two	44,084	3,540	727	48,351	4%	2%	7%	4%
Three	25,516	2,018	414	27,948	5%	26%	20%	7%
Four+	46,472	3,506	738	50,716	-10%	1%	38%	-9%
Total	135,088	10,266	2,199	147,553	0%	-3%	9%	0%
Number of Workers								
Zero	14,689	621	200	15,510	6%	5%	124%	7%
One	52,007	3,581	836	56,424	-3%	-18%	-18%	-4%
Two+	68,391	6,065	1,163	75,620	1%	7%	29%	2%
Total	135,088	10,266	2,199	147,553	0%	-3%	9%	0%
Household Income								
Low	19,127	193	231	19,551	14%	-41%	49%	14%
Medium	37,695	1,791	672	40,158	-4%	-9%	-4%	-4%
High	78,265	8,282	1,296	87,843	-1%	0%	12%	0%
Total	135,088	10,266	2,199	147,553	0%	-3%	9%	0%

Source: Cambridge Systematics, Inc.

Table 8-3 Total Average Daily Household Trips by Household Attributes and Mode – Commute

	Model				Percent Difference from CSHTS			
	Car	Air	CVR	Total	Car	Air	CVR	Total
Household Size								
One	22,952	47	343	23,342	-33%	-62%	100%	-32%
Two	65,689	184	1,021	66,894	12%	16%	-47%	10%
Three	46,184	126	721	47,031	2%	-29%	100%	4%
Four+	95,011	248	1,505	96,764	2%	56%	428%	3%
Total	229,836	606	3,589	234,030	-1%	-2%	62%	0%
Number of Workers								
Zero	10,360	13	129	10,502	-11%	100%	100%	-10%
One	89,963	194	1,331	91,488	-17%	-13%	273%	-16%
Two+	129,512	399	2,129	132,040	17%	0%	14%	17%
Total	229,836	606	3,589	234,030	-1%	-2%	62%	0%
Household Income								
Low	30,375	10	270	30,656	256%	-70%	100%	258%
Medium	65,232	73	1,104	66,409	-28%	-44%	-4%	-28%
High	134,229	522	2,215	136,965	2%	15%	107%	3%
Total	229,836	606	3,589	234,030	-1%	-2%	62%	0%

Source: Cambridge Systematics, Inc.

Table 8-4 Total Average Daily Household Trips by Household Attributes and Mode – Recreation

	Model				Percent Difference from CSHTS			
	Car	Air	CVR	Total	Car	Air	CVR	Total
Household Size								
One	55,779	769	1,089	57,637	42%	-2%	-40%	38%
Two	123,818	1,424	1,557	126,798	1%	-7%	26%	1%
Three	88,082	871	919	89,872	11%	29%	43%	11%
Four+	224,827	2,044	2,072	228,943	-11%	3%	161%	-10%
Total	492,506	5,108	5,636	503,250	0%	3%	26%	0%
Number of Workers								
Zero	77,547	813	1,258	79,618	28%	102%	12%	28%
One	178,885	1,841	2,143	182,868	-7%	-14%	10%	-7%
Two+	236,074	2,454	2,236	240,764	-2%	0%	59%	-2%
Total	492,506	5,108	5,636	503,250	0%	3%	26%	0%
Household Income								
Low	68,140	775	1,673	70,589	-1%	142%	90%	1%
Medium	138,914	1,266	1,660	141,840	3%	91%	-14%	3%
High	285,452	3,066	2,303	290,821	-2%	-23%	39%	-2%
Total	492,506	5,108	5,636	503,250	0%	3%	26%	0%

Source: Cambridge Systematics, Inc.

Table 8-5 Total Average Daily Household Trips by Household Attributes and Mode – Other

	Model				Percent Difference from CSHTS			
	Car	Air	CVR	Total	Car	Air	CVR	Total
Household Size								
One	98,675	1,998	2,118	102,791	31%	-20%	-5%	29%
Two	167,643	3,103	2,380	173,126	0%	-8%	72%	0%
Three	101,197	1,575	1,156	103,928	-1%	-23%	0%	-1%
Four+	232,607	3,204	2,215	238,026	-9%	38%	-7%	-8%
Total	600,122	9,880	7,869	617,871	0%	-3%	10%	0%
Number of Workers								
Zero	139,644	2,153	2,524	144,320	20%	55%	6%	20%
One	233,593	3,788	3,090	240,471	-2%	-6%	34%	-2%
Two+	226,885	3,940	2,255	233,080	-8%	-18%	-9%	-8%
Total	600,122	9,880	7,869	617,871	0%	-3%	10%	0%
Household Income								
Low	137,490	2,022	3,336	142,847	9%	39%	92%	11%
Medium	186,590	2,340	2,254	191,185	-2%	-15%	-5%	-2%
High	276,042	5,519	2,279	283,840	-3%	-8%	-25%	-3%
Total	600,122	9,880	7,869	617,871	0%	-3%	10%	0%

Source: Cambridge Systematics, Inc.

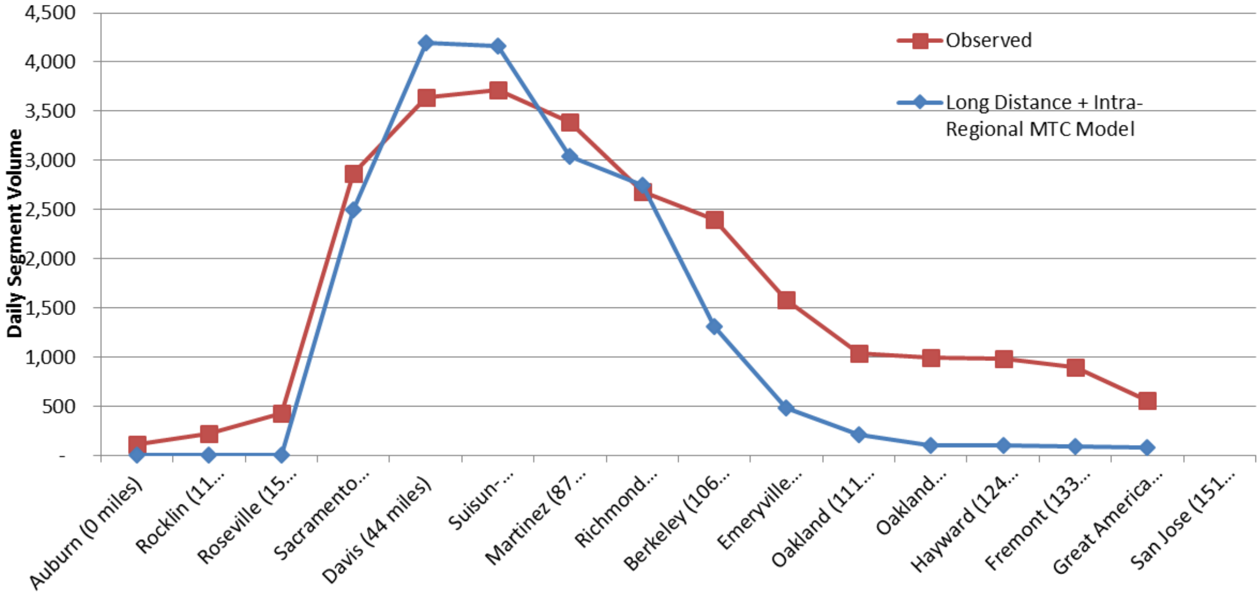
Conventional Rail Validation Measures

Another validation measure checked model results against independently collected CVR data. The model was estimated and calibrated based primarily on data from the 2012-2013 CSHTS. In this section, observed CVR passenger loads by link, obtained from each respective CVR operator, are compared to modeled loads. As documented in Chapter 3, modeled CVR service was based on published schedules, reflecting different service patterns on branches of lines, between specific stations, and by time of day (peak and off-peak). Of course, observed CVR passenger loads also reflect the varying levels of service.

Figure 8-5[30] shows daily passenger loads for the Amtrak Capitol Corridor route from the Sacramento area to San Jose. Modeled load patterns match the observed loads patterns reasonably well, though they are a little low from Auburn to Roseville and low from Richmond to San Jose. Figure 8-6 shows modeled versus observed loads for the Altamont Corridor Express (ACE) service from Stockton to San Jose. Of all the CVR comparisons, this particular corridor is the worst in terms of matching observed loads.

