SCAG Regional Travel Demand Model and 2012 Model Validation

March 2016

Southern California Association of Governments

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SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

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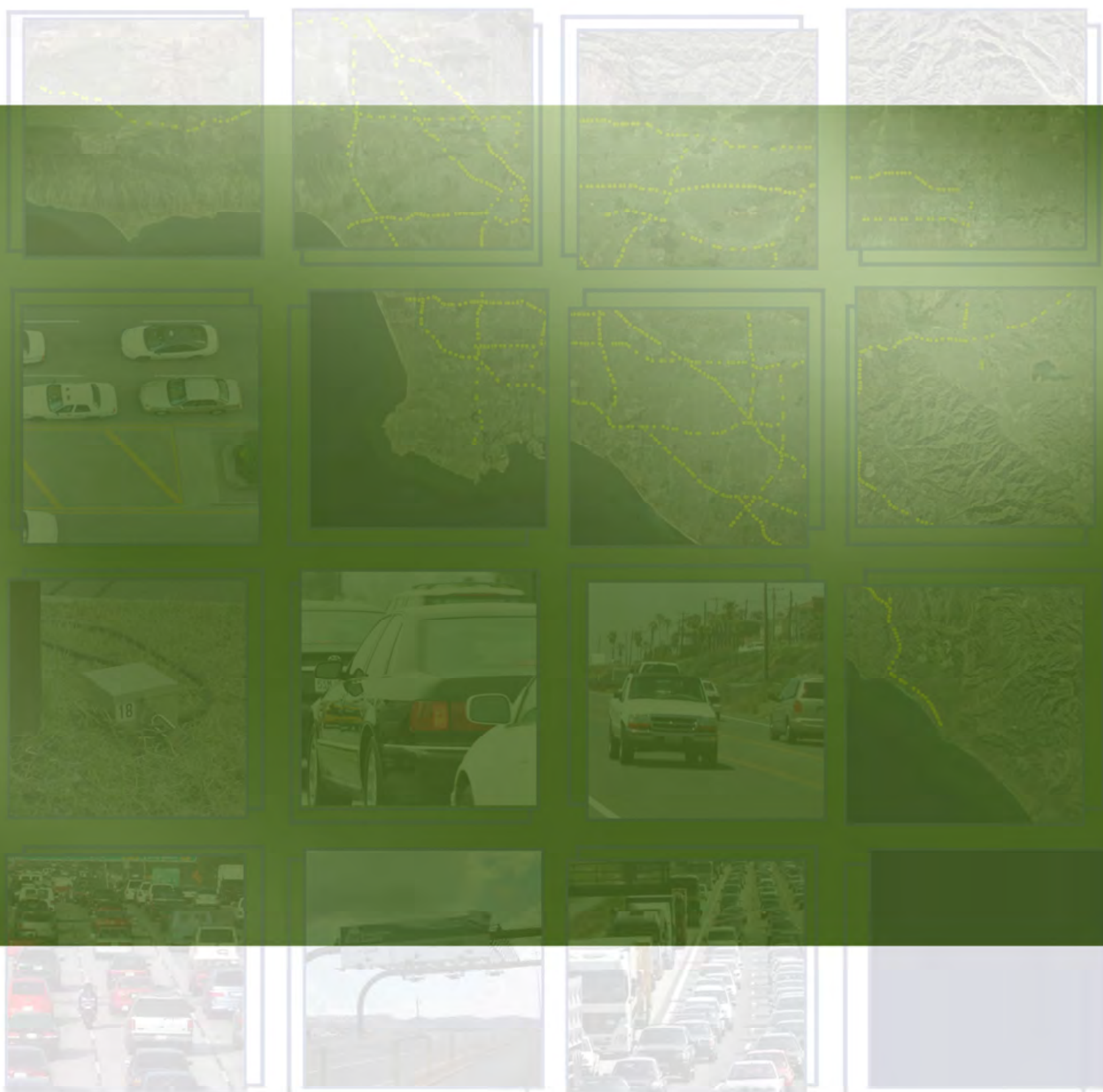
PREFACE



PREFACE

Questions about the content of this report, as well as requests for more detailed information, should be directed to Guoxiong Huang, SCAG's Manager of Regional Transportation Modeling, at (213) 236-1948 or via e-mail at HUANG@scag.ca.gov.The Southern California Association of Governments (SCAG) is a voluntary association of six counties - Los Angeles, Orange, Ventura, Riverside, San Bernardino, and Imperial - and of 191 cities within those counties. SCAG's organizational purpose is cooperative planning and governmental coordination at the regional level. SCAG is mandated by State and federal law to plan and implement a Regional Transportation Plan (RTP) (updated every four years), a bi-annual Federal Transportation Improvement Program (FTIP), and to identify and analyze Transportation Control Measures (TCMs) and Transportation Strategies for incorporation into the South Coast Air Quality Management Plan (AQMP).

This report describes how SCAG forecasts travel behavior for the Southern California Region using computer-based software programs also known as the Regional Transportation Model. The specific focus of this report is on the transportation modeling procedures that have been used to produce travel forecasts for the Year 2012, including recent enhancements to the model to augment its capabilities in addressing policy directives and other transportation programs.

Year 2012 is the base year for the transportation planning period and the current Regional Transportation Model. This model base year is also being applied as part of the Regional Transportation Plan/ Sustainable Communiuties Strategies (RTP/SCS), the AQMP update, and in Congestion Management Programs (CMPs) prepared by individual counties within the Southern California Region.

The Regional Transportation Model provides a common foundation for transportation planning and decision-making by SCAG and other agencies within the Region. The Year 2012 base year travel data contained in this report will be referenced by, and of interest to, the general public, as well as local, State, and federal agencies involved in transportation planning and traffic engineering. A number of State, sub-regional, and local agencies in the SCAG Region also perform travel demand model forecasting for their own transportation planning and engineering purposes. These modeling programs require a high degree of coordination and cooperation with SCAG's regional modeling program.

State agencies involved in travel forecasting include the California Department of Transportation (Caltrans) Districts 7, 8, 11, and 12. Sub-regional agencies include the Los Angeles County Metropolitan Transportation Authority (LA Metro), the Orange County Transportation Authority (OCTA), the Riverside County Transportation Commission (RCTC), San Bernardino Associated Governments (SANBAG), the Ventura County Transportation Commission (VCTC), the Imperial County Transportation Commission (ICTC), the County of Orange Environmental Management Agency, and other regional and local transportation agencies. Local agencies, including cities and counties within the Region, also maintain transportation modeling programs. Several of these agencies have contributed directly to preparation of SCAG's Year 2012 Model Validation.

This report summarizes the enhancement, calibration, and validation of the SCAG Regional Transportation Model to the new 2012 base year. This model update was performed in preparation for the development and evaluation of the SCAG 2016-2040 (RTP/SCS). The model is capable of evaluating a wide variety of projects and transportation policies, including the addition of highway pricing strategies, expansion of existing transit services, introduction of new types of transportation services (such as bus rapid transit and high speed rail), and land use policies. As part of the 2012 model update, various submodels were re-estimated and re-calibrated using information from the 2012 California Household Travel Survey (CHTS). This update also enhanced the model sensitivities required to evaluate the land use and transportation policy scenarios that are envisioned by California's greenhouse gas (GHG) emission reduction legislation, Senate Bill (SB) 375, and meets the requirements and recommendations in the California Transportation Commission's 2010 RTP Guidelines.

The 2012 model exhibits several important features:

- Comprehensive calibration and validation to 2012 travel conditions
- Trip market strata defined by car sufficiency and household income groups used throughout the entire demand models,
- Re-estimated auto ownership model, sensitive to transit and non-motorized accessibility, multi-dwelling family housing, and residential and employment mixed use densities,
- Added auto ownership sensitivity in the destination choice and mode choice models,
- Updated trip production cross-classification models,
- Re-estimated destination choice model
- Re-calibrated nested mode choice model,
- Multi-tiered zone system, consisting of approximately 11,267 zones used thru mode choice, and 4,109 zones used for time-of-day and assignment,
- Addition of a binary toll/no toll choice model to the mode choice model,
- Enhanced sensitivity to housing and employment density, mixed land use development, and accessibility to destinations by transit and non-motorized travel in trip distribution and mode choice models, and
- Ability to forecast intra-regional high-speed rail ridership,
- A High Occupancy Vehicle (HOV) diversion model applied prior to highway assignment to split carpool trips between vehicles that use the HOV lanes and vehicles that remain on the general purpose flow lanes,
- Updated Heavy-Duty Truck (HDT) model, and
- Refinement of congestion and pricing components in the model.

The Year 2012 model results have been compared to independent sources of travel data within the Region, such as auto and truck traffic counts, transit boarding counts, Vehicle Miles of Travel (VMT) from Highway Performance Monitoring System (HPMS), speed data from Freeway Performance Measurement System (PeMS), and other travel survey data. The Regional Transportation Model sufficiently replicates the observed validation data as described herein. As such, the model is validated for use in preparing travel forecasts for the SCAG 2016-2040 RTP/SCS.

Chapter 1 – Overview

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CHAPTER 1 – OVERVIEW

Introduction

SCAG has evolved over the past four decades into the largest of nearly 700 councils of government in the United States. SCAG functions as the Metropolitan Planning Organization for six counties: Los Angeles, Orange, San Bernardino, Riverside, Ventura, and Imperial. The region encompasses a population exceeding 18 million persons in an area of more than 38,000 square miles.

SCAG is the primary agency responsible for the development and maintenance of travel demand forecasting models for the SCAG region. SCAG has been developing and improving these travel demand forecasting models since 1967. SCAG applies the models to provide state of the practice quantitative analysis for the RTP/SCS, the FTIP, and AQMPs. The Regional Model is also used to evaluate other transportation proposals within the region. The model is based on Caliper Corporation's TransCAD modeling software.

This Validation Summary Report combines information from several documents and other sources related to the enhancement and validation of the 2012 Regional Travel Demand Model (Regional Model) for Southern California. The Regional Model is managed and operated by the SCAG with development assistance from private consulting firms and academic institutions. The model is one of several tools used by SCAG to forecast land use and travel demand. Expert panels have overseen the development/enhancement of the SCAG land use and travel demand modeling tools. A Peer Review panel was assembled to review the last major update to the model structure. The panel's recommendations are reflected in the 2012 Regional Model.

Transportation Model Overview

SCAG develops and maintains state-of-the-art transportation models to support SCAG's planning program. These models include:

Trip Based Model	• **2016 RTP/SCS**
Activity Based Model	• **2020 RTP/SCS**
Sub-regional Model Tool	• **Modeling Tools for Locals**
Heavy-Duty Truck Model	• **Truck and Goods Movements**
Air Quality Models	• **Conformity/GHG Determination**

These models are applied by SCAG to forecast transportation conditions and resulting air quality.

Trip-Based Model (Existing Travel Demand Model)

The Regional Travel Demand Model provides travel forecasting capabilities for the analysis of SCAG's plans and programs. The trip-based model was Peer Reviewed in May 2011 and found consistent with the state-of-the-practice. This report describes the various component of the Trip-Based Model, Heavy-Duty Truck Model, and the results of the Year 2012 model validation.

Activity-Based Model

The Activity-Based Model (ABM) is a new generation of travel demand model. The ABM simulates daily activities and travel patterns of all individuals in the region, as affected by transportation system level of service. This new modeling system is designed to meet or exceed federal regulations and state laws/requirements. The ABM Model is in the late stages of development/testing and is expected to be the primary transportation model used in the development of the Year 2020 RTP/SCS.

Subregional Model Tool

The new Subregional Modeling Development Tool (SMDT) greatly simplifies the creation of subregional models. The SMDT fully automates the development of all aspects of a subregional model. The SMDT is used by transportation commissions, counties, subregions, and cities wishing to create subregional models based on SCAG's new Regional Model. The Tool promotes model consistency between the Region's various model agencies and greatly reduces the cost and effort required to create subregional models.

Heavy-Duty Truck Model

Southern California Association of Governments developed the Heavy Duty Truck (HDT) model to evaluate important policy choices and investment decisions. The HDT model is a primary analysis tool to support the goods movement policy decisions made by SCAG and regional stakeholders.

Air Quality Model

EMFAC is an emission factors model developed by the Air Resources Board (ARB) for calculating emission inventories for vehicles in California. This is the emission model approved by the Environmental Protection Agency (EPA) for calculating vehicle emissions for conformity purposes in California.

Focus of Validation Summary Report

The focus of the Validation Summary Report is limited to the existing trip-based model and the Heavy Duty Truck Model.

California SB 375

One of the key factors behind the current model update is California's SB 375 that requires metropolitan areas, such as the SCAG region, to meet regional GHG emission reduction targets for 2020 and 2035. The requirements of SB 375 and the model's implementation and function in this regard were key topics for the May 2011 Peer Review.

California Senate Bill 375 and Sustainable Communities Strategies

SB 375 became law in California effective January 1, 2009. This law requires California's Air Resources Board (ARB) to develop regional greenhouse gas emission reduction targets for passenger vehicles for 2020 and 2035 for each region covered by one of the State's 18 MPOs, including SCAG. SB 375 was adopted as an "implementation mechanism" for California's Assembly Bill (AB) 32, the Global Warming Solutions Act, which requires 2020 greenhouse gas emissions statewide to be no higher than 1990 levels.

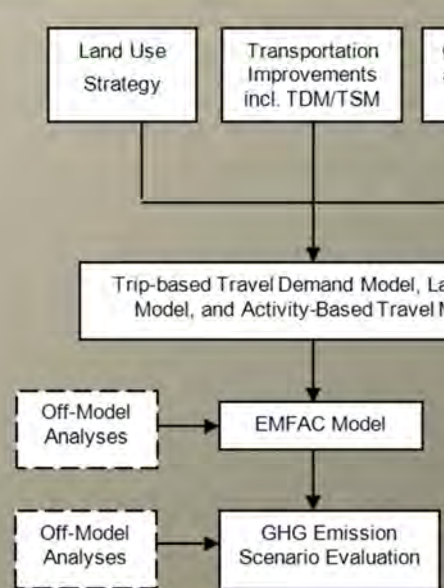
Each Metropolitan Planning Organization (MPO) is required to develop a Sustainable Communities Strategy that demonstrates how the region will meet the greenhouse emission reductions specified by the ARB targets through an integrated process that combines land use, housing, and transportation planning. The SCS becomes part of the Regional Transportation Plan.

SCAG's SCS scenarios comprise seven elements of strategies:

- Land Use and Growth
- Highways and Arterials
- Transit
- Travel Demand Management
- Non-Motorized Transportation System
- Transportation System Management
- Pricing

ARB's website for SB 375 is located at:
www.arb.ca.gov/cc/SB 375/SB 375.htm

Proposed Technical Methodology for Estimating GHG Emissions



Note: TDM - Transportation Demand Management, TSM - Transportation System Management.

Technical Approach of the Validation Process

Model validation is defined as the process by which base year model results are compared to actual, observed travel pattern data such as traffic counts and transit ridership data. SCAG performs a validation of its transportation model for each planning cycle for the Southern California region. A planning cycle is typically four years, corresponding to the update of the RTP/SCS. The "base year" for the current planning period and model is 2012; and 2040 is the forecast year.

Model validation is a regular and essential modeling process that supports the development of the RTP/SCS, FTIP, and AQMPs. In the past, SCAG has prepared a model validation report for each of the previous planning cycle model base years: 1980, 1984, 1987, 1990, 1994, 1997, 2000, 2003 and 2008. The base year of 2012 in the current model replaces the previous base year of 2008.

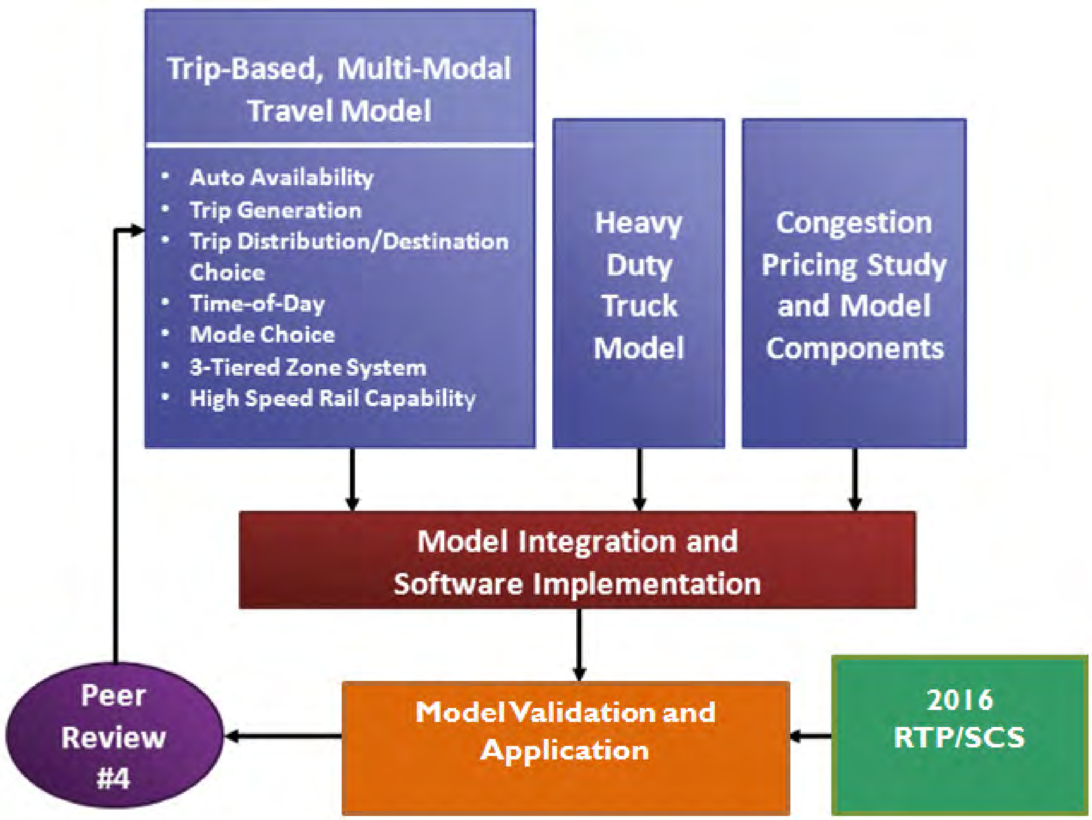
Overview of Model Enhancements

SCAG updated the Regional Travel Demand Model for use in the 2016 RTP/SCS analysis, including calibration of the various components based on the 2012 California Household Travel Survey and a detailed model validation to replicate existing travel conditions. In addition, SCAG implemented a model improvement program, shown in Figure 1-1, to further enhance the model's performance. Specific improvements to update the SCAG model to the 2012 base year and to enhance the model's operation and performance include:

1. Refinement of model features introduced in the 2008 Model:
    a. Trip market strata defined by car sufficiency and household income groups;
    b. Updated auto ownership model, sensitive to transit and non-motorized accessibility, multi-dwelling family housing, and residential and employment mixed use densities;
    c. Added auto ownership sensitivity in the destination choice and mode choice models;
    d. Updated HBW trip production cross-classification model;
    e. Destination choice model, replacing the previous gravity models for all purposes except home-based college and school trips;
    f. Re-designed and re-calibrated mode choice model;
    g. Multi-tiered zone system, consisting of approximately 11,267 zones used through mode choice, and 4,109 zones used for time-of-day choice and assignment;
    h. Addition of a binary toll/no toll choice model to the mode choice model;
    i. Enhanced sensitivity to housing and employment density, mixed land use development, and accessibility to destinations by transit and non-motorized travel in trip distribution and mode choice models;
    j. Ability to forecast intra-regional high-speed rail ridership and its impact on the region's other transit systems;
    k. An HOV diversion model applied prior to highway assignment to split carpool trips between vehicles that use the HOV lanes and vehicles that remain on the general purpose flow lanes;
    l. Updates to the Heavy-Duty Truck Model; and
    m. Refinement of congestion pricing components in the model.