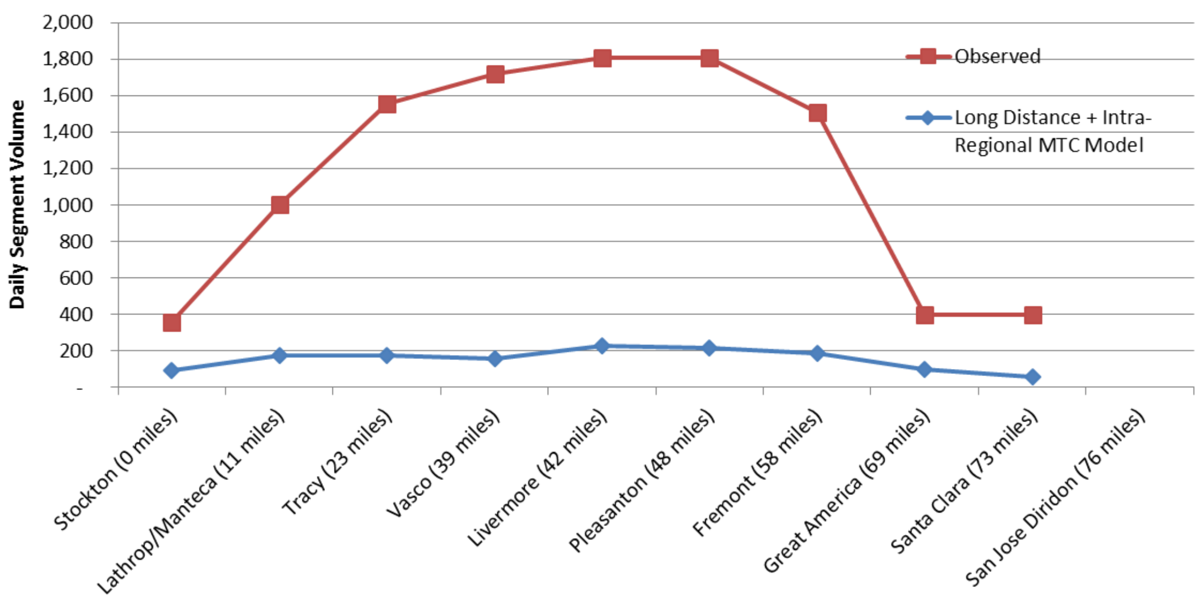
[30] Loads, or segment volumes, are between stations. Segments are defined by the station listed and the next station to the right. The right-most station is the end of the line. Thus, "Great America" represents the segment volume from "Great America to San Jose."

Figure 8-5 Amtrak Capitol Corridor Route: Average Daily Loads (From 2010 City-to-City Volumes)



Source: Cambridge Systematics, Inc.

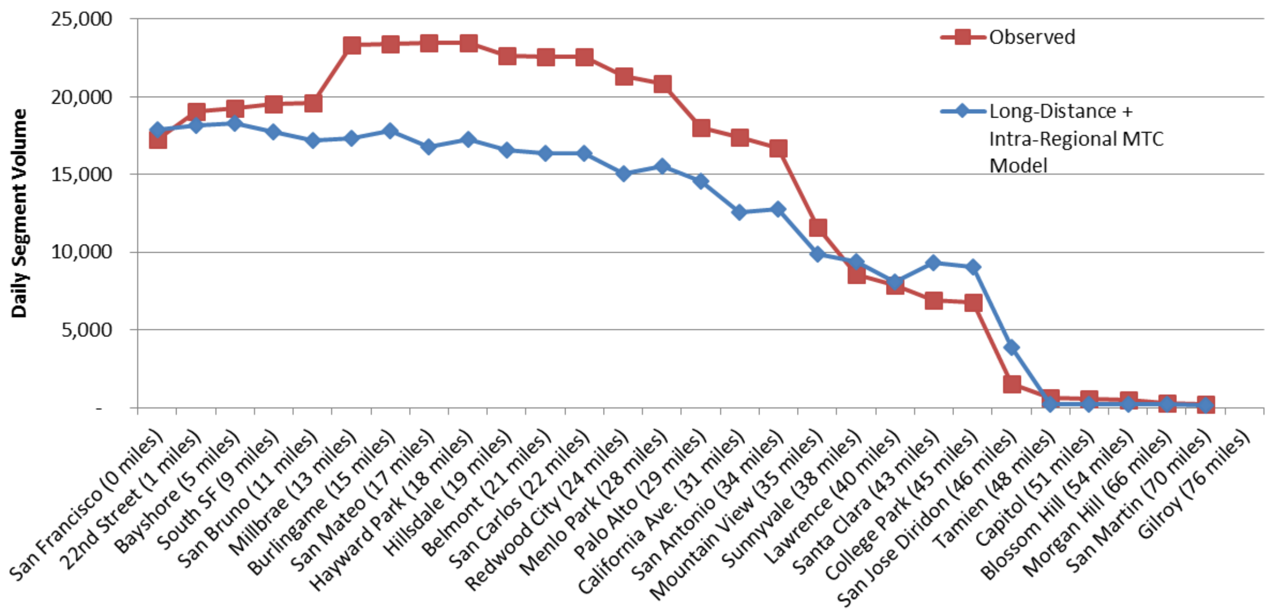
Figure 8-6 Altamont Corridor Express (ACE): Average Daily Loads (Observed Data Derived from 2010 On/Off Volumes)



Source: Cambridge Systematics, Inc.

Figure 8-7 shows Caltrain daily loads. Caltrain runs from downtown San Francisco south along the San Francisco Peninsula to San Jose and continues to Gilroy. Modeled volume patterns reasonably match observed patterns albeit the observed increase in ridership between Millbrae and Sunnyvale is not reproduced.

Figure 8-7 Caltrain: Average Daily Loads (From 2010 City-to-City Volumes)

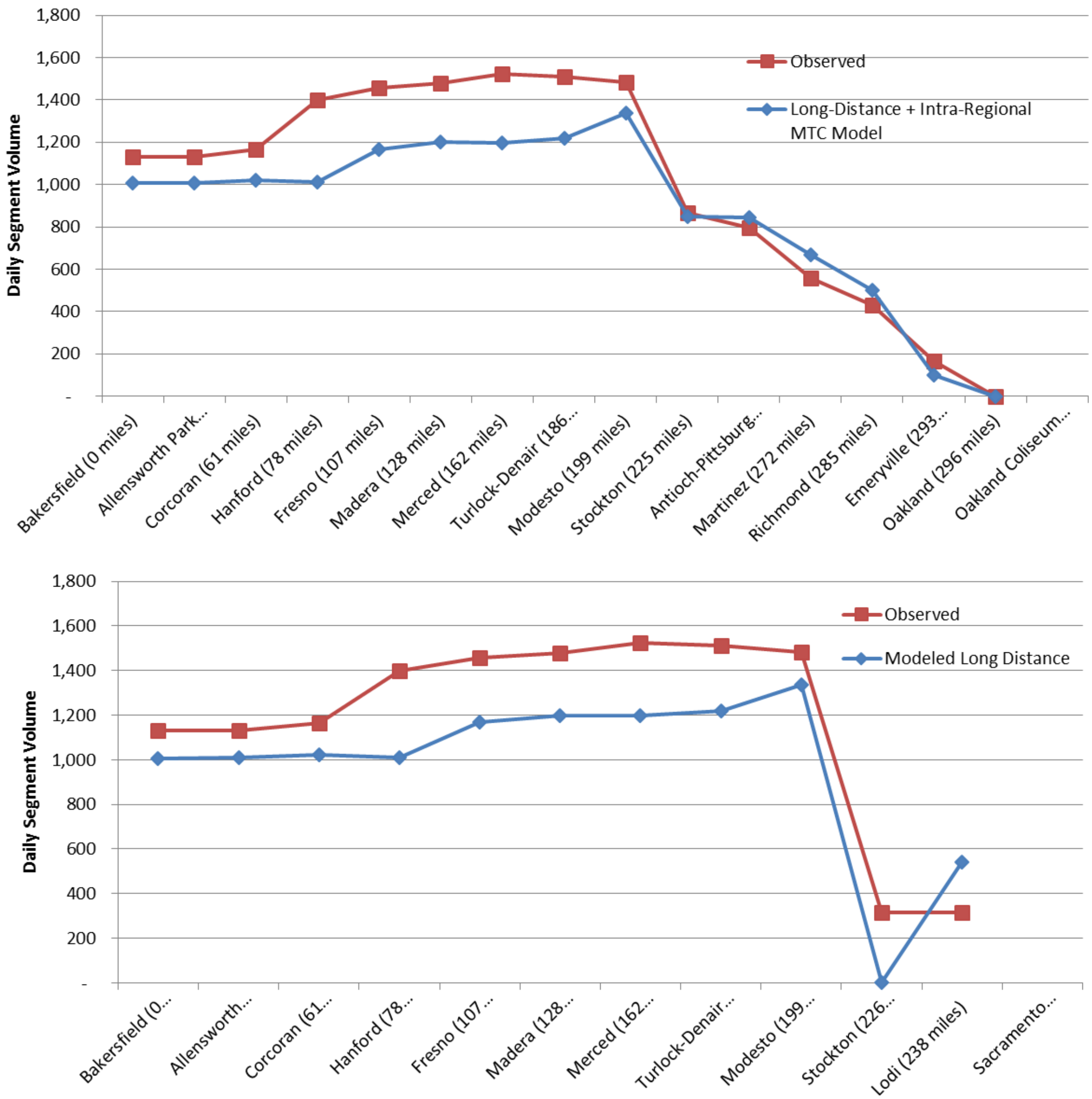


Source: Cambridge Systematics, Inc.

Figure 8-8 shows Amtrak's San Joaquin route running from Bakersfield to Sacramento and to Oakland Coliseum. Model volumes are slightly low between Bakersfield and Modesto compared to observed (from 2010 City-to-City data), but in general, track the observed volumes. Figure 8-9 shows Amtrak's Pacific Surfliner route, running from San Diego, through Los Angeles to San Luis Obispo. Again, modeled conventional rail trips match the observed (from 2010 City-to-City data) reasonably, albeit high from San Diego to Fullerton and low from Los Angeles to San Luis Obispo. The large drop in ridership between Fullerton and Los Angeles is captured by the assignment of the model results.

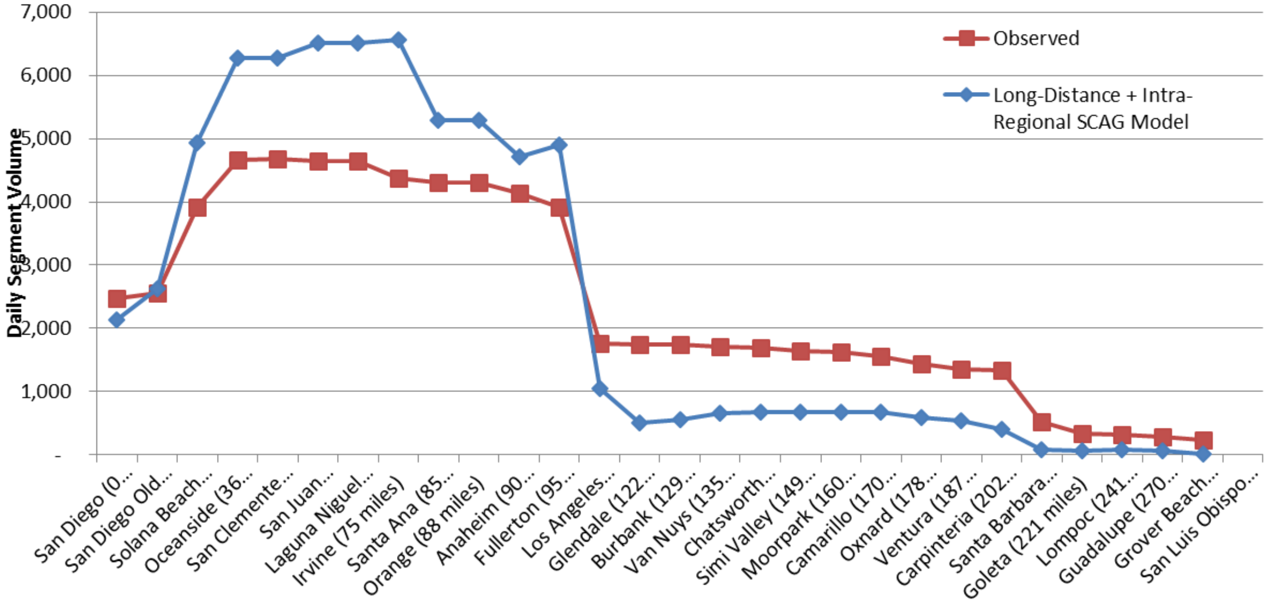
Figure 8-10 shows the Ventura County Metrolink route, extending from Los Angeles Union Station to Montalvo. Modeled conventional rail trips tend to be a little bit high on this route, particularly on the end closest to Los Angeles Union Station. However, the volumes are generally in the reasonable range.

Figure 8-8 Amtrak San Joaquin Route: Average Daily Loads (From 2010 City-to-City Volumes)



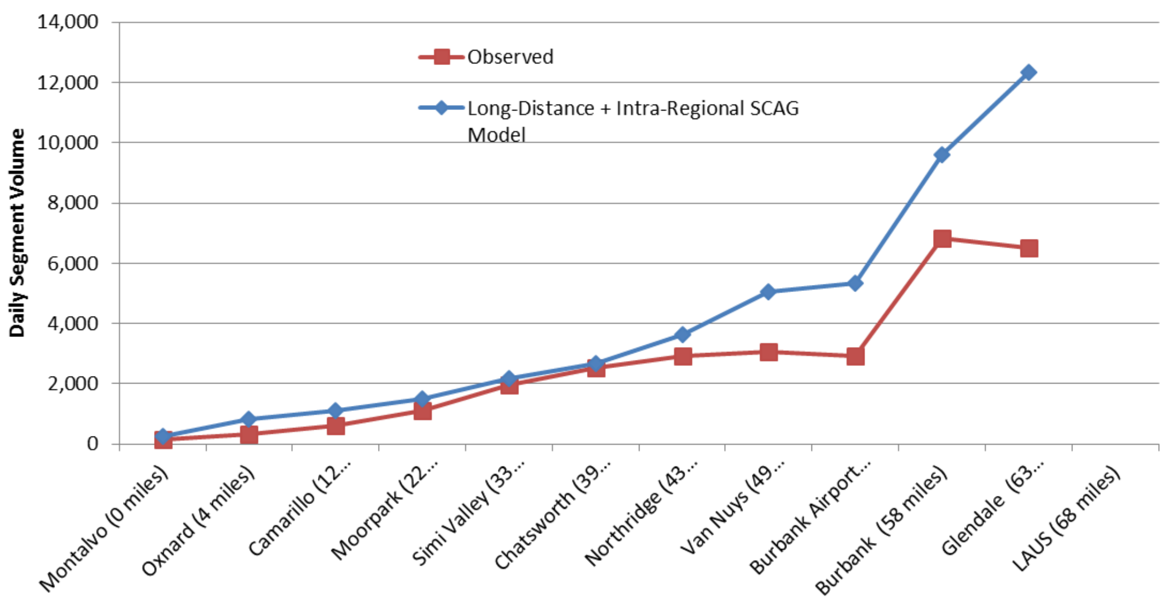
Source: Cambridge Systematics, Inc.

Figure 8-9 Amtrak Pacific Surfliner Route: Average Daily Loads (From 2010 City-to-City Volumes)



Source: Cambridge Systematics, Inc.