2. Model enhancements performed specifically for the 2012 Model include:
   a. Recalibration of the entire model to targets developed based on the 2012 California Household Travel Survey and 2011 transit on-board survey and ridership data.
   b. Updates to the vehicle ownership model,
   c. Re-estimation of trip production rates
   d. Recalibration of the trip distribution and mode choice model,
   e. Upgrades to the heavy-duty truck model,
   f. Updates to the highway and transit networks,
   g. Enhancement of sensitivity to potential SCS strategies such as pricing and transit-oriented development strategies.
   h. All of the Model's basic trip-making characteristics were updated based on the 2012 California Household Travel Survey
   i. Price based variables were updated to represent 2011 dollars, and
   j. A comprehensive model validation was performed to ensure the Model properly replicates base-year (2012) travel conditions

Figure 1-1: SCAG Regional Transportation Demand Model Enhancement Program



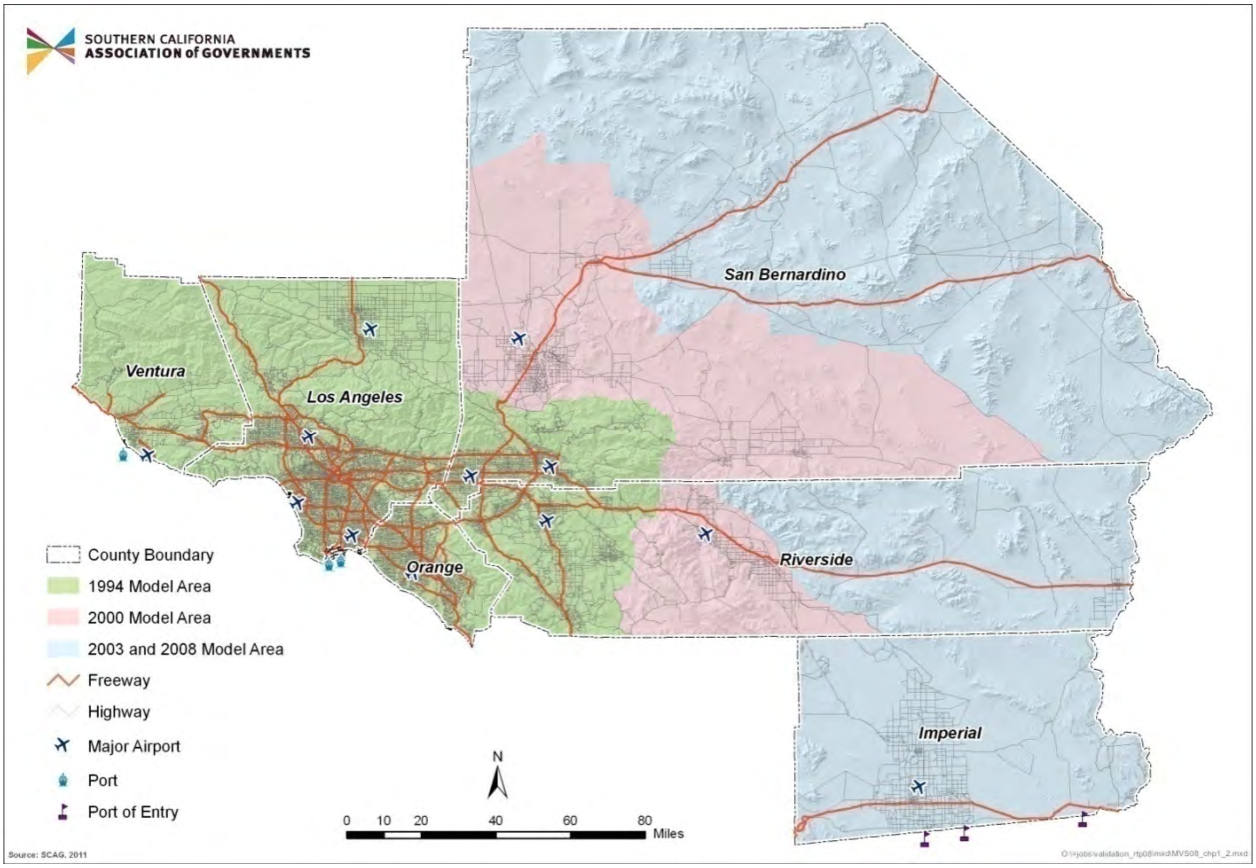
Modeling Area

The modeling area of the SCAG 2012 Regional Travel Demand Model is same as the modeling area of 2008 Model and covers the following six counties in their entirety:

- Imperial County,
- Los Angeles County,
- Orange County,
- Riverside County,
- San Bernardino County, and
- Ventura County.

Figure 1-2 shows the Modeling Area. The figure also indicates how the modeling area has expanded over time.

Figure 1-2: Modeling Area



Zone System

Socioeconomic data and other information for the model are contained in geographically defined areas known as Transportation Analysis Zones (TAZ). The TAZs are attached to the networks using centroid connectors that allow travelers (trips) to access to the transportation system by simulating local and neighborhood streets. They provide the spatial unit (or geographical area) within which travel behavior and traffic generation are estimated. TAZs are ideally, but not always, sized and shaped to provide a relatively homogeneous amount and type of activity.

The SCAG model uses a tiered zone system structure as shown in Figure 2-2 that allows for micro (i.e., neighborhood) and macro-scale (i.e., regional) analysis and reporting.

In order to more accurately model detailed travel movements throughout the region for the base and horizon years, the TAZ structure has been modified to enhance the precision of micro-level land use and smart growth analysis for the RTP/SCS. In addition, The Model contains 40 external stations to facilitate modeling of trips to, from, and through the region. The TAZ modification process involved extensive coordination with sub regional modeling agencies throughout the region. The Regional Model includes two tiers of TAZ. The first tier contains 4,109 internal zones, while the second tier contains

11,267 internal zones. All Tier 2 zones nest within Tier 1 zones. Table 1-1 and Figure 1-3 provide statistical information and a graphical display of the zone structure.

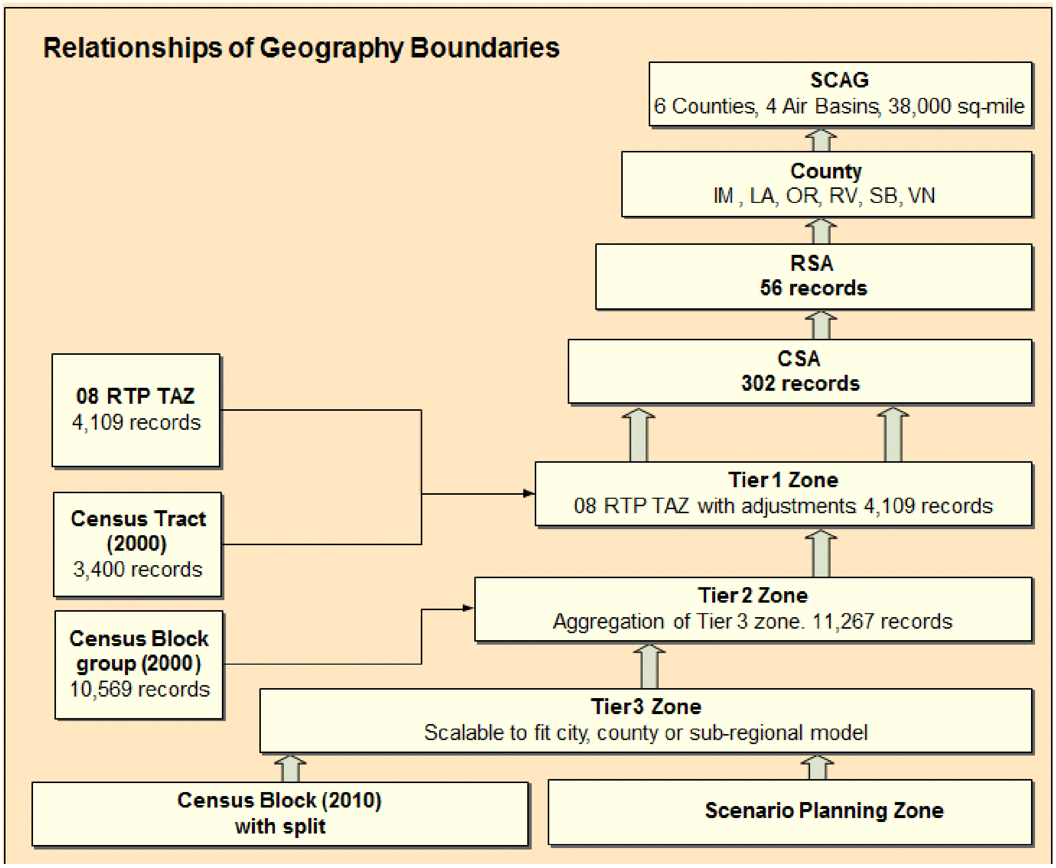
Table 1-1: Summary of different geographic zones

Modeling Area	2010 Census Tract	2010 Census Block Group	RSA *	CSA**	Tier 1 TAZ (Internal)	Tier 2 TAZ (Internal)
Imperial County	31	96	1	15	110	239
Los Angeles County	2,346	6,425	21	155	2,243	5,697
Orange County	583	1,823	10	43	666	1,741
Riverside County	453	1,030	11	38	478	1,532
San Bernardino County	369	1,092	7	34	402	1,395
Ventura County	174	430	6	17	210	663
Total	**3,956**	**10,896**	**56**	**302**	**4,109**	**11,267**

**RSA – Regional Statistical Area*

***CSA - Community Statistical Area*

Figure 1-3: Structure of the Tiered Zone System in the SCAG Model



Methodology

A tiered TAZ system was jointly developed by SCAG and its member agencies, based on sub-regional TAZs and SCAG MPUs (Minimum Planning Units). The 2016 RTP/SCS MPUs were built based on 2010 Census Block data with some splits added according to major road, natural and artificial barriers, satellite photo, land use, and local inputs. The TAZ Tier 1 is an aggregation of TAZ Tier 2 zones, which matches the total number and general geography of the previous Regional TAZs.

The following provides a description of the principles that guided the development of the new Regional TAZ System. These principles follow standard modeling practice.

- ***Consistency with 2009 TIGER/Line Tract Boundaries*** – Both tiers of the Regional TAZs are consistent with Census 2009 Topographically Integrated Geographic Encoding and Referencing (TIGER)/Line Tract boundaries. Regional TAZs are either entire census tracts or are wholly contained within a census tract. Some exceptions occur where census tracts consist of multi-part polygons or local inputs provide better boundaries.

- ***Consistency with 2009 TIGER/Line Block Group or Sub-regional TAZ Boundaries*** – To sensure the consistency, our TAZ boundary is maintained the same as the SCAG 2008 Model development.

- ***Consistency between the Two Tiers of the Regional TAZ System*** – The Tier 2 zones of the Regional Model's TAZ system are consistent with the Tier 1 zones. Tier 2 zones consist either of an entire Tier 1 zone or are wholly contained within a Tier 1 zone.

- ***Consistency with 2009 TIGER/Line Block Boundaries*** –To ease data collection and creation, zonal boundaries generally do not cross Census 2000 Blocks (updated boundary in 2009). Some exceptions occur where Census Blocks consist of multi-part polygons or local inputs provide better boundaries.

- ***Complement the Transportation System*** – A critical step in developing the TAZ system is defining the level of roadway facilities for which accurate forecasts are desired. To ensure an accurate distribution and traffic assignments, existing and future freeways and principal arterials are generally represented as regional TAZ boundaries, consistent with other zonal creation criteria.

- ***Homogeneous Land Use*** – Land use maps and general plan maps were used to identify existing and future land use. Ideally, it is best to limit the number of different land uses contained within a zone. However, given the geographic size of the regional TAZs and the mixed-use development patterns within the urban area, creating zones with uniform land uses was often difficult.

- ***Similar Population/Employment Size*** – Zones were developed to represent similar levels of future development (population and employment). This parameter was not strictly enforced given the sparse development of some areas, the intensity of nonresidential land uses within urban areas, and consideration for special generators (example - universities and airports).

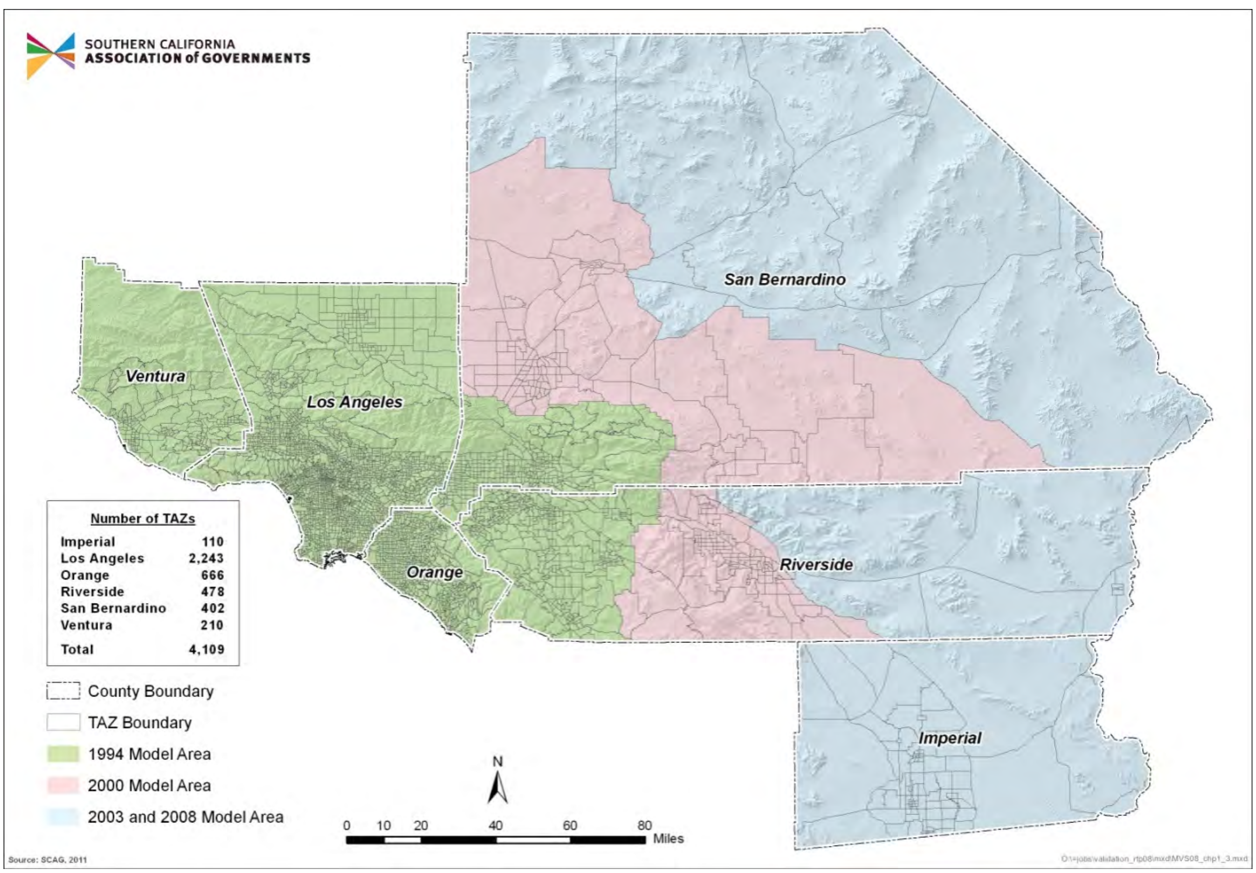
- ***Other Considerations*** – Natural and man-made boundaries are also considered in the definition of the zone system. Political jurisdictions, railroad lines, rivers, mountain ranges and other topographical barriers were considered in developing the two tiers of regional TAZs.

Procedures

Tier 2 zones originated from the 2009 TIGER/Line block group and sub-regional TAZ boundary files. ESRI ArcGIS was used to overlay these original maps with the existing TAZs, the highway network, land use maps, and satellite images. Then, the principles described above were applied. Where a Tier 2 zone needed to be subdivided, the 2009 TIGER/Line boundaries were followed. A tool, TAZDK, was developed in ArcGIS to assist data processing and quality control. Several analyses were undertaken to ensure that all Tier 2 zones were reasonable and that the entire SCAG area was covered by the new zones without slivers or overlaps. An additional step was incorporated in the development of the 2012 zone system to adjust TAZ boundaries to be consistent with the new Scenario Plan Zones (SPZ).

Once a clean Tier 2 TAZ map was created, the final Tier 2 zones were aggregated into 4,109 Tier 1 zones based on the pattern of the previous regional TAZs. Before finalizing the new regional TAZ system, automatic and manual examinations were conducted to ensure consistency with the above principles. The draft and final zone systems were shared with sub regional modeling agencies for their review and concurrence. Figure 1-4 shows the Tier 1 TAZs.

Figure 1-4: Transportation Analysis Zone System (Tier 1)



Overview of the Peer Review Process

A robust peer review process is an important component of the SCAG model development program. SCAG's 2012 Model uses the same model framework as the previous 2008 Model, which was developed using a comprehensive peer review. SCAG's peer review process has involved two levels of review and comment:

1) ***Expert Panels*** – SCAG assembled panels of experts for each of the major model improvement projects to provide review and guidance; and

2) ***Peer Review*** – Academic, MPO, Federal and other modeling experts to review SCAG's overall modeling program and modeling results to determine if they are satisfactory to support regional transportation planning analysis.

A series of four Peer Review panels were convened by SCAG for regional travel model validations. Panels were convened in January 2002 for the 1997 base year model; in November 2003 for the 2000 base year model; in January 2006 for the 2003 base year model; and in June 2011 for the 2008 base year model.

In 2002, SCAG initiated an effort to use new data to update and recalibrate its travel demand model. In January of that year, the first Peer Review of SCAG's model was conducted. At that time, the panel concluded that SCAG's model was at the leading edge of the state of the practice. The panel recommended several changes, including adding trip purpose, creating a vehicle availability model, and modifying the mode choice model. SCAG has implemented many of these recommendations.

The second Peer Review was held in November 2003. Topics reviewed during this meeting included validation targets, the revised vehicle availability model, trip generation, external trips, and the selection of variables for the mode choice model. At this same time, Cambridge Systematics was awarded a contract to address these concerns and update the travel demand model.

The third Peer Review in January 2006 focused on the previously updated model components, especially trip distribution, mode choice, and trip assignment. The panel determined that SCAG had developed a "state-of-the-practice" model. The panel highlighted several strengths, including the freight model, the strategic work trips, and the use of four time periods in assignment. The panel felt that SCAG had done a particularly good job with data collection, and that the planned speed study was a good next step.

The fourth Peer Review was held in June 2011. SCAG's 2008 Regional Travel Model Peer Review Panel was comprised of nationally-recognized experts in the fields of travel demand modeling and data collection and analysis. The panel members are shown in Table 1-2. The Peer Review Panel recommended several short-term considerations, including: addressing auto ownership sensitivity in the trip distribution and mode choice models; sensitivity testing to longer travel by medium and high density areas; traffic count averaging; heavy duty truck model validation; validation of speeds and travel times; and adding demographic profiles and maps to the validation report.

The 2012 validation utilizes the same Trip-Based Model previously peer reviewed in June 2011. The Peer Review Panel at that time found that the "SCAG travel demand model is an advanced 4-step model that meets and in many cases exceeds the state of the practice … the model is suitable for use in preparing the 2012 RTP, conformity analysis, and SCS". The current 2012 Model uses the same model structure and framework as the previous peer reviewed model, but has been updated to replicate current travel conditions. The update included utilizing up-to-date model input data, recalibration using new travel survey data, and validation using 2012 traffic data

Table 1-2: 2011 Regional Travel Model Peer Review Panel #4 (June 27-28, 2011)

Name	Organization
Guy Rousseau (Chair)	Atlanta Regional Commission
Chaushie Chu, Ph.D.	Los Angeles County Metropolitan Transportation Authority (LACMTA)
Chris Forinash	U.S. Environmental Protection Agency (EPA)
David Levinson, Ph.D.	University of Minnesota
David Ory, Ph.D.	Metropolitan Transportation Commission (MTC)
Eric Pihl	Federal Highway Administration (FHWA)
Kara M. Kockelman, P.E., Ph.D.	University of Texas, Austin; Expert Panel – Congestion Pricing
Ken Cervenka	Federal Transit Administration (FTA)
Mark Bradley	Mark Bradley Research and Consulting

Overview of Report

The input data, model enhancements, calibration, validation, and results of each of the modeling components of the SCAG 2012 Regional Model are summarized in the respective chapters:

- Chapter 1 – Overview
- Chapter 2 – Socioeconomic Input Data
- Chapter 3 – Trip Generation
- Chapter 4 – Transportation Networks
- Chapter 5 – Trip Distribution
- Chapter 6 – Mode Choice
- Chapter 7 – Heavy Duty Truck Model
- Chapter 8 – Time of Day Model
- Chapter 9 – Trip Assignment

Supplemental information is contained in the following appendices:

- Appendix A - Highway Network Coding Conventions
- Appendix B – Auto Operating Costs
- Appendix C – SCAG's Model Peer Review

Chapter 2 - Socioeconomic Input Data

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CHAPTER 2 – SOCIOECONOMIC INPUT DATA

Introduction

Socioeconomic data, which describes both demographic and economic characteristics of the region by TAZ, is used as major input to SCAG's travel demand model. Travel demand analysis is based on the concept that travel is a derived demand of activity participation. Zonal demographic data, such as population, households, and income, is directly related to demand for activity participation of the area; economic characteristics, such as jobs by industry, are linked with supply of an activity.

The socio-economic input data for year 2012 consists of various marginal and joint distributions of population and households for each TAZ. A total of 65 socio-economic variables and 8 joint distributions of two or more variables are developed as model inputs (see Tables 2-1 and 2-2). Those variables include population, households, school enrollments, household income, workers, and employment, etc. These variables are available for 4,109 Tier 1 TAZs and 11,267 Tier 2 TAZs, respectively.

The marginal and joint distributions of socio-economic variables were developed by SCAG forecasting staff using diverse public and private sources of data and advanced estimation methods. The major data sources include 2000 and 2010 Census, American Community Survey (ACS), California Department of Finance (DOF), California Employment Development Department (EDD), firm based InfoGroup data, 2012 Existing Land Use and County Assessor's Parcel Database.

The socio-economic input data at the TAZ level is estimated using three major processes: 1) development of three major variables (population, households, employment); 2) development of secondary variables (attributes of three major variables and workers); 3) development of joint distributions of population/households/workers by selected attributes.

Development of Three Major Variables

SCAG started the TAZ level socioeconomic input to the transportation model by estimating Population, Household, and Employment first.

Table 2-1: Description of Socio-Economic Variables

1.	**Population (8 variables)**
1.1.	Total Population: total number of people living within a zone. Total population is composed of residential population and group quarters population.
1.2.	Group Quarters (Non-Institutional) Population: is primarily comprised of students residing in dormitories, military personnel living in barracks, and individuals staying in homeless shelters. Group quarters (non-institutional) population does NOT include persons residing in institutions.
1.3.	Residential Population: the number of residents NOT living in "group quarters."
1.4.	Group Quarters Population living in student dormitories: Population living in college dormitories (includes college quarters off campus).
1.5.	Population by Age (4 variables): the number of population for different age groups: 5-17, 18-24, 16-64, and 65+.
2.	**Households (26 variables)**
2.1.	Total Households: Household refers to all of the people who occupy a housing unit. By definition there is only one household in an occupied housing unit.
2.2.	Households by Household Size (4 variables): the number of one-person households, two-person households, three-person households, and four or more person households.
2.3.	Households by Age of Householder (4 variables): the number of households with age of householder between 18 and 24 years old, 25 and 44, 45 and 64, and 65 or older.
2.4.	Households by Number of Workers (4 variables): the number of households with no worker, with one worker, with two workers, and with three workers or more.
2.5.	Households by Household Income (4 variables): the number of households with annual household income (in 2011 dollars) of less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000 or more.
2.6.	Households by Type of Dwelling Unit (2 variables): the number of households living in single-family detached housing, and living in other housing.
2.7.	Households by Number of College Students (3 variables): the number of households with no college student, with one college student, with two college students or more.
2.8.	Households by Number of Children age 5-17 (4 variables): the number of households with no child, with one child, with two children, and three children or more.
3.	**School Enrollment (2 variables)**
3.1.	K-12 School Enrollment: the total number of kindergarten through 12th grade (K-12) students enrolled in all public and private schools located within a zone. All elementary, middle (junior high), and high school students are included. This variable represents "students by place of attendance."
3.2.	College/University Enrollment: the total number of students enrolled in any public or private post-secondary school (college or university) that grant an associate degree or higher, located within a zone. This variable also represents "students by place of attendance."
4.	**Workers (4 variables)**
4.1.	Total Workers: total number of civilian workers residing in a zone. Workers are estimated by the place of residence.
4.2.	Workers by earning level (3 variables): the number of workers with earnings of less than $34,999, $35,000-$74,999, $75,000 or more.
5.	**Median Household Income (5 variables)**
5.1.	Median Household Income: Median Household Income is the median value of household income for all households within a zone. Household Income includes the income, from all sources, for all persons aged 15 years or older within a household.
5.2.	Median Household Income by Income Categories (4 variables): The median income is estimated for each of four different income categories: less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000.