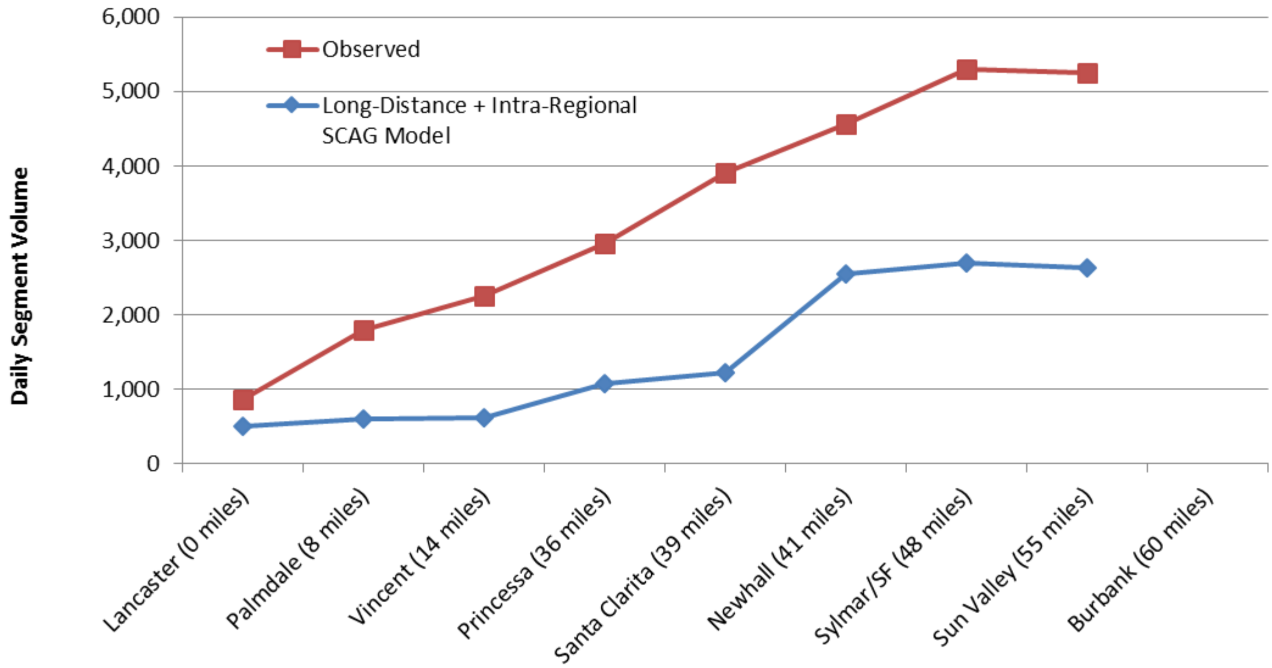
Figure 8-10 Ventura County Metrolink Route: AM Peak Period Peak Direction Average Daily Loads



Source: Cambridge Systematics, Inc.

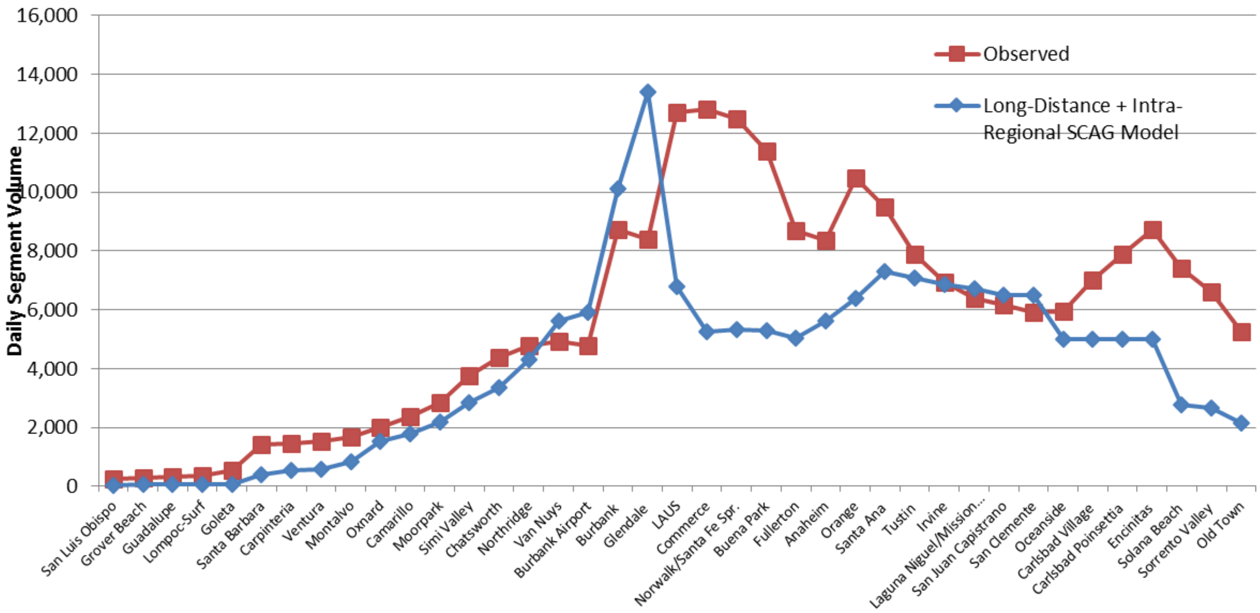
Figure 8-11 shows the Antelope Valley Metrolink route from Lancaster to Burbank and Figure 8-12 shows the LOSSAN corridor extending from San Luis Obispo to San Diego Old Town and consisting of combined Amtrak, Metrolink, and Coaster services. In both cases, modeled flows tend to be on the low side, but the general shapes of flows across the stations tend to match those of the observed totals.

Figure 8-11 Antelope Valley Metrolink Route: AM Peak Period Peak Direction Average Daily Loads



Source: Cambridge Systematics, Inc.

Figure 8-12 LOSSAN Corridor: Average Daily Loads (Amtrak + Metrolink + Coaster)



Source: Cambridge Systematics, Inc.

Air Validation Measures

This section details the validation measures performed based on independently collected air passenger data. The model was estimated and calibrated based primarily on data from the 2012-2013 CSHTS. Table 8-6 and Table 8-7 compare modeled annual air trips for 2010 against annual "local" passenger volumes between airports serving those regions.

Table 8-6 Annual Air Trips – Validation Comparisons Against 10 Percent Ticket Sample Data

		Observed	Calibrated Model	Difference
SANDAG	SANDAG	0	0	0
	SCAG	26,700	302,100	275,400
	MTC	2,370,700	1,325,000	-1,045,800
	SACOG	678,100	408,700	-269,300
	SJV	32,100	18,900	-13,300
	OTHER	0	5,000	5,000
SCAG	SCAG	0	0	0
	MTC	7,308,600	5,043,100	-2,265,500
	SACOG	2,014,900	1,939,200	-75,600
	SJV	37,500	66,500	29,000
	OTHER	4,000	81,400	77,400
MTC	MTC	0	0	0
	SACOG	2,300	26,000	23,700
	SJV	11,700	151,200	139,500
	OTHER	154,600	60,900	-93,700
SACOG	SACOG	0	0	0
	SJV	900	0	-900
	OTHER	27,000	10,700	-16,300
SJV	SJV	0	0	0
	OTHER	0	0	0
Other	OTHER	0	300	300
Total		**12,669,100**	**9,439,000**	**-3,230,000**

Source: Aviation System Consulting, *Potential Airline Response to High-Speed Rail Service in California*. Prepared for Cambridge Systematics, Inc. August 2011.

Table 8-7 Shares of Total Annual Air Trips – Validation Comparisons Against 10 Percent Ticket Sample Data

		Observed	Calibrated Model	Difference
SANDAG	SANDAG	0%	0%	0%
	SCAG	0%	3%	3%
	MTC	19%	14%	-5%
	SACOG	5%	4%	-1%
	SJV	0%	0%	0%
	OTHER	0%	0%	0%
SCAG	SCAG	0%	0%	0%
	MTC	58%	53%	-4%
	SACOG	16%	21%	5%
	SJV	0%	1%	0%
	OTHER	0%	1%	1%
MTC	MTC	0%	0%	0%
	SACOG	0%	0%	0%
	SJV	0%	2%	2%
	OTHER	1%	1%	-1%
SACOG	SACOG	0%	0%	0%
	SJV	0%	0%	0%
	OTHER	0%	0%	0%
SJV	SJV	0%	0%	0%
	OTHER	0%	0%	0%
Other	OTHER	0%	0%	0%
Total		**99%**	**100%**	**–**

Source: Aviation System Consulting, *Potential Airline Response to High-Speed Rail Service in California*. Prepared for Cambridge Systematics, Inc. August 2011.

Observed data have been summarized from the U.S. DOT 10 percent origin-destination survey airline data collected by the Bureau of Transportation Statistics. Local air trips in the 10 percent survey data are those trips between the identified airports that are not transfers to or from flights to other locations outside of California. The observed data include non-California residents who had origins and destinations at California airports as well as international travelers who had an initial domestic origin and a final domestic destination at a California airport. Because of the inclusion of non-California residents in the 10 percent sample data, the calibrated model was expected to have fewer assigned air trips than the observed data.

The differences between the modeled and observed annual numbers of trips for the region to region flows are substantial. However, there is some uncertainty regarding the actual trips and travelers included in the observed data. Due to this uncertainty, region to region flows for modeled and observed air trips were checked. The modeled distribution matched the observed distribution reasonably well.

8.3 Validation Against Year 2000 Data Sources

The BPM-V3 was used for a backcast to Year 2000 conditions. Table 8-8 shows the key model input assumptions used for the Year 2000 scenario along with the source of the data.

Table 8-8 Year 2000 Source Data and Model Assumptions

Inputs	Source or Assumption
SE Dataset	Adopted from CSTDM Year 2000 dataset
Auto Skims	Year 2000 from CSTDM loaded network
Auto Operating Cost	17 cents per mile (2005 dollars)
Auto Parking Costs	Consistent with Year 2010
Air Operating Plan and Fares	Year 2000 (developed for Version 1 and used for Version 2). Airport terminal and wait times reflect post-9/11 conditions.
Air Parking Costs	Consistent with Year 2010
CVR Operating Plan and Fares	2010 adjusted to reflect lower levels of service for 2000 for Capitol Corridor, San Joaquin, Caltrain, and Metrolink
CVR Parking Costs	Consistent with Year 2010

Source: Cambridge Systematics, Inc.

Comparison to Version 1 Calibration Targets of Total Trips between Regions

Modeled total trips between regions for the year 2000 backcast were compared to the calibration targets used for the Version 1 model. The calibration targets were compiled from 2000-2001 California Household Travel Survey, 1995 American Travel Survey, and 2000 Census Transportation Planning Process. While a statewide travel survey was performed in 2000-2001, it did not include a long-distance travel component. As with the daily diary component of the 2012-2013 CSHTS, relatively little detailed information can be derived from the daily diary, alone.

It was difficult to directly compare the calibration targets, because the Version 1 model included all interregional trips, regardless of trip distance. Therefore, only four region pairs were compared directly to Year 2000 Version 1 calibration targets since they represent regions that are greater than 50 miles apart, as shown in Table 8-9. All other regional pairs include trips less than 50 miles, and thus, can not be easily compared to the BPM-V3 results. The results show that the largest HSR regional pair of MTC to SCAG is within eleven percent of the observed totals. The other pairs have greater percentage differences, but represent many fewer trips. The negative differences might also reflect the impacts of changes to long-distance travel resulting from the 9/11 terrorist attacks and the fact that the U.S. was just emerging from the Great Recession in 2010.

Table 8-9 Year 2000 Observed and Modeled Long-Distance Trips (> 50 Miles) between Regions, Greater Than 50 Miles Apart (Millions)

Region Pairs		Interregional Observed	BPM-V3 Backcast	Difference	Percent Difference
SACOG	SCAG	4.2	5.1	0.9	21%
MTC	SCAG	18.3	16.3	(2.0)	-11%
SACOG	SANDAG	0.8	0.6	(0.2)	-25%
SANDAG	MTC	5.5	2.5	(3.0)	-55%

Source: Cambridge Systematics, Inc.

Comparison to Observed CVR Boarding Counts and Segment Volumes

CVR assignment results from the long-distance model for the Year 2000 backcast were compared to estimates of Year 2000 segment volumes for three Amtrak services – the Capitol Corridor, San Joaquin, and Pacific Surfliner. Observed 2000 and 2010 ridership data were collected from the Amtrak ridership reports. Detailed segment volumes for 2000 were not available, so observed Year 2010 segment volumes for the lines were factored by the ratio of the 2000 ridership to the 2010 ridership. Since the observed segment volumes for 2010 were stratified by short- and long-distance trips, it was possible to factor only the long-distance portions to estimate Year 2000 segment volumes for long-distance trips. Table 8-10 shows the 2000 and 2010 ridership by line along with the line specific factors used to factor segment volumes.

Table 8-10 Year 2000 and 2010 Observed Boardings by CVR Line

CVR Line	2010 Ridership	2000 Ridership	Ratio (2000/2010)
Capitol Corridor	1,604,800	879,000	0.55
San Joaquin	986,100	683,900	0.69
Pacific Surfliner	2,640,200	1,594,200	0.60

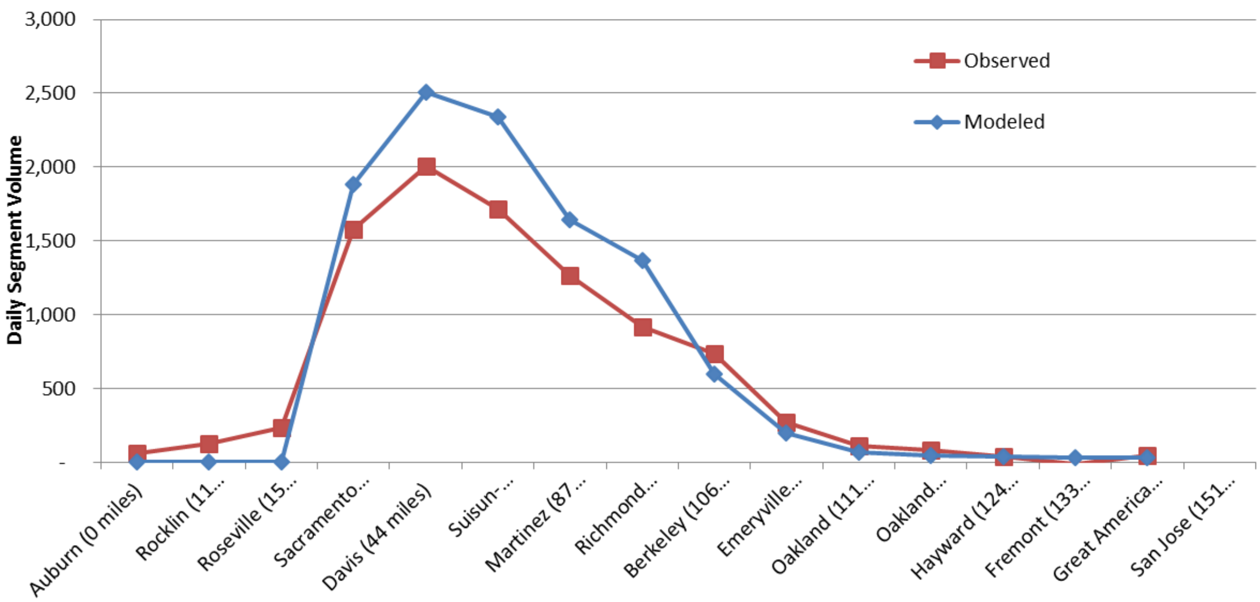
Source: Cambridge Systematics, Inc. based on Amtrak California Ridership by Month, Quarter, State Fiscal Year, Federal Fiscal Year, and Calendar Year from 1997 through 2011.

Year 2010 CVR networks were used as a basis for the analysis since they were the basis for the BPM-V3 model estimation and calibration. While Year 2000 CVR networks had been coded for the Version 1 model, they were not fully compatible with updated network coding techniques used for the BPM-V3. The service frequencies for CVR lines for the Year 2010 networks were adjusted to reflect Year 2000 service frequencies for Caltrain, the Capitol Corridor, and San Joaquin routes. The Caltrain route was updated to reflect Year 2000 service levels and, for Metrolink, the 91 line was removed since it was not in service in 2000, but no other service changes were made. No information on service changes for the Pacific Surfliner, ACE, or Coaster routes was available, so the 2000 backcast represents Year 2010 service levels for those route.

The available documentation did not suggest fare changes for reasons other than inflation so the 2010 fares were used for the Year 2000 backcast (i.e. the 2000 backcast assumed no change from 2010 fares in real terms). Since CVR operates on dedicated track, in-vehicle travel times were assumed to remain the same for 2000 as for 2010. Since Amtrak routes use freight railroad tracks, there could have been differences in reliability between 2010 and 2000; however, no information on reliability in 2000 was readily available, so 2010 reliabilities were used.

Figure 8-13 shows modeled versus observed long-distance segment volumes for the Amtrak Capitol Corridor service from Auburn to San Jose. For the segment between Sacramento and Berkeley, the model predicted higher segment volumes than those estimated for 2000 while between Berkeley and San Jose the modeled long-distance segment volumes were slightly lower than those estimated based on Amtrak route reports.