6. Employment (17 variables)
6.1. The employment variables represent all jobs located within a zone (i.e., employment by place of work). Jobs are composed of wage and salary jobs and self-employed jobs. Jobs are categorized into 13 sectors based on North American Industry Classification System (NAICS) code definition.
6.2. Total Employment: total number of jobs within a zone.
6.3. Employment by 13 Industries: the number of total jobs for 1) agriculture & mining, 2) construction, 3) manufacturing, 4) wholesale trade, 5) retail trade, 6) transportation, warehousing, and utility, 7) information, 8) financial activities, 9) professional and business services, 10) education and health services, 11) leisure and hospitality services, 12) other services, and 13) public administration.
6.4. Employment by wage level (3 variables): total number of jobs by three wage levels: of less than $34,999, $35,000-$74,999, $75,000 or more.
6.5. Warehouse employment 1). light/general warehouse area in square feet, 2). High cube warehouse areas in suare feet, 3) light/general warehouse emp 4)High cube warehouse EMP.

Table 2-2: Joint Distributions of Population/Households/Workers by Selected Attributes

1. Joint distribution of households by
1.1. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+),
1.2. Household size (1,2,3,4+ persons in household),
1.3. Number of workers (0,1,2,3+ workers in household),
1.4. Type of dwelling unit (single-family detached, other)
2. Joint distribution of households by
2.1. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+)
2.2. Number of workers (0,1,2,3+ workers in household),
2.3. Age of head of household (18-24, 25-44, 45-64, 65+ years old)
3. Joint distribution of households by
3.1. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+)
3.2. Household size (1,2,3,4+ persons in household)
4. Joint distribution of households by
4.1. Number of college students (0, 1, 2+),
4.2. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+
5. Joint distribution of households by
5.1. Number of children age 5-17 (0,1,2,3+),
5.2. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+
6. Joint distribution of households by
6.1. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+),
6.2. Household size (1,2,3,4+ persons in household),
6.3. Number of workers (0,1,2,3+ workers in household),
6.4. Household by age (18-24, 25-44, 45-64, 65+)
7. Joint distribution of persons by
7.1. Age (0-4, 5-17, 18-24, 25-64, 65+)
7.2. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+

8. Joint distribution of workers by
8.1. Worker's earnings (less than $34,999, $35,000-$74,999, $75,000+)
8.2. Household income (less than $34,999, $35,000-$74,999, $75,000-$149,999, and $150,000+)

The initial TAZ level household and employment estimates started at the Minimum Planning Unit (MPU) level within the TAZ. The MPU is the smallest geographic computing unit that our calculations take place. In general, the MPUs are equivalent to parcels. 2012 parcel data, the 2010 Census, 2011 firm based employment data, and 2012 EDD (Employment Development Department) data are the key databases used in the development of MPU level 2012 household and employment.

The the new residential construction between 2010 and 2012 to 2010 household estimates from the Census to form the 2012 MPU level household. The 2011 firm based employment served as MPU level data base. It was further controlled and adjusted by referencing the 2012 EDD data.

The aggregation of the MPU level household and employment became the first cut of the TAZ level estimate.Total population is calculated based on the TAZ household estimate. Two components for the total population are group quarter population and residential population. The average number of persons per household is constrained by the updated city PPH. Group quarters population is calculated using the estimates from the 2010 Census and 2012 DOF (Department of Finiance).
TAZ level Population, household and employment are controlled to the 2012 jurisdictional level estimates.

Development of Secondary Variables

Population, Household, and Employment are further broken into necessary attributes (e.g., etc.), as required in the transportation demand model. The additional attribute variables are defined as the secondary variables. These secondary variables at the TAZ level are estimated using the Small Area Secondary Variables Allocation Model (SASVAM). SASVAM is generally based on the probabilistic choice model reflecting the temporal change of the individual attribute and the changing relationship of the related attributes.

Development of Joint Distributions of Population / Households / Workers by Selected Attributes

The joint distributions of household are developed into 8 joint tables of selected secondary variables using the Population Synthesis (PopSyn) generates synthetic populations and households with attribute distributions, which become the basis for computing the joint distributions. SCAG uses the 2010 Census SF3 (Summary File) and 2007-2011 5-year PUMS (Public Use Microdata Sample) individual data at the PUMA level as seed data to produce synthetic populations and households at the TAZ level.

Socioeconomic Input Data Summary

The selected socioeconomic data inputs to the Year 2012 Model Validation process are presented in the following tables and figures. Table 2-3 presents a summary of socioeconomic data totals by county and for the SCAG Region. Figures 2-1 to 2-3 show 2012 population density, household income distributions, and employment density for the Tier 2 level TAZs.

Table 2-3: Year 2012 SCAG Model Socioeconomic Input Data

Population and Workers				
County	**Resident Population**	**Group Quarters Population (Non - Institutional)**	**Total Population**	**Resident Workers**
Imperial	170,278	0	179,591	53,158
Los Angeles	9,740,291	52,946	9,918,214	3,950,146
Orange	3,028,089	11,551	3,071,434	1,284,987
Riverside	2,209,860	7,087	2,244,929	774,300
San Bernardino	2,028,505	1,470	2,067,967	704,849
Ventura	824,530	2,493	835,449	347,060
Total	**18,001,553**	**75,547**	**18,317,584**	**7,114,500**

Households						
County	**Below 35k**	**35k - 75k**	**75k-150k**	**150k Over**	**Total Household**	**Household Size**
Imperial	22,404	14,089	10,342	2,592	49,427	3.45
Los Angeles	1,104,724	968,228	807,149	375,324	3,255,425	2.99
Orange	234,141	280,479	308,520	176,221	999,361	3.03
Riverside	230,382	218,895	183,934	61,260	694,471	3.18
San Bernardino	207,278	204,884	159,224	43,989	615,375	3.30
Ventura	62,897	74,749	85,495	46,152	269,293	3.06
Total	**1,861,826**	**1,761,324**	**1,554,664**	**705,538**	**5,883,352**	**3.06**

Employment				
County	**Retail**	**Service**	**Other**	**Total**
Imperial	6,011	27,694	14,143	47,848
Los Angeles	426,529	2,418,217	1,397,831	4,242,577
Orange	142,227	865,203	518,797	1,526,227
Riverside	85,165	351,085	180,437	616,687
San Bernardino	84,038	374,641	200,784	659,463
Ventura	39,267	169,913	123,070	332,250
Total	**783,237**	**4,206,753**	**2,435,062**	**7,425,052**

School Enrollment		
County	**K Thru 12**	**College and University**
Imperial	40,893	10,754
Los Angeles	1,783,534	704,349
Orange	549,465	225,511
Riverside	470,788	129,840
San Bernardino	451,653	133,893
Ventura	158,995	52,031
Total	**3,455,328**	**1,256,378**

Figure 2-1: Population Density (2012)

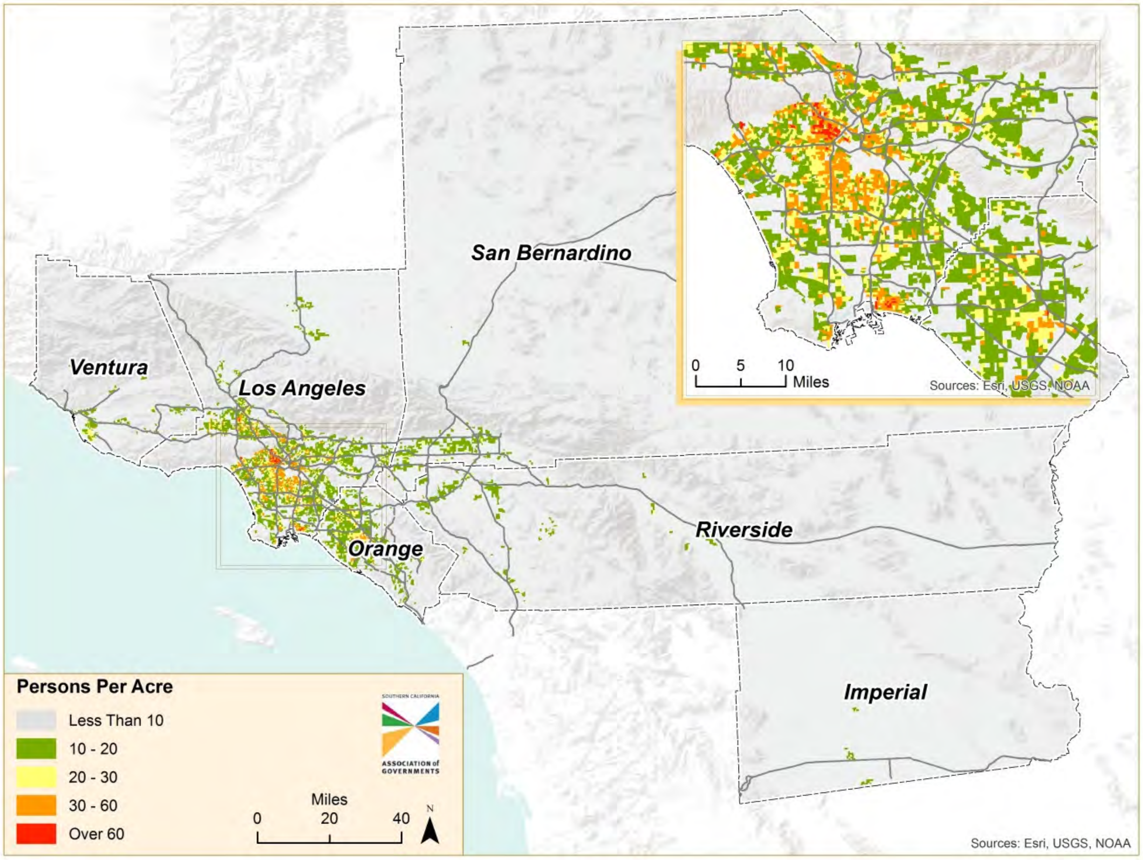


Figure 2-2: Household Income Distributions (2012)

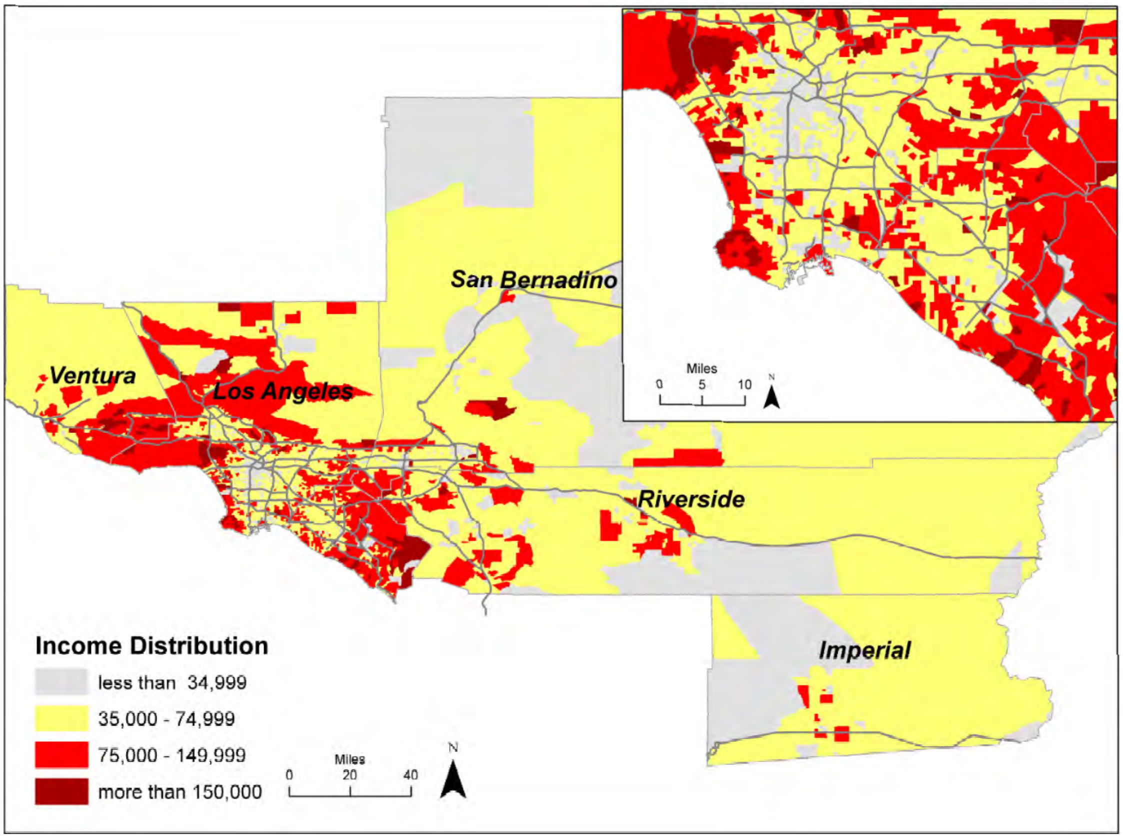
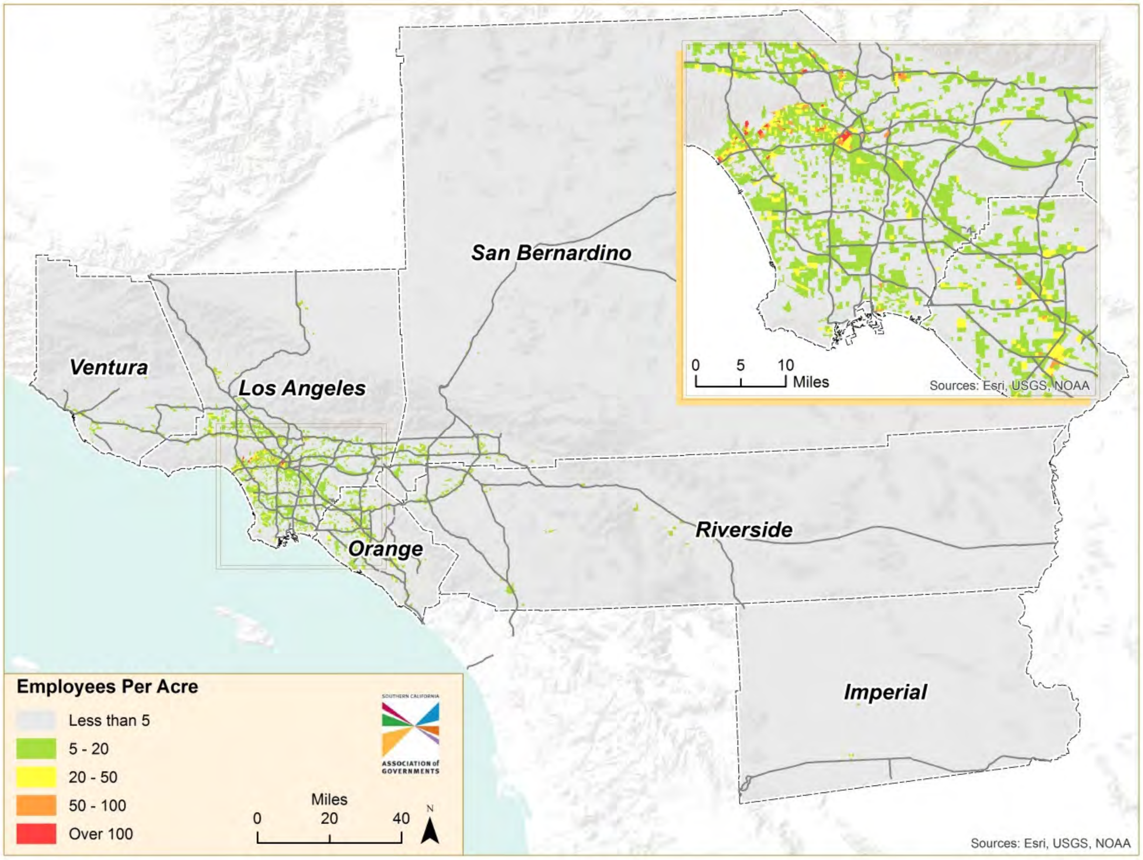


Figure 2-3: Employment Density (2012)



CHAPTER 3 – TRIP GENERATION

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CHAPTER 3 – TRIP GENERATION

Introduction

Trip generation is the process of estimating daily person trips for an average weekday generated by households within each TAZ. The Year 2012 Model contains a series of models to estimate trip productions and trip attractions by trip type. The trip production models estimate the number of person trips generated in each TAZ, and trip attraction models estimate the number of person trip attracted to each TAZ. Trip generation estimates trip production and attraction at the Tier 2 zonal level. The trip generation component includes an Auto Availability model, which forecasts the number of vehicles available to each household in the region. Auto availability, along with household income, household size, number of workers and other variables are used to forecast trip productions, while trip attractions are a function of land use activity measures such as employment, residential households, and school enrollment.

Trip Purpose

The model uses an expanded set of trip purposes. This was done to improve trip distribution and mode choice estimates, and to more accurately link trip productions and trip attractions. The model contains 10 trip purposes, each subdivided into different household markets. Total trips produced by TAZ were estimated for each of the following trip purposes and household segments:

1. Home-Based Work Direct and 2. Home-Based Work Strategic

There are two types of home-based work trips: "direct" home-based work trips and "strategic" home-based work trips. "Direct" home-based work (HBWD) trips are trips that go directly between home and work, without any intermediate stops. "Strategic" home-based work (HBWS) trips are trips between home and work that include one or more intermediate stops, such as to drop-off or pick-up a passenger, to drop-off or pick-up a child at school, or for other reasons. The trip generation model estimates HBWD and HBWS trips for five household markets, which are carried through trip distribution and mode choice:

- Zero Car Households
- Car Insufficient Households
- Car Sufficient Households, Low Income (less than $35,000)
- Car Sufficient Households, Medium Income ($35,000 to $74,999)
- Car Sufficient Households, High Income ($75,000 or greater)

3. Home-Based School

Home-based school (HBSC) trips include all student trips with an at-home activity at one end of the trip and a Kindergarten through 12th grade school activity at the other end. This purpose does not include trips in the college/university category, which follows.

4. Home-Based College and University

Home-based college and university (HBCU) trips include all trips made by persons over the age of 18 with an at-home activity at one end of a trip and a college or university activity at the other end.

5. Home-Based Shopping

Home-based shopping (HBSH) trips include all person trips made with a home activity at one end of a trip and a shopping activity at the other end. The trip generation model estimates HBSH trips for the same five household markets used for HBW trips. This auto sufficiency / household income segmentation is maintained in trip distribution and mode choice. Auto sufficiency is measured differently for work and non-work trips, as described in Table 3-11 below.

6. Home-Based Social-Recreational

Home-based social-recreational (HBSR) trips include all person trips made with a home activity at one end of a trip and a visiting or recreational activity at the other end. The model estimates HBSR trips for the five household markets used for HBSH trips, maintained through trip distribution and mode choice.

7. Home-Based Serving-Passenger

Home-based serve passenger (HBSP) trips include all person trips made with a home activity at one end of a trip and a passenger serving activity, such as driving someone to somewhere, at the other end. Trips that serve passengers while on the way to work are classified as home based work strategic trips rather than serve passenger trips because they are part of a work trip chain. The model estimates HBSP trips for the five household markets used for HBSH trips, also maintained through trip distribution and mode choice.

8. Home-Based Other

Home-based other (HBO) trips include all other home-based (with a home activity at one end of a trip) trips that are not already accounted for in any of the home-based trips categories described above. The model estimates HBO trips for the five household markets used for HBSH trips, also maintained through trip distribution and mode choice.

9. Work-Based Other

Work-based other (WBO) trips are non-home-based trips where at least one end of a trip is from/to a work location. An example of such a trip would be, "running an errand during lunch hour" from one's place of employment.

10. Other-Based Other

Other-based other (OBO) trips are all other trips that do not begin or end at a trip-maker's home or place of work.

Vehicle Availability Model

Introduction

The auto availability model predicts the number of households with 0, 1, 2, 3, and 4 or more available vehicles. The model was estimated in a multinomial logit form using the ALOGIT software. This model is the first model applied in the model chain. As is customary, the model was estimated using household records, and then applied at the aggregate, TAZ level. The auto availability model includes indicators for household size, household income, number of workers, type of housing unit, residential and employment density, and transit and non-motorized accessibilities.

Estimation Dataset

Data for this model estimation was obtained from the 2012 California Household Travel Survey and the 2012 SCAG Add-On survey. Combined, these two surveys yielded a final sample of 35,026 usable households.
Table 3-1 shows the number of sample households by auto availability and by the four household attributes included in the estimation file.