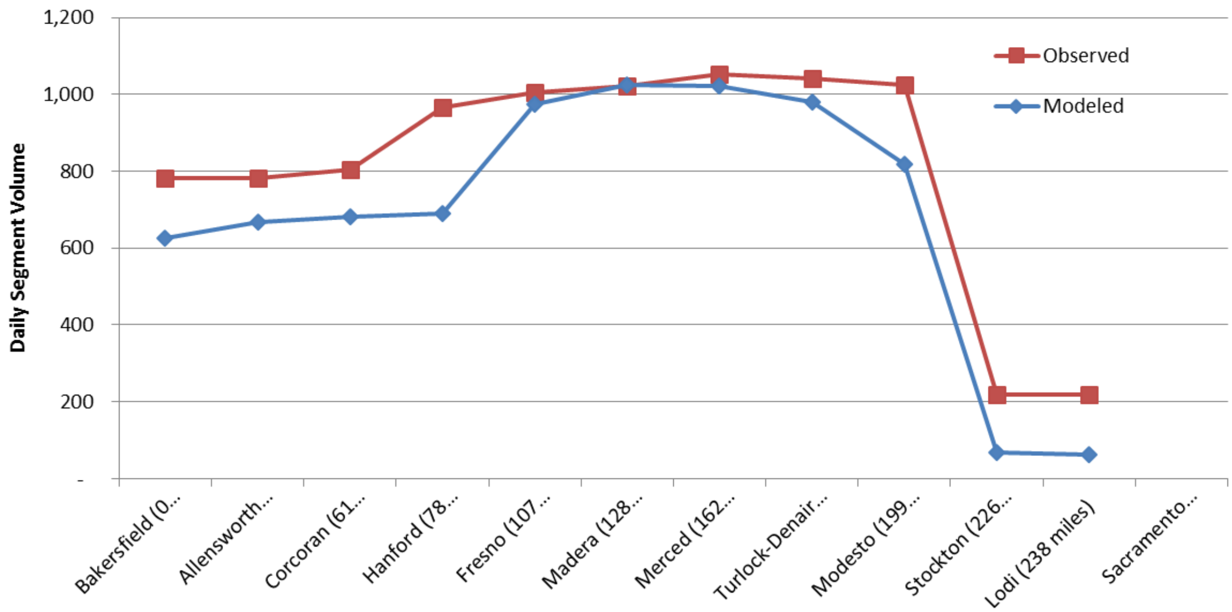
Figure 8-13 Amtrak Capitol Corridor: Average Daily Long-Distance Loads (Observed Data Estimated from 2000 to 2010 Line Ridership)

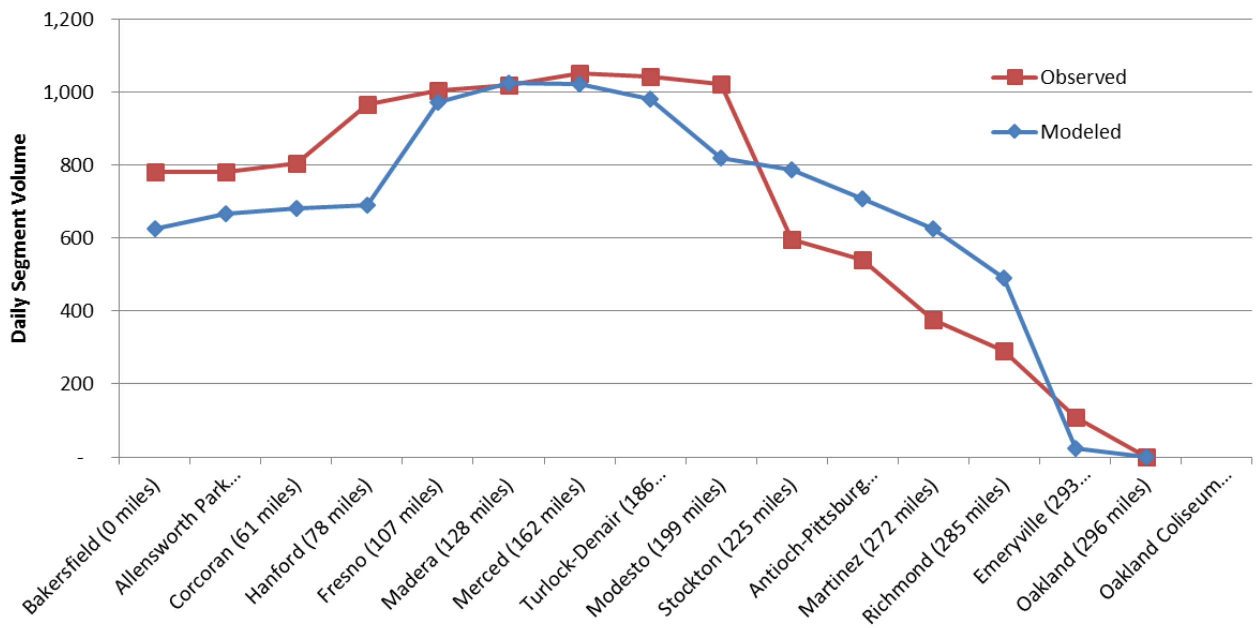


Source: Cambridge Systematics, Inc.

Figure 8-14 shows modeled versus observed long-distance segment volumes for the Amtrak San Joaquin service from Bakersfield to Sacramento and from Bakersfield to Oakland Coliseum. Model segment volumes are slightly lower than estimates of the Year 2000 observed long-distance segment volumes for the Bakersfield to Sacramento branch. Between Stockton and Oakland Coliseum, the modeled long-distance segment volumes are generally higher than the estimates of the observed long-distance segment volumes.

Figure 8-14 Amtrak San Joaquin: Average_Daily Long-Distance Loads (Observed Data Estimated from 2000 to 2010 Line Ridership)

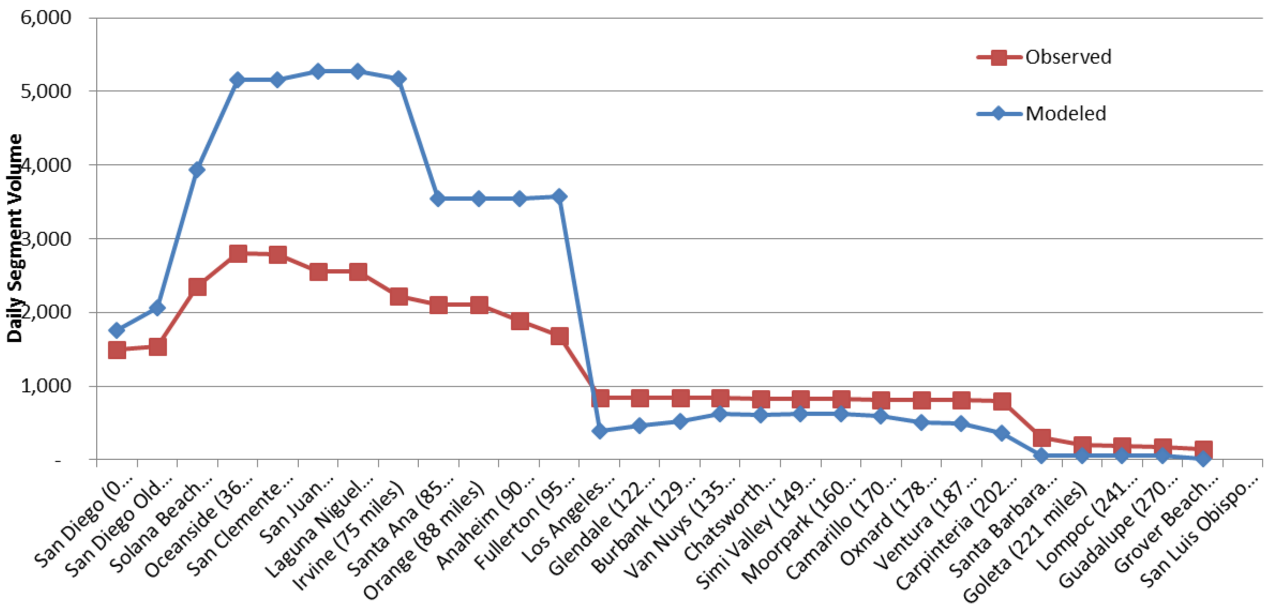




Source: Cambridge Systematics, Inc.

Figure 8-15 shows Amtrak's Pacific Surfliner route, running from San Diego, through Los Angeles to San Luis Obispo. The modeled long-distance segment volumes from San Diego to Los Angeles were overpredicted and long-distance segment volumes from Los Angeles to San Luis Obispo were slightly underpredicted by the model. The overprediction from San Diego to Los Angeles was somewhat expected since Year 2010 service levels were shown for that portion of the route.[31]

Figure 8-15 Amtrak Pacific Surfliner: Average Daily Long-Distance Loads (Observed Data Estimated from 2000 to 2010 Line Ridership)



Source: Cambridge Systematics, Inc.