Table 3-1: Observed Household Frequencies

	Count	Percent
Auto Availability		
Zero vehicle	1,059	6%
One	5,977	35%
Two	6,745	40%
Three	2,232	13%
Four or more	926	5%
Household Size		
One person	5,108	30%
Two	5,929	35%
Three	2,393	14%
Four or more	3,509	21%
Household Workers		
Zero workers	4,055	24%
One	7,214	43%
Two	4,848	29%
Three or more	822	5%
Household Income		
0 - $35K	3,386	20%
$35K- $75K	4,111	24%
$75K - $150K	5,215	31%
$150K or more	2,166	13%
unknown	2,061	12%
Type of Housing Unit		
Single family detached	10,585	62%
Other	6,354	38%

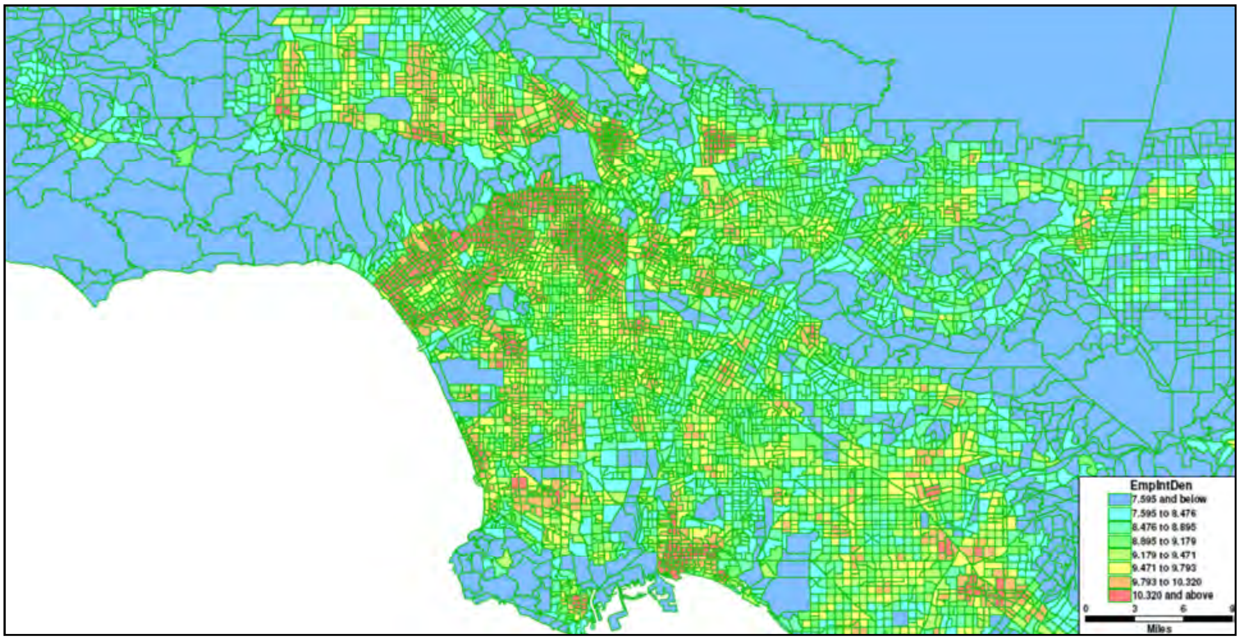
The survey observations were joined with multiple measures of residential density, employment density, and transit and non-motorized accessibility. Table 3-2 shows a complete list and definitions of all the density and accessibility measures examined during model estimation.

Table 3-2: Land Use Form and Accessibility Measures

Measure	Description and Formulas
Density Measures	Density measures are calculated over a 1/2 mile radius of the TAZ centroid. These densities are based on total area, instead of developed area.
Household Density	Total Households / Area
Retail Employment Density	Retail Employment / Area
Total Employment Density	Total Employment / Area
Diversity Measures	The indicators of diversity may be proportional to geometric averages of various land uses. These variables take the highest values when all the uses are high and equally allocated. Diversity can also be expressed as the relative difference between various land uses. The highest diversity occurs when the two land uses are equal, lowest when one or the other dominates. These measures are calculated over a one-half mile radius of the TAZ centroid.
Retail Employment (RE) and Household (HH) Diversity	0.001 x RE x HH / (RE + HH)
Retail/Service Employment (RSE) and Household Diversity	0.001 x RSE x HH / (RSE + HH)
Jobs/Housing diversity (SACOG)	1- [ABS(b*HH - EMP)/(b*HH + EMP)], where EMP is total employment and b = regional employment / regional households
Job Mix Diversity	1-[ABS(b*RE - NRE) /(B*RE + NRE)], Where NRE is non-retail employment and b = regional non retail employment / regional retail employment
Design Measures	The only available urban design indicator is the number of intersections, calculated using the Tele Atlas street network.
Mix Employment, Household and Intersection Density	Ln {[Int*(Emp*a) * (HH*b)] /[Int + (Emp*a) + (HH*b)]}, where: Int= Number of local intersections in 1/2 mile of centroid Emp= Employment within 1/2 mile of centroid HH= Households within 1/2 mile of centroid a= average Int / average Emp b= average Int / average HH
Intersection Density	3-way + 4-way intersections / Area
Street Density	Total street length in 1/2 mile radius
Connectivity Index	Proportion of 4-way intersections
Accessibility Measures	Accessibility variables are proportional to the number of opportunities (such as jobs or retail opportunities) that can be reached by auto, transit or walk means.
Transit Accessibility Logsum	$TrLogsum_p = Ln\left(\sum_q \exp\left(-0.025 * (TransitTime_{pq} - AutoTime_{pq}) + \ln(Emp_q)\right)\right)$ Where $TransitTime_{pq}$ is total transit time including a weight of 2 on all out-of-vehicle time components.
Transit Accessibility to Jobs	Employment within x minutes of transit (walk access), where x is a category 0-30mins, 30-60mins etc.
Transit Accessibility to Retail	Retail employment within 30 minutes of transit (walk)
Transit Stop Density	Number of transit stops / Area
Non-Motorized Accessibility	$WalkAcc_p = Ln\left(\sum_q exp\left(-2.0 * Distance_{pq} + ln(Emp_q)\right)\right)$

The mix employment, household and intersection density indicator proved to be the strongest design and density indicator for this region. Figure 3-1 shows how this mix density measure varies over the most urbanized areas in the SCAG region. It is highest in areas that combine high residential, employment and intersection density –Los Angeles Central Business District (CBD), Santa Monica and Wilshire Boulevard, West Hollywood, Burbank, Glendale, Long Beach, and parts of Santa Ana and Orange.

Figure 3-1: Mixed Employment, Residential and Intersection Density



Utility Structure

The utility (U_{az}) of having (a) autos available for a household of type (h) located in zone (z) is given by

$$U_{az} = \alpha_a + \sum\sum \beta_{hk} \times N_{hk} + \delta_{az} \times TrnAcc_z + \gamma_z \times MixDen_z + \theta_z \times WlkAcc_z$$

This expression includes household attributes, listed below, which are entered as indicator variables with coefficients that vary for each choice. In addition, it includes three location-specific measures that capture land use form as well as accessibility by means other than auto. Land use form is represented via the mixed residential, employment and intersection variable. Accessibility is measured in two ways: walk accessibility, and transit accessibility relative to auto. The mathematical formulation of these variables is shown in Table 3-2. The following variables were examined, proved to be significant in the utility functions, and were selected for the final model:

- Household Size – 1, 2, 3, 4 or more persons
- Household Income (in $2011)
    - Low income (less than $35,000)
    - Medium income ($35,000-$74,999)

  - o High income ($75,000 or more)
  - o Very high income ($150,000 or more)
- Number of Workers in Household – 0, 1, 2, 3 or more workers
- Type of Housing Unit
  - o Single-Family Detached
  - o Multi-Family (duplex, apartment, and condominium)
- Transit Accessibility
- Mixed Household, Employment, and Intersection Density
- Non Motorized Accessibility

Estimation Results

Table 3-3 shows the final auto availability model estimation results. All variables show expected, logical signs, and most are significant at 95% confidence. Auto availability increases with household size, household income and the number of workers in the household, and decreases for households living in multi-family housing. Auto availability decreases with increasing transit and walk accessibility to employment, and also decreases with increasing mixed density. The reference categories are very high income, one person, and zero workers, respectively for the household income, household size and household worker indicator variables.

Many of the candidate density and design variables showed logical, statistically significant effects on their own, but they tended to be correlated with each other. The mixed density measure was preferred because it responds to changes in residential and employment density, as well as urban form density (as measured by the number of intersections).

Table 3-3: Auto Availability Estimation Results

	Auto Availability Choice							
	1 Car		2 Cars		3 Cars		4+ Cars	
	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
Household Income ($2011)								
Low (less than $35,000)	-0.465	-7.0	-1.604	-22.9	-2.396	-28.5	-3.032	-26.6
Medium ($35,000 - $74,999)	1.067	11.9	0.766	8.4	0.402	4.1	0.109	1.0
High ($75,000 - $150,000)	1.765	11.5	2.126	13.8	1.971	12.6	1.929	11.9
Very High ($150,000 or more)	0.000	n/a	0.000	n/a	0.000	n/a	0.000	n/a
Household Size								
1 Person HH	0.000	n/a	0.000	n/a	0.000	n/a	0.000	n/a
2 Person HH	0.126	2.2	1.253	20.9	0.177	2.5	-0.520	-5.6
3 Person HH	0.081	1.0	1.294	15.1	1.836	20.3	0.947	8.9
4+ Person HH	0.112	1.2	1.633	17.0	2.092	20.4	2.306	21.2
Workers in HH								
0 Worker HH	0.000	n/a	0.000	n/a	0.000	n/a	0.000	n/a
1 Worker HH	1.014	19.7	1.497	26.4	0.935	14.1	0.200	2.4
2 Workers HH	0.852	8.7	2.902	29.7	2.628	25.5	2.109	19.1
3+ Workers HH	0.889	1.6	2.081	3.7	3.249	5.8	4.617	8.3
Multi-Family Housing	-0.608	-11.8	-1.516	-26.8	-2.147	-30.0	-2.575	-23.9
Mix Emp, Hhld. And Int. Density	-0.119	-6.2	-0.141	-7.0	-0.170	-8.1	-0.192	-8.4
Non Motorized Accessibility								
Low < 500 jobs	0.000	n/a	0.000	n/a	0.000	n/a	0.000	n/a
Medium: 500 – 1,000 jobs	-0.002	-0.04	-0.158	-2.3	-0.161	-2.0	-0.260	-2.3
High: 1,000 – 5,000 jobs	-0.007	-0.10	-0.205	-2.8	-0.328	-3.7	-0.528	-2.8

Very high: > 5,000 jobs	-0.368	-1.9	-0.458	-1.9	-0.587	-1.7	-0.787	-1.9
Transit Accessibility Logsum								
Low: <=10	0.000	n/a	0.000	n/a	0.000	n/a	0.000	n/a
Medium: 10-12	0.000	n/a	0.000	n/a	0.000	n/a	0.000	n/a
High:12-14	-0.404	-6.7	-0.662	-10.2	-0.871	-12.0	-0.959	-11.0
Very high:>14	-1.478	-4.0	-2.490	-4.2	--2.490	-4.2	-2.490	4.2
Constant	2.529	14.2	2.333	12.7	2.442	12.6	2.569	12.2

Notes:

Observations:	*35,026*
Final log likelihood:	*37,663*
Rho-Squared (zero):	*0.332*
Rho-Squared (constants):	*0.222*

Model Calibration

The final model parameter specification is shown in Table 3-4.

Table 3-4: Auto Availability Model Calibration Results

			Auto Availability Choice Coefficients				
County		**Sub Air Basin Name**	**0 car**	**1 car**	**2 cars**	**3 cars**	**4+ cars**
Ventura	11	'SCCAB (VENTURA COUNTY)'	-0.078	2.594	2.400	2.393	2.011
Los Angeles	21	'SCAB (LOS ANGELES COUNTY)'	-5.222	2.463	4.872	6.442	6.663
	31	'MDAB (ANTELOPE VALLEY)'	-4.238	2.267	2.871	3.078	3.059
Orange	22	'SCAB (ORANGE COUNTY)'	-0.327	2.386	2.383	2.661	2.411
Riverside	23	'SCAB (RIVERSIDE COUNTY)'	-0.109	2.483	2.312	2.599	2.462
	35	'MDAB (RIV DESERT)'	-0.040	2.512	2.281	2.579	2.512
	36	'MDAB (BLYTHE)'	-0.132	2.354	2.398	2.640	2.596
	41	'SSAB (COACHELLA VALLEY)'	1.059	2.139	2.408	2.430	2.855
SBD	24	'SCAB (SAN BERNARDINO CO)'	0.609	2.638	2.479	1.834	1.555
	32	'MDAB (VICTOR VALLEY)'	-0.570	2.479	2.218	2.783	2.653
	34	'MDAB (SBD DESERT)'	0.321	2.602	2.494	2.205	1.255
	33	'MDAB (SEALES VALLEY)'	0.019	2.751	2.465	2.066	1.141
Imperial	42	'SSAB (IMPERIAL/WEST)'	0.522	2.420	2.310	2.619	2.282
	43	'SSAB (IMPERIAL/EAST)'	1.373	2.809	1.661	2.111	0.765
	44	'SSAB (IMPERIAL PM2.5 NON-ATT)	0.294	2.436	2.318	2.561	2.325

The model was applied to the 2012 base year, with all density measures computed at the Tier 2 zone level. The 2012 model forecast was validated to ACS 2008-2012 release data. A comparison of the model forecast to CTPP 2012 and ACS 2008-2012 data, for each county in the SCAG region, is shown in and Table 3-5.

Table 3-5: Year 2012 Auto Availability Forecast – County of Residence Validation

ACS 2008-2012 Auto Availability						
Residence County	**0Cars**	**1Car**	**2Cars**	**3Cars**	**4+Cars**	**Total**
Imperial	5,391	16,169	17,929	7,962	4,052	**51,503**
Los Angeles	312,021	1,125,522	1,128,717	430,780	221,252	**3,218,292**
Orange	47,069	284,327	412,597	159,718	84,622	**988,333**
Riverside	33,586	201,885	265,675	116,809	58,641	**676,596**
San Bernardino	34,596	177,110	230,947	107,884	59,732	**610,269**
Ventura	11,828	70,030	105,740	49,849	25,534	**262,981**
Total	**444,491**	**1,875,043**	**2,161,605**	**873,002**	**453,833**	**5,807,974**
2012 Model Forecast						
Residence County	**0Cars**	**1Car**	**2Cars**	**3Cars**	**4+Cars**	**Total**
Imperial	5,413	15,752	17,711	8,452	4,461	**51,789**
Los Angeles	317,249	1,158,744	1,174,654	451,710	242,653	**3,345,011**
Orange	48,779	297,396	422,478	162,014	92,312	**1,022,980**
Riverside	35,946	211,455	278,446	129,023	65,201	**720,070**
San Bernardino	35,019	182,370	242,713	117,613	66,087	**643,802**
Ventura	12,350	73,360	112,705	50,740	28,752	**277,907**
Total	**454,757**	**1,939,078**	**2,248,706**	**919,552**	**499,466**	**6,061,558**
Forecast Difference (%), County Normalized						
Residence County	**0Cars**	**1Car**	**2Cars**	**3Cars**	**4+Cars**	**Total**
Imperial	-0.14%	-3.12%	-1.76%	5.56%	9.48%	0.0%
Los Angeles	-2.18%	-0.95%	0.13%	0.89%	5.52%	0.0%
Orange	0.12%	1.05%	-1.07%	-2.00%	5.39%	0.0%
Riverside	0.56%	-1.58%	-1.52%	3.79%	4.47%	0.0%
San Bernardino	-4.05%	-2.39%	-0.38%	3.34%	4.88%	0.0%
Ventura	-1.20%	-0.87%	0.86%	-3.68%	6.55%	0.0%
Total	**-1.97%**	**-0.91%**	**-0.32%**	**0.93%**	**5.45%**	**0.0%**

An important validation measure is to ascertain whether the model matches the observed pattern of auto availability level by urban form geographies. A comparison of auto availability obtained from ACS data to the model estimates, classified into density or accessibility bins, shows that the model reproduces the observed patterns, in the aggregate. Similarly, a comparison of zero car households at the Regional Statistical Area (RSA) level shows that the model predicts well the number of zero-car households and the total number of available vehicles. Tables 3-6 to 3-8 and Figures 3-2 and 3-3 provide more information.

Table 3-6: Auto Availability Validation to Mix Employment, Household and Intersection Density

Auto Availability	Share of Households by Mix Density Level							
	ACS 2008-2012				Model 2012 Estimate			
	Low	Meduim	High	Very High	Low	Meduim	High	Very High
0	3%	4%	7%	13%	3%	6%	12%	24%
1	24%	27%	32%	43%	24%	31%	43%	47%
2	42%	40%	37%	32%	39%	39%	34%	25%
3	20%	19%	15%	9%	22%	15%	7%	3%
4+	10%	10%	8%	4%	11%	9%	4%	1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 3-7: Auto Availability Validation to Non Motorized Accessibility

Auto Availability	Share of Households by Non Motorized Accessibility							
	ACS 2008-2012				Model 2012 Estimate			
	Low	Meduim	High	Very High	Low	Meduim	High	Very High
0	4%	8%	13%	25%	6%	10%	12%	32%
1	25%	33%	43%	43%	29%	37%	40%	34%
2	41%	37%	32%	26%	38%	35%	34%	24%
3	20%	15%	9%	4%	17%	11%	10%	6%
4+	10%	8%	4%	2%	9%	7%	5%	3%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 3-8: Auto Availability Validation to Transit Accessibility Logsum

Auto Availability	Share of Households by Transit Accessibility Logsum							
	ACS 2008-2012				Model 2012 Estimate			
	Low	Meduim	High	Very High	Low	Meduim	High	Very High
0	5%	5%	7%	17%	4%	2%	13%	0%
1	29%	27%	33%	42%	27%	19%	44%	0%
2	40%	40%	38%	29%	39%	40%	34%	0%
3	18%	19%	15%	8%	20%	25%	6%	0%
4+	9%	9%	8%	4%	10%	13%	3%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**0%**

Figure 3-2: Validation of Zero Car Households for Regional Statistical Areas

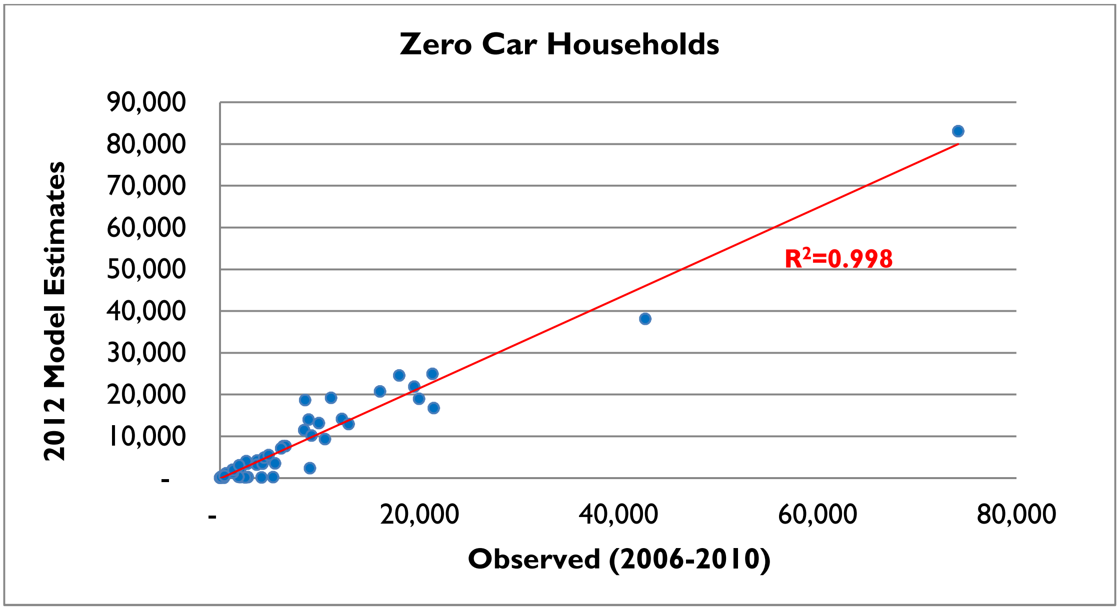
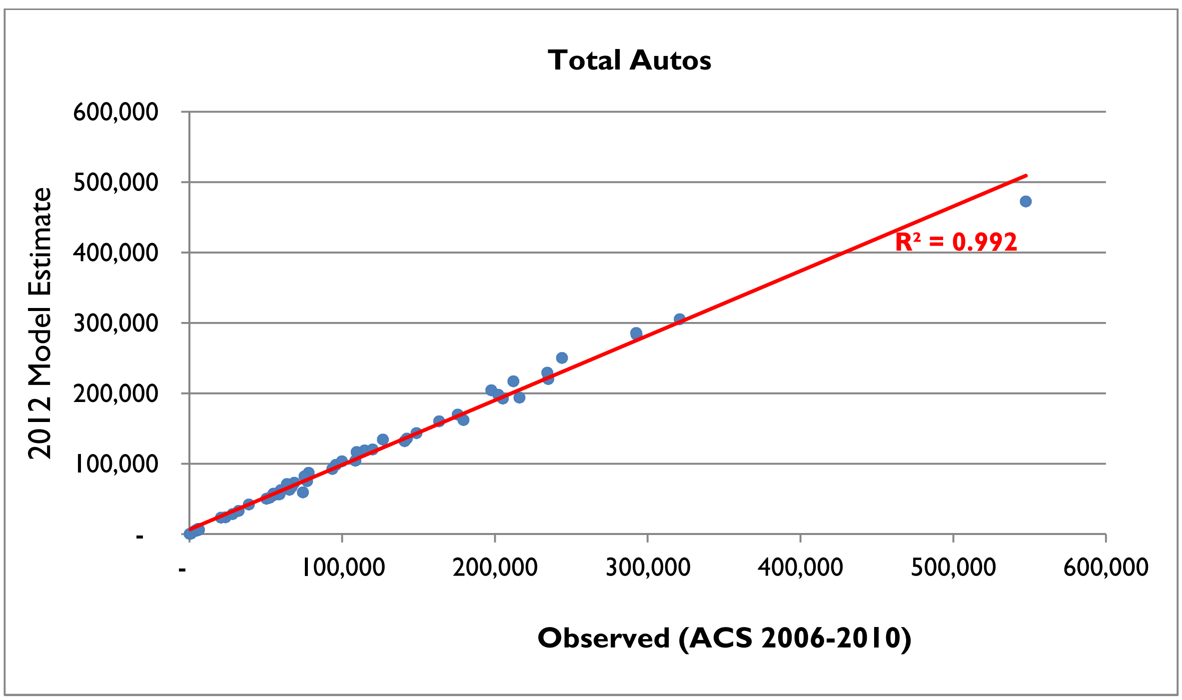


Figure 3-3: Validation of Total Auto Availability for Regional Statistical Areas



Trip Market Segmentation

Market segmentation is the technique used in trip-based models to subdivide the population into groups expected to exhibit similar travel behavior. The model segmentation is partly determined by the availability of survey and census data to identify specific markets or population subgroups and support the estimation and validation of separate models for each subgroup.

Trip Purposes

The internal person trip market is stratified into the ten purposes listed in Table 3-9. The external trip market is segmented into internal-external and external-external (IE/EI) trips.

Table 3-9: Trip Purposes

Purpose	Description
HBWD	Home Based Work - Direct
HBWS	Home Based Work - Strategic
HBCU	Home Based College and University
HBSC	Home Based School
HBSH	Home Based Shop
HBSR	Home Based Social and Recreation
HBSP	Home Based Serve Passenger
HBO	Home Based Other
WBO	Non Home Based Work
OBO	Non Home Based Other

Time Periods

As is customary in a trip-based model, the SCAG model segments the demand models (auto ownership, trip generation, trip distribution, and mode choice) into two time periods - peak and off-peak. The peak periods are 6:00 AM to 9:00 AM in the morning and 3:00 PM to 7:00 PM in the evening. The transit assignments are also performed for these two time periods.

The model uses five periods for highway assignment. The five highway assignment time periods are:

- AM Peak: 6:00 AM to 9:00 AM
- Midday: 9:00 AM to 3:00 PM
- PM Peak: 3:00 PM to 7:00 PM
- Evening: 7:00 PM to 9:00 PM
- Night: 9:00 PM to 6:00 AM

A representative peak period travel time is fed back from the highway assignment to the demand model. This representative time is a weighted average of the AM peak travel time and the PM peak travel time (transposed), where the weights equal the proportion of peak period trips that occur in the AM and PM periods respectively.

Household Classifications

In addition to trip purpose and time period, the trip market is further defined by household attributes. The proposed classifications for each model component are summarized in Table 3-10. The groups to be used for each household classification variable are the following:

- Household Income: low (less than $35,000, medium ($35,000 to $74,999), high ($75,000 to $149,999) and very high ($150,000 and more), in 2011 dollars.
- Household Size: one, two, three, four or more persons in household.
- Workers in Household: zero, one, two, three or more workers in household.
- Auto Availability: zero, one, two, three, and four or more autos in household.
- Type of Housing Unit: single-family detached unit, all other unit types.
- Age of Head of Household: 18 to 24, 25 to 44, 45 to 64, 65 years old or older.
- Age: number of household members younger than 5, 5 to 17, 18 to 24, 25 years old or older.

Table 3-10: Person and Household Attributes

Model	Hhld. Income	Hhld. Size	Hhld Workers	Auto Availability	Type of Housing Unit	Age of Head of Hhld.	Age
Auto Ownership	X	X	X		X		
Trip Production							
HBW, WBO	X		X	X		X	
HBSC, HBCU							X
HBO, OBO	X	X		X			
Trip Distribution							
HBW, WBO	X		X	X			
HBO, OBO	X	X		X			
Mode Choice	X						
HBW, WBO	X		X	X			
HBO, OBO	X	X		X			

The trip production, destination choice and mode choice models use a market stratification defined by household income and car sufficiency. Car sufficiency is defined relative to household workers for HBW trips, and relative to household size for HBO trips. The specification of each stratum is shown in Table 3-11.

Table 3-11: Trip Market Strata

Trip Market	HBW Trips	HBO Trips
1	Zero car households, all incomes	Zero car households, all incomes
2	Households with fewer cars than workers, all incomes	1 car, 2+ person households, all incomes
3	Equal or more cars than workers, income less than $35,000	1 car, 1 person households or 2+ car households, and income less than $35,000
4	Equal or more cars than workers, income equal or higher than $35,000 and less than $75,000	1 car, 1 person households or 2+ car households, and income equal or higher than $35,000 and less than $75,000
5	Equal or more cars than workers, and income equal or higher than $75,000	1 car, 1 person households or 2+ car households, and income equal or higher than $75,000

Trip Productions Model

Introduction

The trip productions model predicts average weekday trip frequency for each household trip type. It takes the form of a cross-classification model. The productions represent total daily trips for all travel modes (auto, transit and non-motorized). Trip rates per household are applied to the estimate of households classified across various attributes. The household classifications vary with the trip purpose. Unlike previous versions of the SCAG model, these classifications are now prepared off-model using a population synthesizer. The relationship between trip frequency and land use density was explored during the trip rate estimation process; no consistent, statistically significant relationship was found between total daily person trips and various measures of land use density and diversity, after controlling for household attributes such as income, size and vehicles available.

Estimation Dataset

The 2012 California Household Travel Survey and SCAG Add-on Survey provided the data for the trip rate estimation. The trip sample size by purpose is shown in Table 3-12.

Table 3-12: Trip Sample Size

Trip Purpose	Count	Percentage
HBWD	21,336	18%
HBWS	6,498	6%
HBSC	6,872	6%
HBU	2,048	2%
HBSH	11,386	10%
HBSR	10,559	9%
HBSP	12,276	10%
HBO	17,699	15%
WBO	7,386	6%
OBO	21,471	18%
Total	**117,531**	**100%**

Home-Based Work Trip Productions Models

The household classification variables chosen for the HBW trip productions model are number of workers, household income, and age of the head of household. Other classification variables were tested, including household size and auto availability. Separate trip rates were estimated for direct and strategic trips. Household classes with few observations were collapsed to obtain a large enough sub-sample. Table 3-13 shows the HBWD trip production rates; Table 3-14 shows the HBWS trip production rates. As expected, the HBW trip rates increase with the number of workers in the household. Households headed by young (18-24 years old) and senior (65 years old or older) persons exhibit lower trip rates than other households. HBW trip rates tend to increase with household income. The rates shown in Table 3-13 are applied separately by auto availability, so that the HBW trip productions can be reported over car sufficiency and income groups, for input to the trip distribution and mode choice models.

Table 3-13: HBWD Trip Production Rates

Workers	Age of Head of Household	Household Income ($2011)			
		<35K	35K-75K	75K-150K	>150K
1	18-24	1.222	1.327	1.414	1.424
1	25-44	1.449	1.435	1.426	1.422
1	45-64	1.261	1.289	1.293	1.420
1	65+	1.259	1.312	1.280	1.350
2	18-24	2.203	2.147	2.159	2.168
2	25-44	2.428	2.431	2.532	2.606
2	45-64	2.466	2.526	2.534	2.526
2	65+	2.324	2.685	2.527	2.486
3+	18-24	3.056	3.224	3.339	3.369
3+	25-44	3.643	4.111	4.218	4.144
3+	45-64	3.721	3.947	4.063	4.020
3+	65+	3.325	3.404	3.568	3.687

Table 3-14: HBWS Trip Production Rates

Workers	Age of Head of Household	Household Income ($2011)			
		<35K	35K-75K	75K-150K	>150K
1	18-24	0.203	0.177	0.170	0.181
1	25-44	0.266	0.305	0.327	0.342
1	45-64	0.247	0.256	0.281	0.324
1	65+	0.238	0.187	0.223	0.244
2	18-24	0.441	0.505	0.508	0.510
2	25-44	0.552	0.553	0.664	0.655
2	45-64	0.535	0.536	0.591	0.629
2	65+	0.303	0.322	0.564	0.635
3+	18-24	0.544	0.575	0.596	0.600
3+	25-44	0.675	0.753	0.706	0.804
3+	45-64	0.617	0.671	0.697	0.781
3+	65+	0.509	0.521	0.502	0.518

Home-Based School (HBSC) and Home-Based College (HBCU) Trip Productions Models

The HBSC trip productions were estimated based on the number of school-age children in a household. A classification of households by the number of children aged 5 to 17 years old is prepared off-model, along with all the other household classifications. The HBSC trip rates are shown in Table 3-15.

The HBCU trip productions are estimated based on the number of college-age persons in the household, household income, and the group quarters population. The HBCU trip rates are shown in Table 3-16.

Table 3-15: HBSC Trip Production Rates

Number of Household Members 5-17 years old	Trip Rate
0	0.140
1	1.583
2	2.302
3+	4.282

Table 3-16: HBCU Trip Production Rates

Household Income ($2011)	Number of Household Members 17 to 25 years old		
	0	1	2+
0-35K	0.054	0.351	0.466
35K-75K	0.097	0.368	0.550
75K-150K	0.052	0.370	0.552
150K+	0.052	0.372	0.554

Home-Based Non-Work (HBNW) Trip Productions Models

The household classification variables chosen for the HBNW trip productions model are household size, income and auto availability. Separate trip rates were estimated for HBSH, HBSR, HBSP, and HBO trips. Household classes with few observations were collapsed to obtain a large enough sub-sample. The HBNW trip production rates are shown in Table 3-17. As expected, the HBNW trip rates increase with household size and with auto availability. The HBNW trip rates do not vary much with household income, but the income classification was kept so it is available for trip distribution and mode choice.

Table 3-17: HBNW Trip Production Rates

Auto Availability	Household Income	Household Size	Trip Production Rates			
			HBSH	HBSR	HBSP	HBO
0	0-35K	1	0.410	0.370	0.050	0.670
		2	0.720	0.640	0.160	.1.030
		3	0.640	0.750	1.180	1.370
		4+	0.1.240	1.010	0.850	1.950
	35K-75K	1	0.250	0.370	0.50	0.670
		2	0.450	0.650	0.140	1.030

Auto Availability	Household Income	Household Size	Trip Production Rates			
			HBSH	HBSR	HBSP	HBO
		3	0.640	0.750	1.180	1.030
		4+	0.1.140	1.010	0.850	2.010
	75K-150K	1	0.250	0.370	0.040	0.670
		2	0.430	0.660	0.130	.1.030
		3	0.640	0.750	1.140	1.370
		4+	0.1.140	1.010	0.810	2.770
	150K+	1	0.250	0.370	0.040	0.670
		2	0.430	0.660	0.120	1.030
		3	0.640	0.750	0.1.130	1.370
		4+	0.1.140	1.010	.0.850	2.770
1	0-35K	1	0.410	0.410	0.090	0.770
		2	0.770	0.820	0.480	1.090
		3	0.920	1.110	1.450	1.450
		4+	1.650	1.380	3.010	2.010
	35K-75K	1	0.300	0.510	0.070	0.770
		2	0.630	0.830	0.370	1.100
		3	0.730	.1.130	1.430	1.470
		4+	1.330	1.540	2.890	2.060
	75K-150K	1	0.300	0.520	0.050	0.770
		2	0.550	0.850	0.320	1.270
		3	0.730	1.150	1.410	1.500
		4+	1.330	1.850	2.800	2.830
	150K+	1	0.300	0.530	0.050	0.770
		2	0.650	0.850	0.140	1.270
		3	0.730	.1.170	1.400	1.750
		4+	1.330	1.900	2.780	2.830
2	0-35K	1	0.450	0.450	0.060	0.790
		2	0.770	0.850	0.300	1.380
		3	1.920	1.200	1.170	1.450
		4+	1.1270	1.550	2.930	2.350
	35K-75K	1	0.300	0.520	0.060	0.840
		2	0.700	0.880	0.200	1.190
		3	0.720	.1.220	1.120	1.470
		4+	1.030	1.740	2.810	2.410
	75K-150K	1	0.300	0.550	0.040	0.850
		2	0.630	0.890	0.170	1.330
		3	0.720	1.240	1.650	1.680
		4+	1.860	1.900	2.720	3.000
	150K+	1	0.300	0.590	0.040	0.940
		2	0.570	0.900	0.170	1.330
		3	0.720	1.250	0.650	1.680
		4+	1.860	1.2.180	2.720	3.000
3+	0-35K	1	0.450	0.600	0.060	0.790
		2	0.770	0.640	0.340	1.380
		3	1.130	0.750	0.580	1650
		4+	1.270	1.010	2.630	2.350
	35K-75K	1	0.400	600	0.060	0.840
		2	0.710	0.990	0.260	1.200
		3	0.750	1.240	.0.400	1.740
		4+	1.370	1.750	2.520	3.000
	75K-150K	1	0.400	0.600	0.040	0.850

Auto Availability	Household Income	Household Size	Trip Production Rates			
			HBSH	HBSR	HBSP	HBO
		2	0.710	.1.010	0.240	1.240
		3	0.750	1.260	0.300	1.750
		4+	1.060	1.940	2.440	3.000
	150K+	1	0.400	600	0.040	0.140
		2	0.590	.1.030	0.220	1.280
		3	0.170	.300	0.280	1.750
		4+	1.060	2.180	2.430	3.000

Non-Home Based (NHB) Trip Productions Models

The household classification variables chosen for the NHB trip productions are income, workers and age of householder for work-based trips; and income, size and auto availability for all other non-home based trips Table 3-18 and Table 3-19 show the WBO and OBO trip rates, respectively.

Table 3-18: WBO Trip Production Rates

Workers in Household	Household Size	Household Income ($2011)			
		<35K	35K-75K	75K-150K	>150K
1	1	0.380	0.460	0.600	0.600
	2	0.300	0.770	0.700	0.550
	3	0.400	0.750	0.720	0.620
	4+	0.400	0.410	0.430	0.590
2	1				
	2	0.730	0.880	0.950	0.910
	3	0.760	0.880	1.470	1.470
	4+	0.760	0.660	0.810	0.920
3+	1				
	2				
	3	0.460	0.460	0.630	1.640
	4+	0.510	0.510	1.070	2.010

Table 3-19: OBO Trip Production Rates

		Trip Production Rates			
Household Income	Household Size	Auto Availability			
		0	1	2	3+
0-35K	1	0.0.420	1.150	1.360	1.400
	2	1.100	1.780	1.850	1.850
	3	1.420	2.470	2.550	2.410
	4+	2.320	3.480	3.510	3.550
35K-75K	1	0.420	1.150	1.370	1.420
	2	1.100	1.780	1.850	2.080
	3	1.500	2.470	2.500	2.540
	4+	2.320	3.620	3.650	3.700

75K-150K	1	0.420	1.170	1.370	1.460
	2	1.100	1.780	1.920	1.890
	3	1.520	2.470	2.550	2.550
	4+	2.320	3.620	3.700	3.720
150K+	1	0.420	1.170	1.370	1.460
	2	1.100	1.860	1.930	1.890
	3	1.520	2.490	2.790	2.790
	4+	2.320	3.620	3.700	3.730

Trip Attractions Model

The trip attraction models for all non-HBW purposes are linear regression models that estimate attractions for each trip purpose, and then allocate total attractions to car ownership/income markets in proportion to the share of productions by household income in each car ownership market. The models are applied in two steps. First, total attractions for each purpose are calculated using the attraction equations shown in Table 3-20. For HBSH trips, attractions are estimated by applying a trip rate R to the zonal retail employment. The steps for calculating R are as follows:

Step 1: Calculate regionwide resident population to retail employment ratio, R1.
Step 2: Calculate the same ratio for each RSA, R2.
Step 3: Calculate for each RSA the relative retail service index RSI = R2/R1.
Step 4: Range bracket RSI to 0.5 – 1.5.
Step 5: Assign this RSI to each TAZ of that RSA
Step 6: Apply the equation R = 2.105 + 4.108*RSI to estimate the attraction rate

The trip attraction regression models forecast total attractions by TAZ for all non-HBW purposes. An allocation process is applied to segment the HBSH, HBSR, HBSP and HBO attractions into the household markets used by the trip distribution and mode choice models -- zero cars all income, car insufficient all income, car sufficient low income, car sufficient medium income and car sufficient high income. This process allocates total TAZ attractions to household trip markets in proportion to the share of trip productions in the market.

The HBSC and HBCU attraction models are based on school and university enrollment, respectively. The trip attraction rates are shown in Table 3-21. In application, the school productions get allocated to school attractions within the same school district. This is accomplished by balancing the trips at the school district level. Similarly, the group quarters population is assigned to a college location, to keep the model from assigning some of these students to the wrong campus. There are several instances of student dormitories located on a TAZ adjacent to the campus TAZ, so not all of the group quarters population HBCU trips are intra-zonal trips.

Table 3-20: HBSC and HBCU Trip Attraction Rates

Trip Purpose	Trip Attraction Rate (attractions per enrolled student)	R^2
Home-Based School	1.326	0.84
Home-Based College, non GQ	0.542	0.77
Home-Based College, GQ	1.500	n/a

The HBWD and HBWS attraction models are linear equations based on thirteen categories of employment. Given that the relative attractiveness of jobs varies depending on the type of worker and residential location, the coefficients of the attraction models vary by household market and by the production TAZ.

Table 3-21: Trip Attraction Model Regression Coefficients

Trip Purpose	Households	Total Employment	Residential Population	Low-Wage Employment	Medium-Wage Employment	High-Wage Employment	Retail	Information	Professional Services	Education & Health Services	Arts, Entertainment, Accommodations and Food Services	Other Services	Public Administration	K12 Enrollment	College Enrollment
HBWD1 Low Inc.				1.181											
HBWD2 Med Inc.					1.040										
HBWD3 High Inc.						1.040									
HBWS1 Low Inc.				0.324											
HBWS2 Med Inc.					0.339										
HBWS3 High Inc.						0.347									
HBCU															0.549
HBSC														1.326	
HBO			0.270				0.993			0.544	0.993	0.993	3.439		
HBSR			0.166								2.126				
HBSP			0.357							0.703					
OBO Attraction	0.508	0.180					4.678			0.698	3.136	3.303			
WBO Attraction	0.036	0.202					0.513				1.147				
OBO Production	0.538	0.162					4.393			1.118	2.568	3.784			
WBO Production		0.137						0.227	0.250			5.743			

Trip Production Model Validation

The model was validated to the expanded 2012 California survey and SCAG Add-on surveys.

Table 3-22 shows a comparison of seurvey vs. model genereated by trip purposes. As shown, the model generates trips by purpose within 4% of the observed trips and replicates overall of the total observed trips.

Table 3-22: Trip Production Validation to Household Survey, 2012

Trip Purpose	2012 Household Survey	2012 Model Estimate	% Diff.
HBWD	8,960,693	9,220,900	3%
HBWS	1,884,606	1,939,400	3%
HBSC	4,718,142	4,581,800	-3%
HBCU	699,938	672,600	-4%
HBSH	4,897,836	4,803,000	-2%
HBSR	7,409,153	7,380,700	0%
HBO	10,575,864	10,457,300	-1%
HBSP	6,433,085	6,541,300	2%
OBO	14,579,200	14,566,100	0%
WBO	3,372,527	3,221,700	-4%
Total	**63,531,045**	**63,384,800**	**0%**

Tables 3-23 and 3-24 provide summary statistics for person trips, by county and for the SCAG region. Table 3-23 shows the summary of trips by county and trip purpose. Table 3-24 identifies selected comparative statistics, such as trips per household, trips per vehicle, and trips per capita (resident person).