The results shown above show that the BPM-V3 is reasonably sensitive to the changes in socioeconomic conditions and CVR levels of service that occurred between the 2000 and 2010.

Comparison to Year 2000 Observed Air Data

Background

The BPM-V3 was calibrated to reproduce intra-California air travel by California residents estimated from the 2012-2013 California Statewide Household Travel Survey. The model was validated against air trips between California airports estimated from the U.S. DOT 10 percent origin-destination survey airline data collected by the Bureau of Transportation Statistics. The 10 percent ticket sample data provides information on the originating, connecting, and final destination airports, but not the residence of the ticket holder. Thus, the intra-California air travel by only residents of California cannot be determined. The intra-California travel includes travel by non-residents of California and may also include some travel for connecting flights. For

[31] An archived Amtrak press release from 1999 documented 11 round trips per day on the newly branded Pacific Surfliner service:

http://www.trainweb.com/amtrak_press_releases/news/pr/atk_nov18.html#sthash.CiN4OX79.dpbs

while an archived 2010 Pacific Surfliner schedule showed 12 round trips per day between San Diego and Los Angeles Union Station:

http://juckins.net/amtrak_timetables/archive/timetables_Pacific_Surfliner_CA_Coastal_Services_20100510.pdf

Service between specific stations may have varied more depending on stop patterns.

example, international travelers arriving at, say, San Francisco or Los Angles on a foreign carrier and transferring to a domestic intra-California flight to complete their travel are considered as intra-California flights, not connecting flights.

For 2010, the results for intra-California air travel by California residents based on the calibrated BPM-V3 was about 75 percent of the 2010 air travel between California airports estimated from the 10 percent ticket sample data.

Table 8-11 shows the observed and modeled air travel for 2010 and 2000 between regions for four major regions in California. Even though there were nine percent fewer statewide households in 2000 than 2010, the observed 2000 air travel for the selected airports was 25 percent higher than 2010. Overall, the 14 percent decrease in air travel for the key interchanges was close to the 13 percent decrease in total long-distance trips from 2010 to 2000 backcast by the BPM-V3.

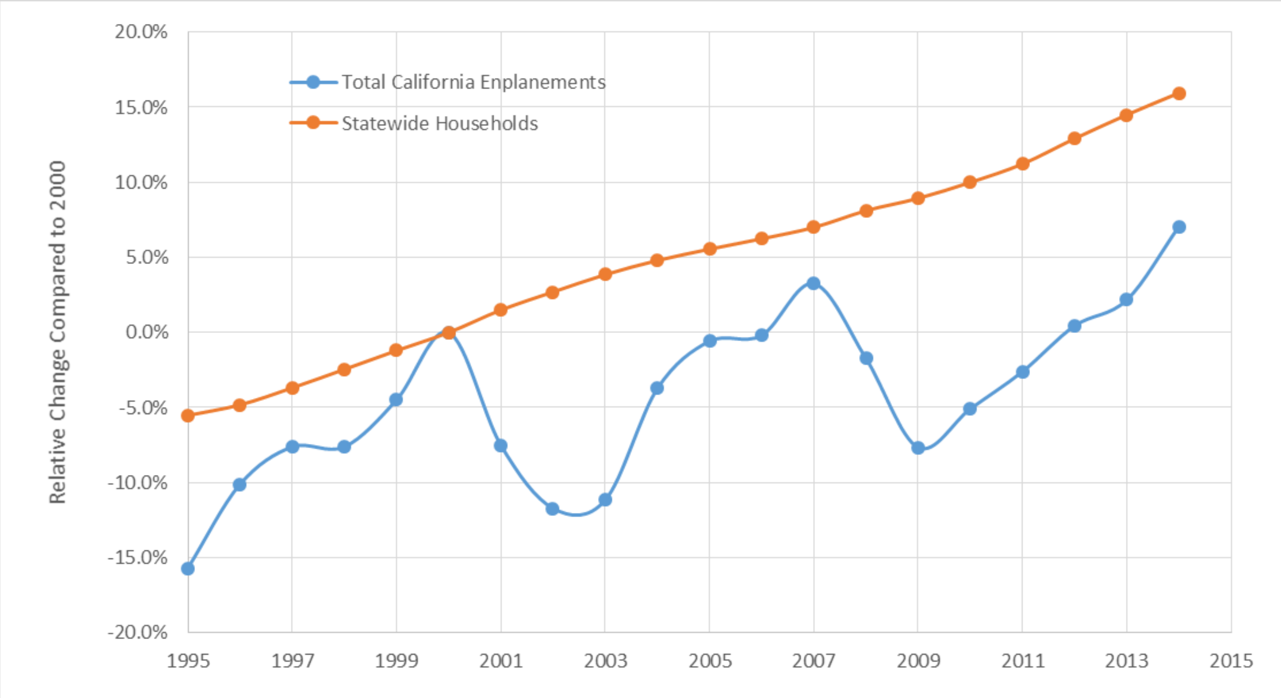
Table 8-11 Observed and Modeled Annual Air Trips for Year 2000 and Year 2010 between Key Regions

		Observed[a]			Modeled		
		2010	2000	Percent Difference (2000 vs. 2010)	Calibrated 2010	2000 Backcast	Percent Difference (2000 vs. 2010)
SANDAG	MTC	2,458,650	2,615,790	6%	1,324,994	993,528	-25%
	SACOG	695,660	723,700	4%	408,745	331,466	-19%
SCAG	MTC	6,967,880	9,365,240	34%	5,043,070	4,431,177	-12%
	SACOG	1,909,160	2,313,250	21%	1,914,261	1,690,116	-12%
Total		**12,031,350**	**15,017,980**	**25%**	**8,691,070**	**7,446,287**	**-14%**

[a] Source: Summarized by CS from data provided by Parsons Brinckerhoff estimates of total intra-California air enplanements based on 10 percent ticket sample data.

The 2000 to 2010 time period, of course, covered two major upheavals that had major impacts on air travel: the impact of the September 11, 2001 terrorist attack and the impact of the 2008 Great Recession. Those upheavals are clearly evident in Figure 8-16 which shows the relative differences in total enplanements (to all destinations) from 2000 for California airports. Figure 8-16 also shows the relative difference in statewide households from 2000.

Figure 8-16 Relative Change from 2000 Conditions in California Airport Enplanements and Households



Source: Cambridge Systematics, Inc.

In the year 2000 backcast results presented in Table 8-11, terminal and wait times were assumed to be identical to those used for Year 2010. Specifically, in 2010, 22 minutes of terminal time and 55 minutes of wait time[32] at the origin airport have been included as component parts of the air mode constants. As a test, the air constants were reduced by an equivalent of 30 minutes to represent changes in terminal and wait times resulting from less security processing time in 2000. Table 8-12 shows the numbers of air trips for the key regions.

[32] Terminal time is the time from curb to the gate at the origin or from the seat to the curb at the destination. Wait time is the time from arrival at the gate to push-back from the gate.

Table 8-12 Observed and Modeled Annual Air Trips for Year 2000 and Year 2010 between Key Regions – Reduced Terminal and Wait Times for 2000

		Observed[a]			Modeled		
		2010	2000	Percent Difference (2000 vs. 2010)	Calibrated 2010	2000 Backcast	Percent Difference (2000 vs. 2010)
SANDAG	MTC	2,458,650	2,615,790	6%	1,324,994	1,141,591	-14%
	SACOG	695,660	723,700	4%	408,745	379,243	-7%
SCAG	MTC	6,967,880	9,365,240	34%	5,043,070	5,252,759	4%
	SACOG	1,909,160	2,313,250	21%	1,914,261	2,023,932	6%
Total		**12,031,350**	**15,017,980**	**25%**	**8,691,070**	**8,797,525**	**1%**

[a] Source: Summarized by CS from data provided by Parsons-Brinckerhoff (Lou Wohlinetz) estimates of total intra-California air enplanements based on 10 percent ticket sample data.

The 30-minute decrease in terminal and wait times was simply a test to show the possible impact of changes in security processing time. While that change did not result in BPM-V3 backcast fully matching the observed differences in air travel between 2010 and 2000, it did move the 2000 backcast in the correct direction.

Other changes in the air travel experience occurred between 2000 and 2010. Table 8-13 lists time components for air travel and changes that occurred during that period. Not included in Table 8-13 are the changes in travelers' perceptions of air travel due to 9/11 and due to other changes to the airline experience, such as reduction of in-flight food, new fees, higher load factors, less legroom, the burden of having to pack carry-on bags that adhere to security protocol, and a general anxiety associated with air travel due to perceived security threats. In addition, many airlines have changed their business models from focusing on load factors to managing yield. The focus on load factors frequently resulted in fare discounts being offered for flights during the few days prior to departure as well as feeder flights from smaller airports being offered by major airline "partners." The focus on yield management has changed many of the former practices. All of these changes in air travel could be contributing to the differences between estimated observed air trips in 2000 and the backcast results.

Table 8-13 Changes in Air Travel Time Components between 2000 and 2010

Time Component	Changes Since 2000
Wait Time	
Arrival at gate to push-back of airplane	• Boarding starts 30 minutes or more prior to departure • Boarding by section rather than row • Changes in baggage fees led to increases in carry-on luggage and longer boarding times • Need to arrive at gate early to get good place in line so overhead baggage space might be available
Origin Terminal Time	
Time to walk (or ride a shuttle) between the parking area and terminal	• Elimination of some close in parking for security • Increased parking charges may encourage more remote parking
Time to receive a ticket or boarding pass	• Increased use of internet check-in • Increased use of boarding pass kiosks • Changes (reductions) in airline ticket counter personnel as cost-savings measures
Time to check luggage	• Changing baggage rules – checked baggage charges led to more carry-on baggage (see wait time) • Increased security (e.g. x-ray of baggage) led to earlier cut-off times for baggage checking
Time to clear security	• Changing TSA rules including, for example: • Increased screening times • Introduction of full body scans led to need to remove shoes, belts, all pocket contents, etc. • Changes in reliability of screening time
Time to walk from security to the boarding area or platform	• Need to "get dressed" after passing security
Destination Terminal Time	
Time to de-board the airplane or train	• Increases in carry-on baggage increased de-boarding time
Time to walk from the plane/train to baggage claim	• No real change
Time to pick up baggage	• Increased use of carry-ons may have decreased need to retrieve baggage • Increased cost cutting (personnel reductions) may have led to increased wait times for luggage to arrive at baggage claim
Time to walk (or ride a shuttle) between the terminal and parking area, or to other ground transportation modes	• Increased security eliminated ability for rides to wait at the curb for passengers • Increased parking charges may encourage more remote parking (i.e. for return trip)

Source: Cambridge Systematics, Inc.

8.4 Year 2010 Sensitivity Analysis

In addition to validation, a number of model runs for Year 2010 were performed to assess the model's sensitivity to various changes in level-of-service characteristics for different modes. This sensitivity testing included evaluating a high-speed rail system that has similar level-of-service characteristics as the Northeast Corridor and by performing a number of model runs, adjusting one variable at a time, to evaluate self- and cross-elasticities of level-of-service variables.

HSR Service Levels Approximating Those for the NEC

HSR ridership and revenue were forecasted using service similar to the Northeast Corridor in the U.S. ("NEC-like") for 2010 conditions, and compared the result to forecasted results for a CHSRA Phase 1 service for Year 2010. The primary value of the NEC-like run is the comparison of the forecasts based on a system with NEC-like service (much inferior to CHSR) to those from a Phase 1 service to determine if the model is reasonably sensitive to level-of-service changes.

Table 8-14 compares average station-to-station level-of-service for NEC-like scenario to the CHSRA Phase 1 scenario. CS developed fare models for the NEC-like system by developing regression models using a Year 2008 Acela (the NEC system train service operated by Amtrak) fare table coupled with distance information to estimate boarding- and distance-based fare components that could be applied for the NEC-like service. The NEC-like fare structure is substantially higher than the fare structure assumed for the CHSRA system. Year 2011 Acela scheduled travel times between stations coupled with distance information were used to develop a regression equation of speed versus distance between stations. The regression equation was then applied to the CHSRA stations to obtain in-vehicle travel times between stations. The resulting average in-vehicle travel times on the NEC-like service were approximately 50 percent higher than the Phase 1 travel times. Average headways between trains for station-to-station movements for the NEC-like service were between 30 and 60 minutes, closely matching the published Year 2011 Acela schedule. On average, headways for the NEC-like scenario are 30 to 50 percent higher than those for the Phase 1 scenario.

Table 8-14 Average Station-to-Station Level-of-Service for NEC-Like Scenario and Phase 1 Scenario

	Peak			Off-Peak		
	Phase 1	NEC-Like	Percent Difference	Phase 1	NEC-Like	Percent Difference
Fare (2014 Dollars)	$64	$114	78%	$64	$114	78%
In-vehicle Time (Minutes)	102	157	54%	111	158	42%
Headway (Minutes)	32	47	47%	35	47	34%

Source: Cambridge Systematics, Inc.

The increase in fare and travel time for the NEC-like scenario compared to the Phase 1 scenario resulted in 47 percent less ridership on the NEC-like system, as shown in Table 8-15. These results indicate that the BPM-V3 model is sensitive to level-of-service changes. If the CHSRA system was more similar to the Acela service provided in the Northeast Corridor, forecasted ridership would be much lower than the ridership forecast for the proposed CHSRA system.

Table 8-15 HSR Ridership: Year 2010 Phase 1 Blended versus NEC-Like Scenario

	Phase 1	NEC-Like	Percent Change
Long-Distance (Excluding Intra-SCAG and Intra-MTC)	19.6	10.5	-47%
Total (Including Intra-SCAG and Intra-MTC)	24.7	14.0	-43%

Source: Cambridge Systematics, Inc.

Elasticity Analysis

Model sensitivity test runs were evaluated using the Year 2010 Phase 1 Scenario. A system characteristic (e.g., travel time) was uniformly factored in each run to produce new estimates of mode use for each mode. Overall mode shares, elasticities, and cross-elasticities for each mode for each run were estimated. The elasticities reflect the change in demand for HSR based on a change in a HSR input variable. A cross-elasticity measures the change in demand for a competing mode (e.g. auto) based on a change in an input variable for HSR. The log arc elasticity formula has been identified as the measure that most closely replicates point elasticity and was used for elasticity calculations, as shown in Equation 1.

$$\eta = \frac{\Delta LN(Q)}{\Delta LN(P)} = \frac{LN(Q_2) - LN(Q_1)}{LN(P_2) - LN(P_1)}$$ (Equation 1)

Table 8-16 presents the mode shares and model elasticities and cross-elasticities based on the sensitivity test runs for the BPM-V3, the Version 2 model, and the Version 1 model. In most cases, the BPM-V3 model is relatively inelastic (i.e. less than 1.0, or that point where a one percent change in the "price" produces a one percent change in "quantity") with respect to changes in the input variables. Auto shares are very inelastic with respect to changes in input variables. This should be expected since auto generally captures over 90 percent of the travel market.

HSR mode share elasticities show that high-speed rail mode share reacts to key system variables but is relatively inelastic (i.e. less than 1.0) with regard to cost, in-vehicle time, and headway.

The BPM-V3 is more sensitive to changes in cost, headway, and reliability and less sensitive to changes in in-vehicle time than the Version 2 model.

Table 8-16 Summary of BPM-V3, Version 2, and Version 1 Models Elasticities

Variable Modified (for HSR Skims)	Percent Change from Base Skim	BPM-V3 Elasticities				Model V2 Elasticities				Percent Change from Base Skim	Model V1 Elasticities			
		Auto	Air	HSR	CVR	Auto	Air	HSR	CVR		Auto	Air	HSR	CVR
Cost	-50%	0.02	0.16	-0.58	-0.18	0.02	0.09	-0.42	0.12	-25%	0.04	0.37	-0.53	0.22
Cost	50%	0.02	0.17	-1.00	-0.28	0.02	0.11	-0.72	0.19	25%	0.04	0.44	-0.71	0.23
IVT	-50%	0.01	0.10	-0.26	-0.15	0.01	0.11	-0.35	0.06	50%	0.05	0.67	-1.05	0.24
IVT	50%	0.01	0.12	-0.45	-0.22	0.02	0.12	-0.57	0.11					
Headway	-50%	0.01	0.04	-0.21	-0.08	0.00	0.01	-0.10	0.04	33%	0.02	0.12	-0.22	0.07
Headway	50%	0.01	0.05	-0.30	-0.11	0.00	0.01	-0.14	0.05					
Reliability	-25%	-0.02	-0.12	0.85	0.26	-0.01	-0.04	0.43	-0.13					
Reliability	-50%	-0.01	-0.09	0.72	0.20	-0.01	-0.03	0.36	-0.11					

Bold, italicized are direct elasticities.

Source: Cambridge Systematics, Inc.