Table 3-23: Year 2012 Trip Generation Summary by Trip Purpose and by County

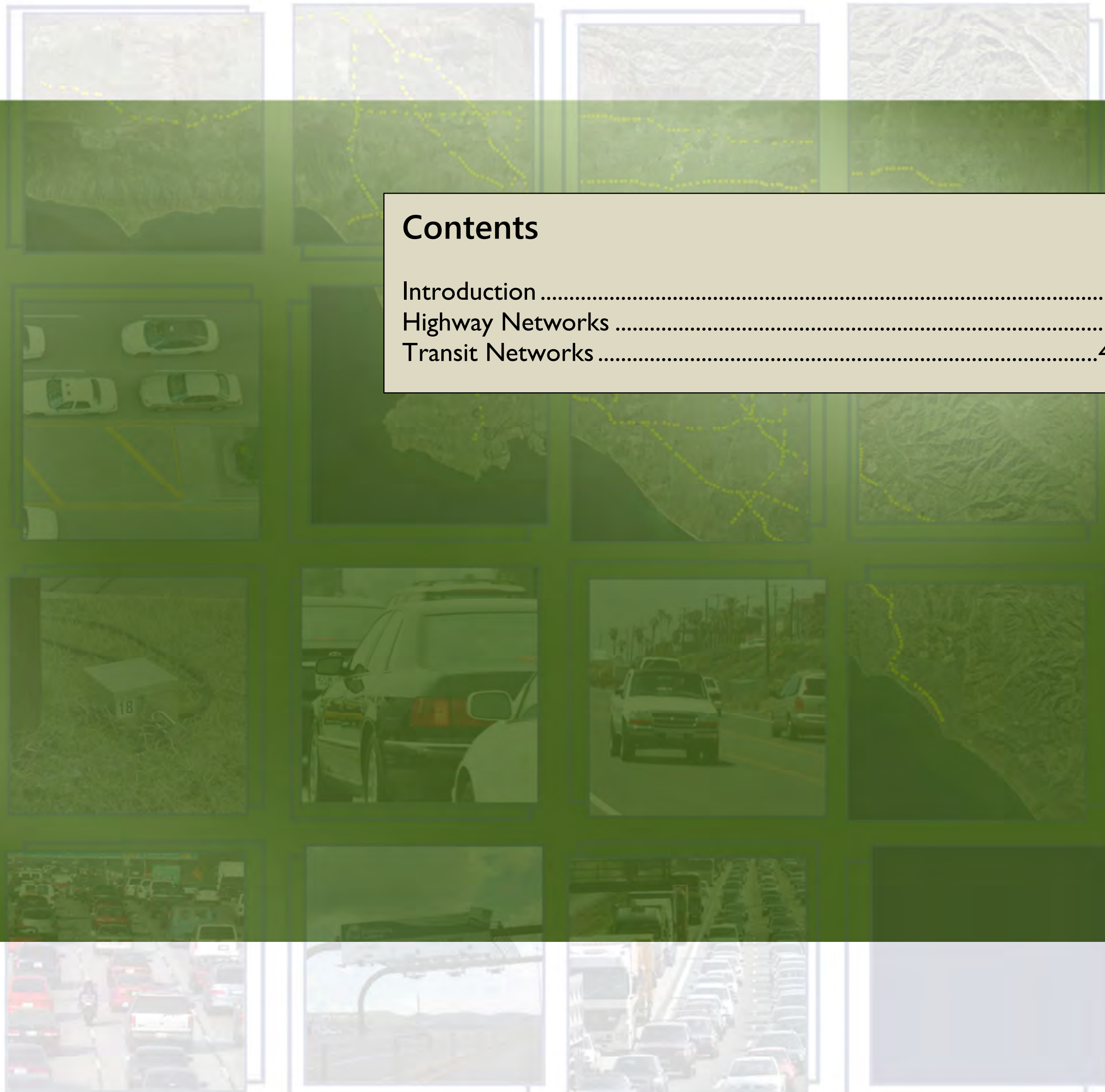
Trip Purpose	Person Trip Productions						
	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Model Area Total
HBWD No Cars	1,263	170,046	44,254	8,455	9,657	3,442	237,118
HBWD Car Competition	2,311	653,243	242,313	40,790	31,666	21,798	992,122
HBWD Car Suf. 0-35K	12,114	656,328	125,391	137,228	128,569	37,611	1,097,239
HBWD Car Suf. 35-75K	22,472	1,350,697	336,893	305,793	313,851	105,537	2,435,244
HBWD Car Suf. over 75K	27,573	2,293,232	899,330	500,739	466,813	271,443	4,459,128
HBWS No Cars	264	33,721	8,874	1,536	1,757	618	46,770
HBWS Car Competition	495	127,031	46,885	8,190	6,255	4,366	193,222
HBWS Car Suf. 0-35K	2,610	127,443	24,472	27,762	25,047	7,627	214,961
HBWS Car Suf. 35-75K	4,915	273,174	68,307	64,295	63,355	21,624	495,670
HBWS Car Suf. over 75K	6,660	505,287	201,042	113,862	101,394	60,504	988,749
Total Home Based Work	**80,677**	**6,190,202**	**1,997,760**	**1,208,650**	**1,148,364**	**534,570**	**11,160,224**
HBSC	54,225	2,364,977	728,604	624,276	598,887	210,829	4,581,798
HBCU	4,919	371,566	115,640	72,646	78,147	29,667	672,584
HBSH	45,756	2,610,630	796,113	590,246	542,793	217,428	4,802,966
HBSR	58,033	3,968,957	1,269,293	904,225	829,449	350,728	7,380,684
HBSP	66,830	3,502,833	1,061,550	834,248	783,820	292,038	6,541,319
HBO	80,765	5,633,979	1,788,291	1,284,038	1,176,697	493,552	10,457,322
Total Home Based Non Work	**310,528**	**18,452,941**	**5,759,491**	**4,309,678**	**4,009,793**	**1,594,242**	**34,436,673**
WBO	10,349	1,908,675	637,281	260,673	274,285	130,390	3,221,653
OBO	91,668	8,148,298	2,770,067	1,477,801	1,423,448	654,810	14,566,092
Total Non-Home Based	**102,017**	**10,056,974**	**3,407,347**	**1,738,474**	**1,697,734**	**785,200**	**17,787,745**
Total Person Trips	**493,222**	**34,700,117**	**11,164,598**	**7,256,802**	**6,855,890**	**2,914,012**	**63,384,641**

Table 3-24: Year 2012 Trip Generation Comparative Statistics

Home Based Work Trips	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Model Area Total
Trips	80,677	6,190,202	1,997,760	1,208,650	1,148,364	534,570	11,160,224
Trips per Household	1.63	1.90	2.00	1.74	1.87	1.99	1.90
Trips per Vehicle	0.84	1.04	0.98	0.83	0.87	0.92	0.98
Trips per Worker	1.52	1.57	1.55	1.56	1.63	1.54	1.57
% Home Based Work Trips	16.36%	17.84%	17.89%	16.66%	16.75%	18.34%	17.61%
Home Based Non Work Trips	**Imperial**	**Los Angeles**	**Orange**	**Riverside**	**San Bernardino**	**Ventura**	**Model Area Total**
Trips	310,528	18,452,941	5,759,491	4,309,678	4,009,793	1,594,242	34,436,673
Trips per Household	6.28	5.67	5.76	6.21	6.52	5.92	5.85
Trips per Vehicle	3.21	3.10	2.82	2.97	3.04	2.75	3.01
Trips per Person	1.73	1.86	1.88	1.92	1.94	1.91	1.88
% Home Based Non Work Trips	62.96%	53.18%	51.59%	59.39%	58.49%	54.71%	54.33%

Non Home Based Trips	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Model Area Total
Trips	102,017	10,056,974	3,407,347	1,738,474	1,697,734	785,200	17,787,745
Trips per Household	2.06	3.09	3.41	2.50	2.76	2.92	3.02
Trips per Vehicle	1.06	1.69	1.67	1.20	1.29	1.35	1.55
Trips per Person	0.57	1.01	1.11	0.77	0.82	0.94	0.97
% Home Based Non Work Trips	20.68%	28.98%	30.52%	23.96%	24.76%	26.95%	28.06%
Total Trips	**Imperial**	**Los Angeles**	**Orange**	**Riverside**	**San Bernardino**	**Ventura**	**Model Area Total**
Trips	493,222	34,700,117	11,164,598	7,256,802	6,855,890	2,914,012	63,384,641
Trips per Household	9.98	10.66	11.17	10.45	11.14	10.82	10.77
Trips per Vehicle	5.11	5.83	5.46	5.01	5.20	5.02	5.54
Trips per Person	2.75	3.50	3.63	3.23	3.32	3.49	3.46

Chapter 4 - Transportation Networks



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CHAPTER 4 – TRANSPORTATION NETWORKS

Introduction

This section summarizes the highway, transit, toll, and heavy-duty truck networks used in the Year 2012 Regional Travel Model Validation.

The Year 2012 highway network went through an extensive review to examine network coding accuracy and to ensure proper network connectivity. Once complete, the transit network was built directly off of the highway network ensuring an integrated network approach.

Attributes for the Year 2012 highway network were determined based on the Federal Highway Functional Classification system, SCAG highway network, and inputs from sub-regional and regional agencies. SCAG conducted an extensive review of the Year 2012 highway network using aerial photography to examine network coding accuracy and ensure proper network connectivity. The new highway network was distributed to interested transportation commissions and Caltrans districts for further review. Several meetings of these agencies were conducted to discuss coding conventions and to accept comments.

Sensitivity model runs using the new networks were performed, and loaded volumes plots were carefully examined to ensure proper network flows and connectivity. A summary of the number of links, roadway centerline miles, and number of lane miles in the highway network is provided later in this chapter (see Table 4-7). The free flow speed and roadway capacity used by trip distribution and assignment were assigned to the network using speed/capacity lookup tables (see Tables 4-1through 4-6).

The transit network is a key input to the mode choice model and is used in the transit trip assignment process. All elements used to determine level of service for transit mode choice calculations are identified and defined in this section. The various transit modes (e.g., Metrolink, local bus) that constitute the mode choice set are also identified.

Highway Networks

In 2007-08, SCAG conducted an extensive Highway Network Inventory program to gather information on the regional highway network and to transfer attributes to SCAG's TransCAD network. The Highway Inventory was built on a very detailed geographic information system (GIS) network that included over 21,000 centerline miles for all freeways, arterials, and urban major collectors. This GIS data was later transferred to the TransCAD-based 2008 highway network. A detailed review and update of the highway network was completed using aerial photography to ensure the base year network accurately represented 2012 conditions.

As part of the network inventory, primary and secondary attributes were geo-coded. Primary attributes were identified as critical to the performance of the travel demand model and include:

- Speed Limits
- Number of Lanes (by time period)
- Intersection Control (at model nodes)
- Median Type
- Directionality (one-way versus two-way streets)

Secondary attributes include:

- Linear Reference System Based on Model Network
- Shoulder type
- Other Controlled Intersections
- Parking
- School Zones
- Advisory Speeds
- HOV Access
- Ramp Gore Points
- Bike Lanes

The highway network was developed and coded using the TransCAD Transportation Planning Software. TransCAD uses a GIS-based network approach to ensure geographic accuracy and provide enhanced editing capabilities. The GIS-based database structure allows for an almost unlimited number of attributes and is very flexible. The Year 2012 highway network includes detailed coding of the region's freeway system (e.g., mixed-flow lane, auxiliary lane, HOV lane, toll lane, and truck lane), arterials, major collectors, and some minor collectors. To simulate roadside parking restrictions and other lane changes during the day, separate networks were developed for each of the following five modeling time periods:

- AM peak period (6:00 AM to 9:00 AM)
- PM peak period (3:00 PM to 7:00 PM)
- Midday period (9:00 AM to 3:00 PM)
- Evening period (7:00 PM to 9:00 PM)
- Night period (9:00 PM to 6:00 AM)

Facility Types

The facility type (FT) definitions used in SCAG's Year 2012 highway network are generally consistent with the Federal Functional Highway Classification system. The major categories used for defining facility type are as follows:

- FT 10 - Freeways
- FT 20 - HOV
- FT 30 - Expressway/Parkway
- FT 40 - Principal Arterial
- FT 50 - Minor Arterial
- FT 60 - Major Collector

- FT 70 - Minor Collector
- FT 80 - Ramps
- FT 90 - Truck lanes
- FT 100 - Centroid connector

Area Types

The area types (AT) used in the highway network were prepared based on development density (population and employment density) and other land use characteristics. The area types used in the highway network are:

- AT 1 - Core
- AT 2 - Central Business District
- AT 3 - Urban Business District
- AT 4 - Urban
- AT 5 - Suburban
- AT 6 - Rural
- AT 7 - Mountain

Free Flow Speeds and Capacities

Free-flow speeds and capacities assigned to each link in the highway network were determined based on the posted speed (PS), facility type and area type of each link. Free flow speeds and capacities are presented in Tables 4-1 through 4-6.

Table 4-1: Year 2012 Freeway/Expressway Free-Flow Speed

Functional Class	AT1	AT2	AT3	AT4	AT5	AT6	AT7
Freeway	PS+5	PS+5	PS+5	PS+5	PS+5	PS+5	PS+5
HOV	PS+5	PS+5	PS+5	PS+5	PS+5	PS+5	PS+5
Expressway (Limited Access)	PS+5	PS+5	PS+5	PS+5	PS+5	PS+5	PS+5
Fwy-Fwy Connector	45	45	50	50	55	55	55
On-Ramp (peak)	15	15	20	20	30	35	35
On-Ramp (off-peak)	25	25	30	30	35	35	35
Off-Ramp	25	25	30	30	35	35	35

Notes:
AT1: Core *AT3: Urban Business District* *AT5: Suburban* *AT7: Mountain*
AT2: Central Business District *AT4: Urban* *AT6: Rural* *PS = Posted Speed*

Table 4-2: Year 2012 Arterial Free-Flow Speed

Posted Speed		AT1	AT2	AT3	AT4	AT5	AT6	AT7
		-- Principal Arterial --						
20		21	22	22	24	25	27	27
25		23	24	25	27	28	31	31
30		25	26	27	29	31	34	34
35		27	28	29	32	35	38	38
40		28	30	32	34	37	41	41
45		30	32	34	37	40	45	45
50		33	35	37	41	45	51	51
55		34	38	39	44	49	56	56
		-- Minor Arterial --						
20		19	20	21	23	24	27	27
25		21	22	23	25	27	30	30
30		22	24	25	28	30	34	34
35		24	26	27	30	33	37	37
40		25	28	29	32	36	41	41
45		27	29	31	34	38	44	44
50		29	32	33	38	43	50	50
55		30	33	35	40	46	55	55
		-- Major Collector --						
20		17	18	19	21	23	26	26
25		18	20	21	23	26	30	30
30		19	21	22	25	28	33	33
35		20	22	24	27	31	36	36
40		21	24	25	28	33	39	39
45		22	25	26	30	35	43	43
50		23	27	28	33	39	48	48
55		24	28	30	35	42	52	52

Notes: *Add 4% for divided streets*

AT1: Core *AT4: Urban* *AT7: Mountain*

AT2: Central Business District *AT5: Suburban*

AT3: Urban Business District *AT6: Rural*

Table 4-3: Year 2012 Arterial / Expressway Capacity (Signal Spacing <2 miles)

On\Crossing		2-Lane	4-Lane	6-Lane	8-Lane
		-- AT1_Core --			
2-Lane		475	425	375	375
4-Lane		650	600	500	500
6-Lane		825	700	600	550
8-Lane		825	700	650	600
		-- AT2_Central Business District --			
2-Lane		575	525	475	475
4-Lane		725	675	550	550
6-Lane		875	750	650	600
8-Lane		875	750	700	650
		-- AT3_Urban Business District --			
2-Lane		600	525	475	475
4-Lane		750	675	575	575
6-Lane		900	775	675	625
8-Lane		900	775	725	675
		-- AT4_Urban --			
2-Lane		625	550	500	500
4-Lane		800	725	600	600
6-Lane		950	825	700	650
8-Lane		950	825	775	700
		-- AT5_Suburban --			
2-Lane		675	600	525	525
4-Lane		825	750	625	625
6-Lane		975	850	750	675
8-Lane		975	850	800	750
		-- AT6_Rural --			
2-Lane		675	600	525	525
4-Lane		825	750	625	625
6-Lane		975	850	750	675
8-Lane		975	850	800	750
		-- AT7_Mountain --			
2-Lane		575	500	425	425
4-Lane		750	675	550	550
6-Lane		925	800	700	625
8-Lane		925	800	750	700

Notes: Capacities are in passenger car per lane per hour (pcplph).
Lanes are mid-block 2-way lanes.
Add 20% for one-way streets.
Add 5% for divided streets.

Table 4-4: Year 2012 Arterial / Expressway Capacity (Signal Spacing >=2 Miles)

Type	Posted Speed	Capacity (Per Lane)
Multi-Lane Highway	45	1,600
	50	1,700
	55	1,800
	60	1,900
2-Lane Highway	--	1,400

Table 4-5: Year 2012 Freeway Capacity

Type	Posted Speed (mile per hour)	Capacity (passenger car per lane per hour)
Freeway/HOV	55 and below	1,900
	60 and 65	2,000
	70 and above	2,100
Freeway-Freeway Connector	40 and below	1,400
	45	1,600
	50	1,700
	55	1,800
	60 and above	1,900
Auxiliary Lane	--	1,000

Table 4-6: Year 2012 Ramp Capacity

		AT1	AT2	AT3	AT4	AT5	AT6	AT7
On-Ramp (first lane)		720	720	720	720	1,400	1,400	1,400
On-Ramp (additional lane)		480	480	480	480	600	1,400	1,400
On-Ramp (off-peak)		1,300	1,300	1,300	1,300	1,400	1,400	1,400

Notes: Use arterial/expressway capacity estimation procedure for off-ramps.
AT1: Core
AT2: Central Business District
AT3: Urban Business District
AT4: Urban
AT5: Suburban
AT6: Rural
AT7: Mountain

Toll Roads

The 2012 highway network incorporates all toll facilities, including the SR- 91 Express Lanes and the San Joaquin Eastern and Foothill Toll Roads developed by the Transportation Corridor Agency (TCA). All toll facilities are located in Orange County.

Heavy Duty Truck Designation

The Year 2012 highway network incorporates special network coding that allows for heavy-duty trucks to be converted into Passenger Car Equivalents (PCE). This conversion enables the model to account for the effects of trucks on link capacity in the mixed flow vehicle traffic stream. The highway network also includes coding to identify truck-only lanes and truck climbing lanes.

Freeway Lane Type

For the purpose of the Regional Model, the Year 2012 highway network includes a detailed coding of the region's freeway system. Freeway lanes are identified by the following three lane types:

- ***Freeway Main Lane*** (Through Lane) includes continuous freeway lanes that extend more than 2 miles and that pass through at least one interchange.
- ***Freeway Auxiliary Lane*** (Auxiliary Lane of Capacity Significance) includes auxiliary freeway lanes that extend more than one mile or that extend from interchange to interchange.
- ***Freeway Acceleration/Deceleration Lane*** (Other Freeway Lane) includes all types of acceleration and deceleration lanes or freeway widening that do not satisfy the conditions for main lane and auxiliary lane classifications.

Year 2012 Highway Network Summary

Table 4-7 summarizes the Year 2012 Highway Network by tallying the number of highway facility routes and lane-miles represented in the network for each county and facility type. The route mile summary includes both directions of travel, even if the roadway is represented by two separate one-way links in the coded network. Figures 4-1 through 4-3 depict the Year 2012 highway network by facility type and area type. Figure 4-4 shows the locations of the external cordon sites on the network at the modeling area's boundary.

Table 4-7: Year 2012 Highway Network Summary

County	Centerline Miles	Lane Miles				
		AM Peak	Midday	PM Peak	Evening	Night
Freeway (Mixed-Flow, excluding HOV and Toll Facilities)						
Imperial	95	380	380	380	380	380
Los Angeles	634	4,581	4,581	4,581	4,581	4,581
Orange	167	1,298	1,298	1,298	1,298	1,298
Riverside	307	1,727	1,727	1,727	1,727	1,727
San Bernardino	472	2,534	2,534	2,534	2,534	2,534
Ventura	94	528	528	528	528	528
Subtotal	**1,770**	**11,048**	**11,048**	**11,048**	**11,048**	**11,048**
Toll Facilities (including HOT)						
Imperial	0	0	0	0	0	0
Los Angeles	0	0	0	0	0	0
Orange	61	329	329	329	329	329
Riverside	0	1	1	1	1	1
San Bernardino	0	0	0	0	0	0
Ventura	0	0	0	0	0	0
Subtotal	**61**	**330**	**330**	**330**	**330**	**330**
Freeway (HOV)						
Imperial	0	0	0	0	0	0
Los Angeles	246	505	505	505	505	505
Orange	114	233	233	233	233	233
Riverside	40	82	82	82	82	82
San Bernardino	52	105	105	105	105	105
Ventura	0	0	0	0	0	0
Subtotal	**453**	**926**	**926**	**926**	**926**	**926**
Major Arterial						
Imperial	183	611	611	611	611	611
Los Angeles	1,941	8,351	8,346	8,351	8,343	8,345
Orange	692	3,493	3,493	3,493	3,493	3,493
Riverside	306	1,208	1,208	1,208	1,208	1,208
San Bernardino	533	1,798	1,798	1,798	1,798	1,798

Ventura	215	795	795	795	795	795
Subtotal	**3,870**	**16,256**	**16,252**	**16,257**	**16,249**	**16,251**
Minor Arterial						
Imperial	266	546	546	546	546	546
Los Angeles	2,868	8,948	8,945	8,947	8,942	8,942
Orange	779	2,733	2,733	2,733	2,733	2,733
Riverside	997	2,870	2,869	2,870	2,869	2,869
San Bernardino	1,448	3,860	3,860	3,860	3,860	3,861
Ventura	357	992	992	992	992	992
Subtotal	**6,715**	**19,949**	**19,946**	**19,949**	**19,943**	**19,943**
Collector						
Imperial	1,217	2,465	2,465	2,465	2,465	2,465
Los Angeles	3,140	6,698	6,697	6,697	6,696	6,696
Orange	380	931	931	931	931	931
Riverside	2,032	4,755	4,755	4,755	4,755	4,755
San Bernardino	3,076	6,507	6,507	6,507	6,507	6,507
Ventura	478	1,010	1,010	1,010	1,010	1,010
Subtotal	**10,323**	**22,366**	**22,366**	**22,366**	**22,364**	**22,365**
Total All Facilities (excluding truck, ramps, centroid connector)						
Imperial	1,760	4,002	4,002	4,002	4,002	4,002
Los Angeles	8,830	29,083	29,075	29,083	29,068	29,070
Orange	2,192	9,017	9,017	9,017	9,017	9,017
Riverside	3,683	10,642	10,642	10,642	10,642	10,642
San Bernardino	5,581	14,805	14,805	14,805	14,805	14,805
Ventura	1,144	3,326	3,326	3,326	3,326	3,325
Total	**23,191**	**70,876**	**70,868**	**70,876**	**70,861**	**70,862**

Figure 4-1: Year 2012 Network by Facility Type

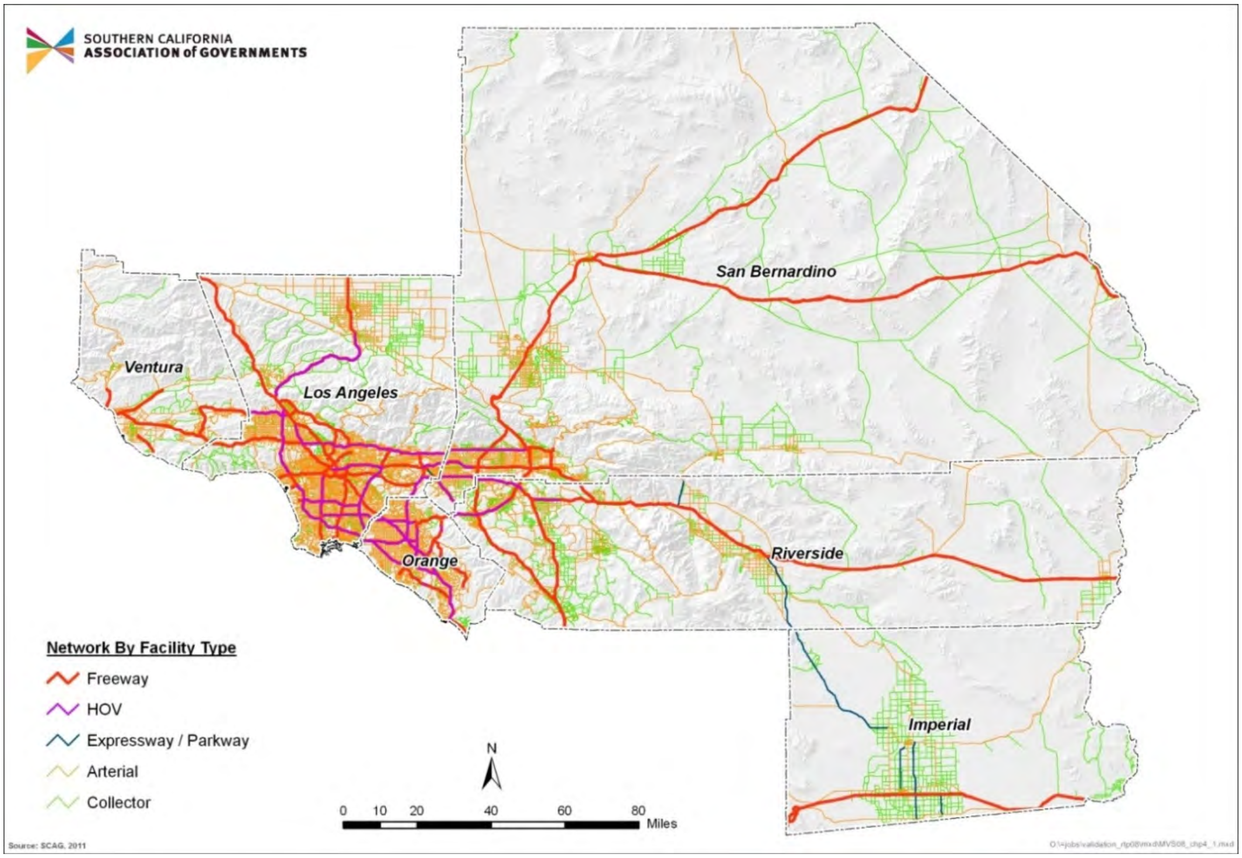


Figure 4-2: Year 2012 Modeling Area by Area Type

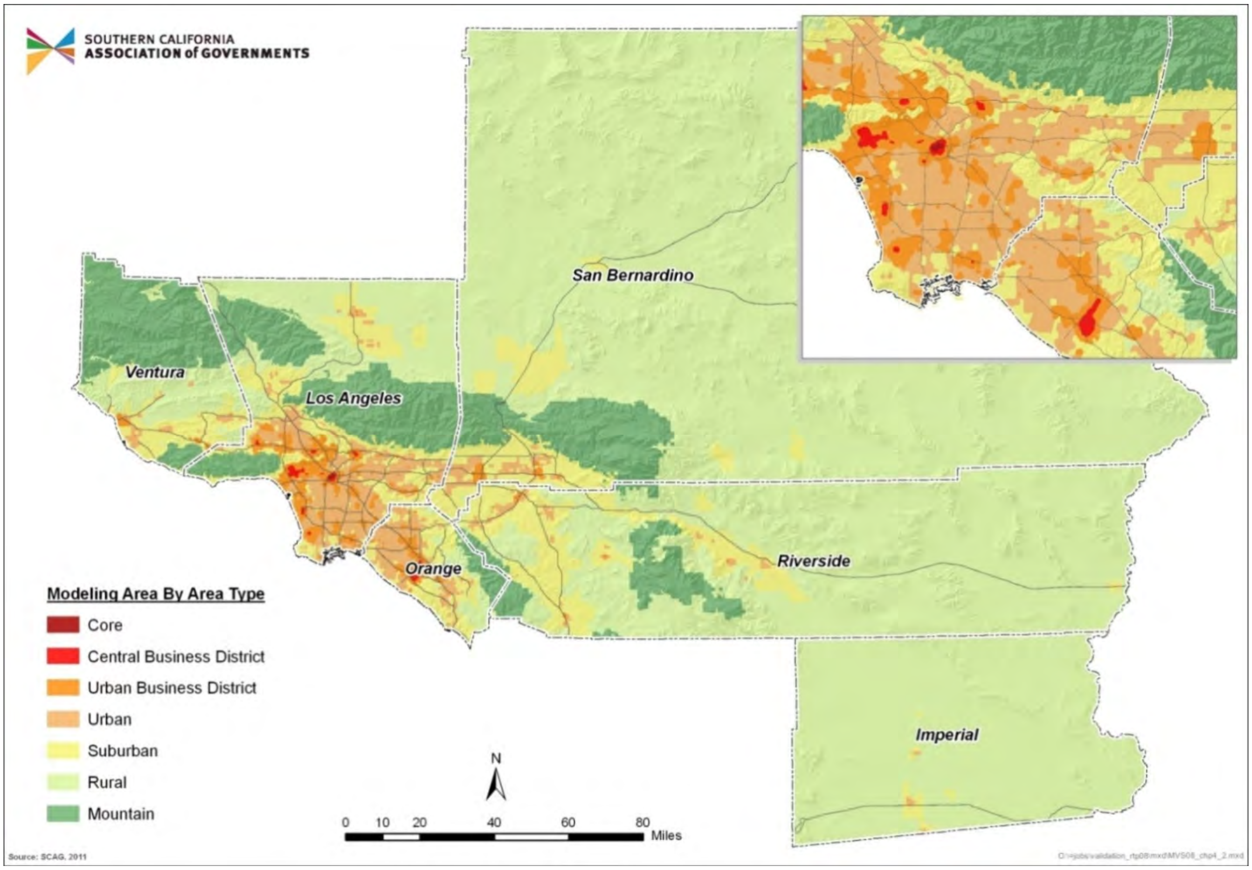


Figure 4-3: Year 2012 Network by Area Type

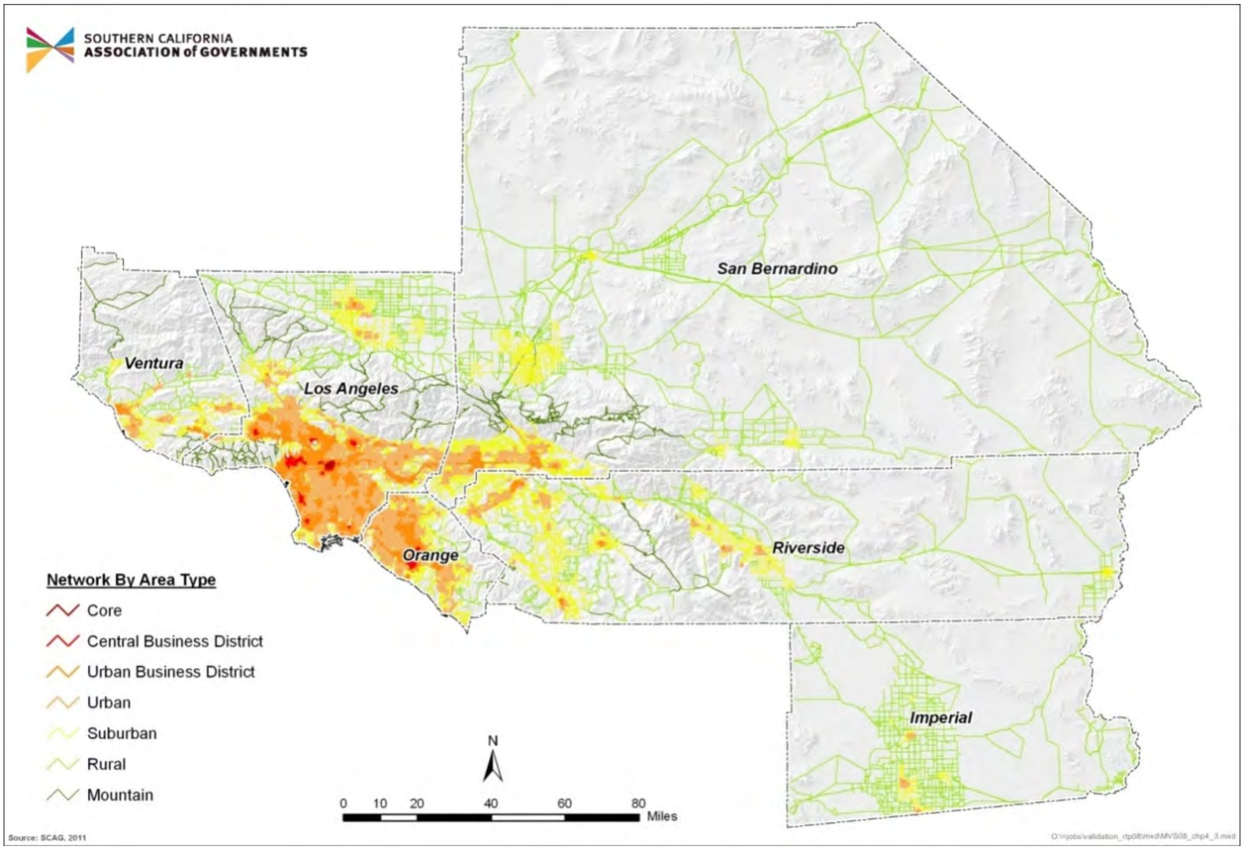
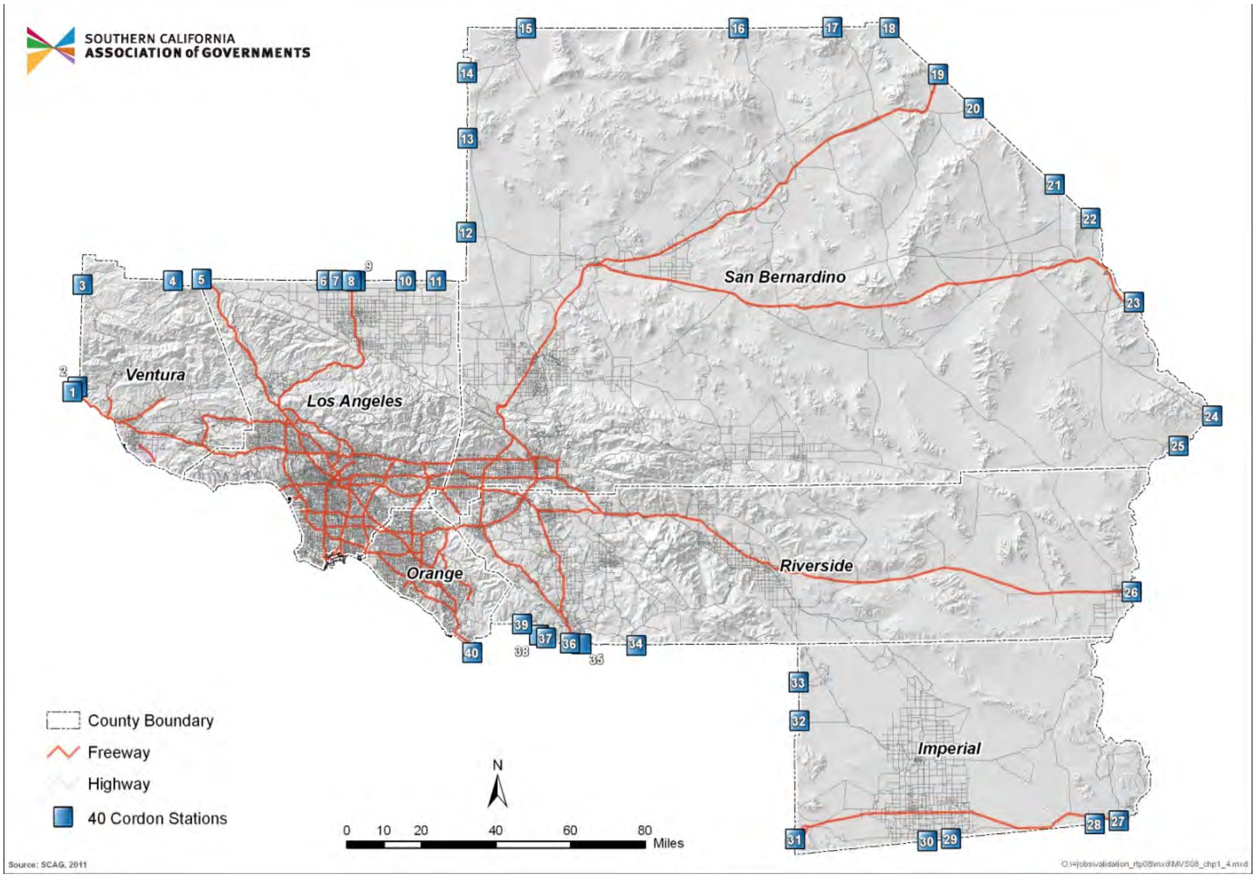


Figure 4-4: Modeling Area External Cordon Locations



Transit Networks

Consistent with the Regional Model highway network, the Year 2012 transit network covers the entire SCAG region, with nearly 3,000 transit route patterns for more than 70 transit carriers in six counties. The year 2012 transit network includes the following key features:

- Uses a more comprehensive transit database that covers key attributes of the Los Angeles County Metropolitan Transit Authority TripMaster and FTA National Transit Database (NTD) for the SCAG region.
- Automatically separates out all route patterns that have different pairs of start and end stops to calculate headways more accurately.
- Automatically converts TripMaster into the TransCAD transit network.
- Includes coding fares at the route level and fare factors at the carrier level.
- Reflects transit operations by five times of day (AM, MD, PM, EVE, NT), rather than peak and off-peak.
- Uses a TeleAtlas-based street network to create transit walk access/egress links and compute average walk times of all paths from every street node in a TAZ to a nearby stop with the path cost weighted by Census Block Group data

For the Year 2012 transit network, transit services in the SCAG region are grouped into seven transit modes and four non-transit modes, according to their service characteristics and fare structures. An additional mode, High Speed Rail, has been added to future year transit networks. The Year 2012 transit network covers only fixed-route transit services. It does not include dial-a-ride, charter services, airport shuttles, limousines, or Uber/Lyft/taxicabs.

Transit routes in each transit network are characterized by attributes such as route ID, route name, route head sign, transit operator, route distance, direction, transit modes, and fares. The transit network also includes detailed headway, frequency, start time and end time of the service for each of the five time periods.

Stops are placed along the route with information such as route ID, stop coordinates, milepost, and corresponding highway node ID. For rail transit (commuter rail and local rail), station-to-station rail time, rail station information, and Metrolink's fare zone are also coded in the network.

Transit Modes

The following seven transit modes are included in the Year 2012 transit network.

1. Commuter Rail is defined as transit service that has a fixed-guideway, traverses long-distances, has distinctive branding and vehicles, and is mostly used by commuters. In the SCAG region, commuter rail includes Metrolink and Amtrak.
2. Local Rail also has a fixed-guideway, but mainly refers to subway and light rail. Currently, LACMTA runs two subway lines (the red and purple lines) and three light rail lines (the Blue, Gold, and Green lines).
3. Express Bus is defined as transit service with limited stops and a limited span of service that operates partly in mixed-flow freeway traffic and may require an additional fare. Many transit operators in the SCAG region have express bus service.
4. Rapid Bus has limited stops and distinctive branding, but usually does not operate on freeways.
5. Local Bus is the most common bus service that uses local streets and makes frequent stops. Almost every operator runs local bus service.
6. Transitway Bus is similar to the express bus but operates on a semi-dedicated right of way (busway, HOV lanes) with limited stops at freeway stations. In the SCAG region, transitway bus refers to any express bus that uses either El Monte Busway or Harbor Transitway.
7. Bus Rapid Transit (BRT) has limited stops, a dedicated guideway, distinctive branding and vehicles. In Year 2012, only the LACMTA Orange line is considered BRT.

Non-Transit Modes / Transit Access Links

Two types of transit access links are coded in the Year 2012 transit network and described as follows:

- Walk access and egress links - coded as two-way links between a zone centroid and a transit stop location
- Park-and-ride lot to stop and transfers between stations links - coded as two-way walk links between a park-and-ride lot and a transit stop location, and connections between stations

Transit Fares

The Year 2012 transit network includes three types of transit fares: base boarding fares, zone fares, and transfer fares; and two types of fare factors: base fare factor and transfer fare factor. Fare values were collected through the Transit Level of Service Data Collection program and are represented in 2011 dollars. Considering the complex fare structure for most carriers only published full cash fares for initial boarding and transfers are used to represent the base fare and transfer fare. To account for the revenue composition of different fare types, such as one-way walkup fares, daily/weekly/monthly passes, Senior/Student/Disabled fares, and other special fares, base fare factors and transfer fare factors are estimated from the boarding and revenue data provided by transit operators. By applying fare factors to the published full cash fare, the resulting fares represent actual fares paid by an average passenger. Finally, all boarding fares (base fare and transfer fare) are converted to 2011 dollars using a Consumer Price Index (CPI) adjustment factor derived from the CPI factor published by the US Department of Labor for the Los Angeles-Riverside-Orange County metropolitan area.

The fare structure varies significantly by operator and by service for the same operator. For example, LACMTA has both local and express bus service. For local bus, the general fare is a flat rate of $1.50. For express bus, there is a surcharge of $ 0.70 for each zone in addition to the $ 1.50 fare. However, OCTA, another major operator in the region, charges a general fare of $1.50 for local bus. For express bus, the fare is a flat rate of $4.00 or $6.00 depending on the route. To accommodate variations in the fares for different routes, the Year 2012 transit network codes general flat fares (i.e., base fares, transfer fares) at the route level, while the fare factors are calculated at the carrier level.

Two other major operators, Metrolink and Amtrak, follow a zone-based fare structure. For example, Metrolink fares are calculated with a distance-based formula using the shortest driving distance between stations, with an 80-mile maximum charge. To capture the published cash fare between two station pairs, a fare matrix was developed for Metrolink and Amtrak. Similarly, the LACMTA Express bus and Los Angeles Department of Transportation (LADOT) Commuter Express bus that have zone-based fare are also included as a zone-to-zone fare matrix.

Similar to the development of fare factors for flat-rate routes, a fare factor matrix was developed based on Metrolink sales and boarding data to represent the weighted average fare for each station pair. In addition, regression analysis was conducted to generate the relationship between the distance and fares for Metrolink to predict future fares for new stations.

Year 2012 Transit Network Summary

Table 4-8 summarizes the number of transit patterns/routes represented in the peak and off-peak transit network, by "transit mode" as defined above. Figure 4-6 shows the geographic distribution of the existing rail transit network (Metrolink and Local Rail). Figure 4-7 shows the entire Year 2012 transit network.

Table 4-8: Year 2012 Transit Network Route Patterns and Route Pattern Miles

Mode ID(s)	Mode Number	Description	Route Patterns		Route Pattern Miles	
			Peak	Off Peak	Peak	Off Peak
10	1CR	Commuter Rail	36	29	3,109	2,568
11	2LR	Local Rail	13	13	213	210
20-22	3EX	Express Bus	99	66	2,741	1,805
33	4RB	Rapid Bus	78	66	1,201	1,017
30-32	5LB	Local Bus	1,601	1,339	23,062	19,664
23	6TW	Transitway	47	30	1,196	790
19	7BR	Bus Rapid Transit	6	4	76	65
Total			**1,880**	**1,547**	**31,598**	**26,118**

Figure 4-5: Year 2012 Metrolink and Local Rail Network

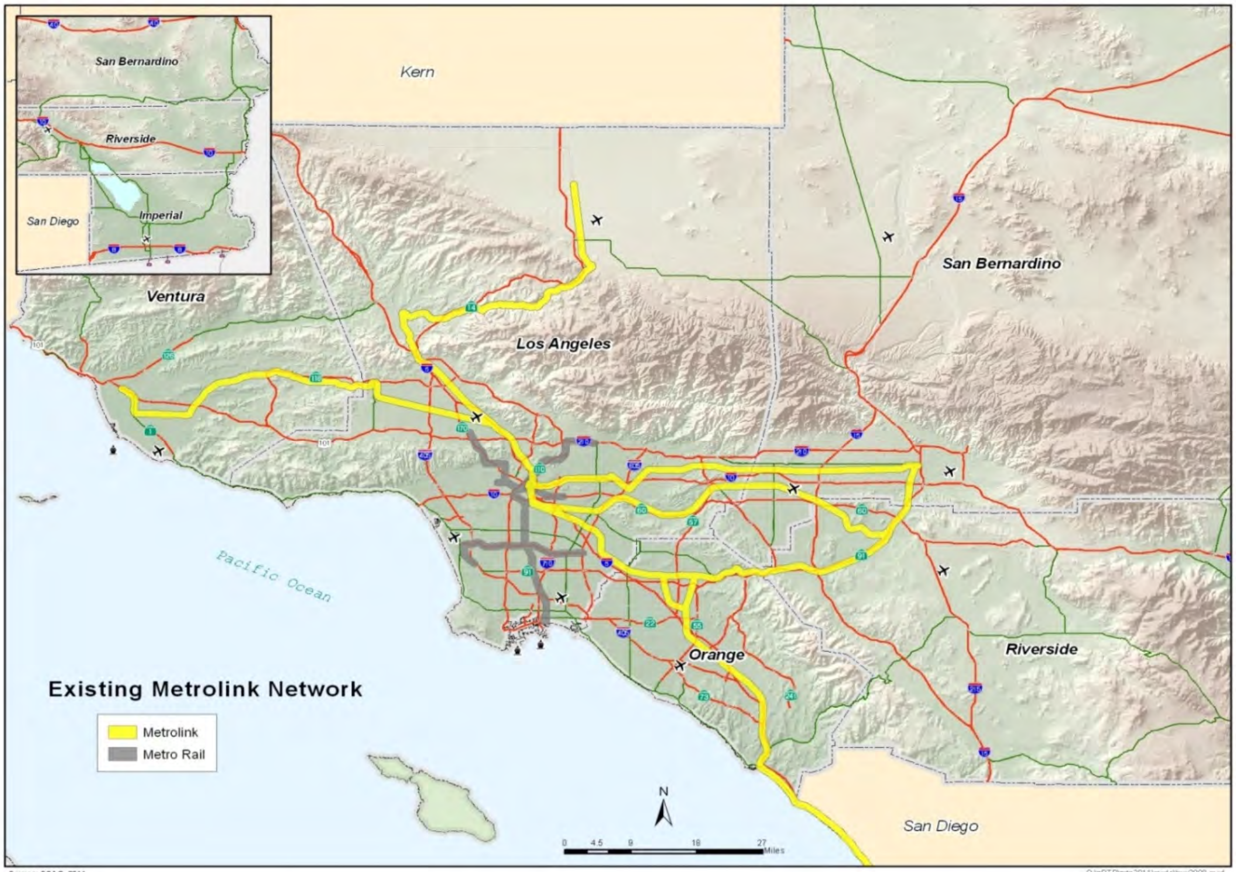
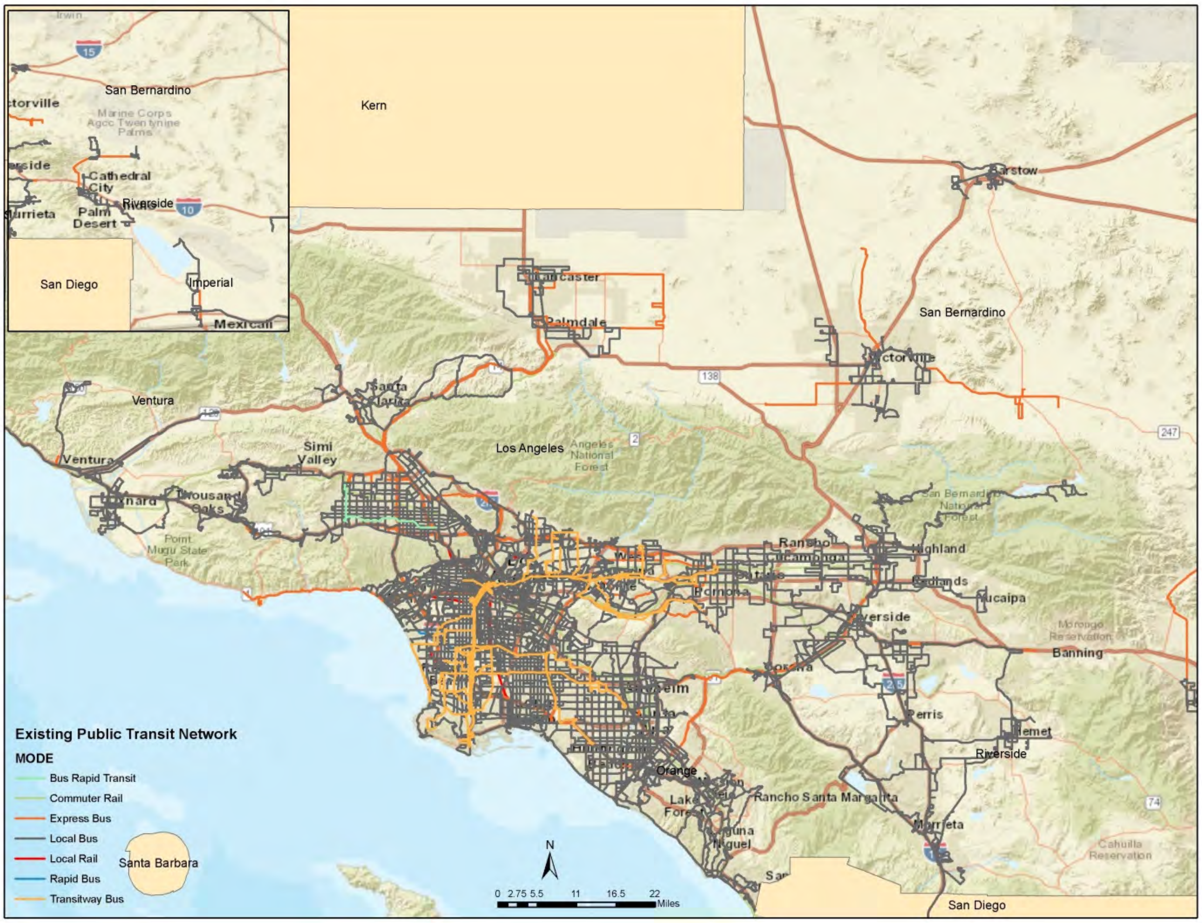


Figure 4-6: Year 2012 Public Transit Network



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CHAPTER 5 - TRIP DISTRIBUTION

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CHAPTER 5 – TRIP DISTRIBUTION

Introduction

The SCAG model uses two types of trip distribution models. The HBSC and HBCU distribution models are gravity models. The HBWD, HBWS, HBSH, HBSR, HBSP, HBO, WBO and OBO distribution models are destination choice models.

The destination choice models were estimated in multinomial logit form using the ALOGIT software. The HBWD, HBWS, HBSH, HBSR, HBSP and HBO models are stratified by the car sufficiency/income market segments shown in Table 3-11. The WBO and OBO models are not stratified, as is customary for non-home-based models. The purpose of the model estimation is to obtain an initial set of utility coefficients. In the subsequent calibration phase, the distance-based terms of the utility function were adjusted to improve the model validation. In addition, some distance-based constants were added to better fit the shape of the observed trip length distributions.

Estimation Dataset

The 2012 California Household Travel Survey provided the trip records for model estimation. Because of the large number of destination alternatives (11,267 in the Tier 2 zone system), it is impractical to include all alternatives in the estimation dataset. A sampling-by-importance approach, combined with an exploded sample, was used to choose alternative sets for each trip observation. Each trip record was duplicated 10 times and different choice sets with 40 alternatives each were selected based on the size term and distance. A weight of 1/10 is applied to each observation to scale the standard error. This approach has been shown to produce results that are nearly statistically equivalent to selecting 400 alternatives for the choice set.

As described in Ben-Akiva and Lerman[1], sampling by importance consists of defining an importance function that gives the probability of selection into the sample, and then selecting zones into the destination choice set by sampling with replacement according to these probabilities. The estimator can be shown to give unbiased, consistent and efficient coefficient estimates. The importance function used for the SCAG destination choice models is defined as:

$$W_j = A_j \times exp\left(-2D_{ij}/D\right)$$

$$P_j = \frac{W_j}{\sum_j W_j}$$

Where *D* is the regional observed average distance, *Aj* is a size variable, and *Dij* is the distance to each zone.

[1] Ben-Akiva, M., and S. Lerman. Discrete Choice Analysis. Theory and Application to Travel Demand. MIT Press, 1985.

Main Explanatory Variables

The following variables were examined and proved to be significant in the utility functions:

- Mode choice logsum
- Distance between production zone and potential attraction zone destinations
  - Linear distance
  - Distance squared
  - Distance cubed
- Household income interacted with distance
- Mix employment, household and intersection density (mix density) interacted with distance
- Intra-zonal indicator interacted with mix density
- Auto availability interacted with distance
- Employment by industry

The mode choice logsum coefficients were constrained to a value consistent with utility maximization theory, that is, between 0 and 1.

Utility Structure

The utility (U_{ij}) of choosing destination (j) for a trip (m) produced in zone (i) is given by:

$$U_{ijm} = \theta \times LS_{ijm} + \sum_k \beta^k f^k(D_{ij}) + \sum_k \gamma^k M^k IZ_j + LN(A_{jm}) + c_{jm}$$

Where:

- LS_{ijm} is the mode choice logsum corresponding to trip market (m);
- $\beta^k f^k(D_{ij})$are the terms of a distance polynomial;
- M^k represents attributes of the trip production zone, such as density, interacted with the intra-zonal alternative IZ_j;
- A_{jm} is the size or attraction variable;
- and c_{jm} is an importance sampling correction term.

The sampling correction term compensates for the sampling error in the model estimation (i.e., represents the difference between the sampling probability and final estimated probability for each alternative). This sampling correction term is not included in the utility function when the model is applied, since in application all 11,267 TAZs are in the choice set.

Estimation Results

Table 5-1 shows the final HBW estimation results. The coefficient on mode choice logsum was constrained to 0.9, because it was consistently estimated to be larger than 1.0 across several different specifications. The distance polynomial results in a monotonically decreasing utility. The distance disutility was capped at 50 miles, to avoid a very large negative coefficient on the linear term, and/or non-monotonic disutility specifications. Variables tested but ultimately dropped from the utility specification due to illogical and/or insignificant coefficients include mixed density interacted with distance and household income interacted with distance. Interacting the mixed density variable with the intrazonal indicator also resulted in a counterintuitive relationship, and therefore the preferred specification is a pure intrazonal indicator variable.

Table 5-1: HBW Destination Choice Estimation Results

Explanatory Variable	HBWD		HBWS	
	Coefficient	t-Stat	Coefficient	t-Stat
Mode Choice Logsum	0.9	n/a	0.9	n/a
Distance	-0.10696	-42.3	-0.093875	-19.0
Distance Squared	0.00140870	19.3	0.0014159	8.4
Distance Cubed	-0.00000643	-11.8	-0.0000100	-6.5
Intra-Zonal Indicator	1.007	12.1	-0.052	-0.3
Observations	16,167(x20)	--	3,289(x20)	--
Final Log-Likelihood	-56666	--	-24144	--
Rho-Squared (Zero)	0.0986	--	0.0758	--
Rho-Squared (Constants)	0.0956	--	0.0736	--

Separate models were estimated for peak and off-peak period trips, but because the differences between them were small, the observations were pooled to estimate the final model. Observed time-of-day differences in average trip lengths were captured in the distance polynomial parameters during model calibration.

The final estimation results for the home-based non-work models are shown in Table 5-2. Overall similar relationships were observed as in the HBW models. In all cases the mode choice logsum coefficient was constrained because its estimated values were greater than 1.0. A value of 0.9 was chosen, similar to the value assumed for the HBW models. Higher density at the production zone end results in a higher likelihood of an intrazonal shopping trip.

The final estimation results for the non-home based models are shown in Table 5-3. No household attributes were explored since they cannot be used in model application. The distance decay and intrazonal effects are similar to those estimated for the home-based models.

Table 5-2: Home-Based Non-Work Destination Choice Estimation Results

Explanatory Variable	HBSH		HBSR		HBSP		HBO	
	Coefficient	t-Stat	Coefficient	t-Stat	Coefficient	t-Stat	Coefficient	t-Stat
Mode Choice Logsum	0.9	n/a	0.9	n/a	0.9	n/a	0.9	n/a
Distance	-0.39444	-69.0	-0.19760	-82.4	-0.51420	-73.2	-0.32393	-108.1
Distance Squared	0.006084	29.6	0.002263	41.7	0.010249	27.7	0.004846	49.2
Distance Cubed	-3.01E-05	-17.2	-0.75E-05	-25.2	-6.91E-05	-15.7	-2.26E-05	-28.8
Intra-Zonal Indicator	0.729	3.8						
Intra-Zonal * Density								
Low Density	0.556	1.9						
Medium Density	0.974	3.0						
High Density	1.819	5.6						
	--	--	--	--	--	--	--	--
Observations	16,706(x10)	--	11,538(x10)	--	8,841(x10)	--	18,430(x10)	--
Final Log-Likelihood	-17328	--	-353425	--	-16828	--	-43969	--
Rho-Squared (Zero)	0.407	--	0.194	--	0.508	--	0.342	--
Rho-Squared (Constants)	0.393	--	0.185	--	0.500	--	0.334	--

Table 5-3: Non-Home Based Destination Choice Estimation Results

Explanatory Variable	WBO		OBO	
	Coefficient	t-Stat	Coefficient	t-Stat
Mode Choice Logsum	0.9	n/a	0.9	n/a
Distance	-0.07764	-25.8	-0.15228	-92.8
Distance Squared	0.000491	15.0	0.000478	43.6
Distance Cubed	-0.24E-05	-6.9	-0.050E-05	n/a
Intra-Zonal Indicator	1.703	11.5	0.71129428	8.2
Intra-Zonal * Density				
Low Density	0.677	2.9	0.389	3.02
Medium Density	1.646	5.99	1.260	8.44
High Density	2.280	11.09	1.790	13.22
Observations	4,520(x10)	--	15,634(x10)	--
Final Log-Likelihood	-12915	--	--40160	--
Rho-Squared (Zero)	0.2497	--	0.3229	--
Rho-Squared (Constants)	0.242	--	0.314	--

Gravity Models (HBSC and HBCU Trip Purposes)

The gravity model is used to distribute HBSC and HBCU trips from origin zone to each destination zone in the region. It is based on Newton's law of gravity, which describes the gravitational force between two bodies. The number of trips between zones in transportation models is a function of the attractiveness of a zone and the travel impedance between zones:

$$T_{ij} = \frac{P_i * (A_j * F(I_{ij}) * K_{ij})}{\sum_j (A_j * F(I_{ij}) * K_{ij})}$$

where, Tij is the number of trips produced in zone i and attracted to zone j;
Pi is the number of trips produced in zone i;
Aj is the number of trips attracted to zone j;
Iij is a measure of impedance of travel from i to j;
F is a friction factor, which is a function of the impedance that represents the disutility of travel between i and j; and
Kij is the zone-to-zone adjustment factor, which takes into account the effect of undefined socioeconomic linkages not otherwise incorporated in the gravity model.

The gravity model in this application will apportion the trips produced at each production zone among attraction zones according to the attractiveness of each zone and the disutility of travel for each trip interchange. The SCAG gravity models are doubly constrained, which means that the program will iterate until the trips produced from and attracted to each zone are consistent with the trip productions and attractions forecasted in trip generation.

The friction factors for were derived by fitting the trip length frequency distributions to the observed HBSC and HBCU distributions for each time period (peak and off-peak). The basic formula for the friction factors is given by the gamma function below.

$$f(x) = ax^{-b}e^{-cx}$$

where a, b, and c are parameters to be calibrated, and x is the trip impedance.

Two exponential decay parameters (c parameter) were calibrated, to better match the tail of the trip length distribution. The calibrated gamma function parameters, and the travel time that corresponds to the change from c1 to c2 (curve inflection) are shown in Table 5-4.

Table 5-4: Trip Distribution Gamma Function Parameters by Time Period

Purpose	Time Period	Gamma a	Gamma b	Gamma c1	Gamma c2	Inflection (travel time)
HBSC	Peak	650,000	1.4352	0.2198	0.0276	15.00
	Off-peak	6,500,000	2.0889	0.2184	0.0192	13.00
HBCU	Peak	500,000	1.4066	0.1148	0.0681	15.00
	Off-peak	500,000	2.4734	0.1474	0.0580	15.00

Model Application and Calibration

In application the destination choice models are stratified by five trip markets, defined by car sufficiency and income levels. Since the mode choice models are similarly stratified, the mode choice logsums are matched at the trip market level.

During the calibration phase the estimated distance polynomials were modified to improve the fit of the estimated trip length distribution to the observed data. The calibration consisted of adjusting the distance disutility terms by comparing the estimated and observed trip lengths at one-mile increments. Several different measures of the fit of the model to the observed data were examined, including average trip length by trip purpose, time period and trip market level, average trip length by trip purpose market and density level, trip length distribution and coincidence ratio, ACS 5-year county-level worker flow patterns .

Below the county level, the only sources of trip flow data are the 2012 California household travel survey, and the CTPP ACS 2012 5-Year Release worker flow matrix.

Table 5-5 shows the validation of average trip lengths by trip purpose, time period and household market. The estimated trip length is typically within 10% of the observed trip length, except in a few cases where the observed values appear biased by small sample sizes in the observed data. In such instances the model was calibrated to exhibit a logical progression of average trip lengths across household markets. Table 5-5 also shows the coincidence ratio for each trip purpose, time period and market segment. The coincidence ratio is a measure of the goodness of fit of the calibrated trip length distribution compared to the observed trip length distribution.

Table 5-5: Trip Distance Validation

Purpose	Period	Household Segment	Number of Obs.	Average Distance (mi)			Coincidence Ratio
				Target	Estimated	Ratio	
HBWD	Peak	Zero	215	12.4	8.59	0.69	0.78
		Insuf	627	14.7	12.56	0.85	0.86
		Suf/Low	1,225	14.4	14.59	1.01	0.95
		Suf/Med	2,699	15.7	16.38	1.04	0.94
		Suf/Hi	5,948	17.4	17.32	1.00	0.93
	Off-Peak	Zero	136	11.1	7.94	0.71	0.80
		Insuf	407	13.5	12.10	0.90	0.88
		Suf/Low	988	13.2	12.44	0.95	0.88
		Suf/Med	1,592	14.5	14.12	0.98	0.87
		Suf/Hi	2,788	16.1	15.59	0.97	0.89
HBWS	Peak	Zero	7	10.5	7.78	0.74	0.83
		Insuf	111	14.3	12.49	0.87	0.85
		Suf/Low	210	16.3	13.87	0.85	0.87
		Suf/Med	515	15.4	15.19	0.98	0.89
		Suf/Hi	1,416	17.3	17.05	0.99	0.88
	Off-Peak	Zero	6	10.5	7.67	0.73	0.82
		Insuf	42	14.3	13.16	0.92	0.85
		Suf/Low	139	16.3	15.82	0.97	0.89
		Suf/Med	288	15.5	16.40	1.06	0.90
		Suf/Hi	564	17.3	17.19	0.99	0.85
HBSH	Peak	Zero	173	6.3	6.03	0.96	0.90
		Insuf	583	7.2	6.98	0.98	0.94
		Suf/Low	400	7.2	6.78	0.94	0.92
		Suf/Med	728	7.4	7.23	0.97	0.92
		Suf/Hi	1,323	7.5	7.35	0.98	0.90
	Off-Peak	Zero	274	6.5	6.30	0.97	0.91
		Insuf	912	7.4	6.92	0.94	0.91
		Suf/Low	791	7.4	7.28	0.99	0.87
		Suf/Med	1,351	7.6	7.48	0.98	0.87
		Suf/Hi	2,187	7.7	7.60	0.99	0.88

Purpose	Period	Household Segment	Number of Observations	Average Distance (mi)			Coincident Ratio
				Observed	Estimated	Ratio	
HBSR	Peak	Zero	147	10.1	9.92	0.98	0.89
		Insuf	702	12.4	12.48	1.01	0.90
		Suf/Low	545	12.7	13.00	1.02	0.89
		Suf/Med	1,127	13.2	13.19	1.00	0.89
		Suf/Hi	2,443	12.9	13.76	1.07	0.87
	Off-Peak	Zero	214	10.3	9.73	0.94	0.82
		Insuf	935	12.6	11.56	0.92	0.89
		Suf/Low	776	12.9	13.01	1.01	0.87
		Suf/Med	1,605	13.4	13.30	0.99	0.89
		Suf/Hi	3,582	13.1	13.58	1.04	0.87
HBSP	Peak	Zero	103	4.2	3.55	0.84	0.83
		Insuf	920	4.5	4.27	0.95	0.87
		Suf/Low	618	4.7	4.68	0.99	0.84
		Suf/Med	1,370	4.9	4.97	1.01	0.84
		Suf/Hi	2,623	5.1	5.32	1.04	0.86
	Off-Peak	Zero	65	4.4	3.48	0.79	0.81
		Insuf	557	4.7	4.05	0.87	0.82
		Suf/Low	435	4.9	4.50	0.92	0.80
		Suf/Med	795	5.1	5.11	1.00	0.80
		Suf/Hi	1,598	5.3	5.13	0.97	0.80
HBO	Peak	Zero	350	8.2	7.24	0.88	0.84
		Insuf	1,240	8.7	8.36	0.96	0.81
		Suf/Low	1,045	8.8	8.19	0.93	0.84
		Suf/Med	1,874	9.0	9.03	1.00	0.80
		Suf/Hi	4,122	9.1	9.41	1.03	0.82
	Off-Peak	Zero	473	8.5	7.54	0.89	0.87
		Insuf	1,411	9.0	9.03	1.01	0.81
		Suf/Low	1,406	9.1	10.36	1.14	0.80
		Suf/Med	2,442	9.3	9.69	1.04	0.81
		Suf/Hi	4,637	9.4	9.76	1.04	0.82
WBO	Peak	All	1,434	9.7	9.58	0.99	0.85
	Off-Peak	All	3,474	8.3	8.54	1.03	0.89
OBO	Peak	All	6,940	7.4	7.09	0.96	0.91
	Off-Peak	All	10,348	7.4	7.41	1.00	0.93
HBCU	Peak	All	456	11.9	12.54	1.05	0.76
	Off-Peak	All	564	13.0	12.45	0.96	0.51
HBSC	Peak	All	3,986	3.8	3.74	0.99	0.76
	Off-Peak	All	1,442	3.6	3.52	0.99	0.73

(1)*See Table 3-12 for the household market segments definitions*

Table 5-6 shows the validation of the estimated 2012 county-to-county HBW trip flows. Note that the ACS data show worker flows, not trip flows. Figures 5-1 to 5-8 show a comparison of observed and estimated trip length frequency distributions for each trip purpose. The observed trip lengths were obtained from the most recent region-wide household survey, conducted in 2012.

Table 5-6: County-To-County HBW Trip Validation

	Worker Flows, 2008-2012 ACS							
	County	**25**	**37**	**59**	**65**	**71**	**111**	**SCAG**
25	Imperial	51,070	123	58	1,235	100	10	52,596
37	Los Angeles	197	4,049,070	180,799	15,160	57,039	36,538	4,338,803
59	Orange	25	178,031	1,178,730	15,171	12,110	534	1,384,601
65	Riverside	654	50,875	66,986	585,391	89,406	578	793,890
71	San Bernardino	100	126,465	34,918	64,978	569,504	831	796,796
111	Ventura	25	66,683	1,174	237	439	294,158	362,716
	SCAG Region	**52,071**	**4,471,247**	**1,462,665**	**682,172**	**728,598**	**332,649**	**7,729,402**
	HBW Trips, 2012 Model Estimate							
	County	**25**	**37**	**59**	**65**	**71**	**111**	**SCAG**
25	Imperial	77,255	321	246	2,573	274	7	80,677
37	Los Angeles	21	5,502,212	475,992	29,761	105,550	76,668	6,190,204
59	Orange	9	384,405	1,547,114	29,877	34,822	1,533	1,997,761
65	Riverside	1,697	131,892	168,017	723,570	182,331	1,143	1,208,650
71	San Bernardino	208	248,195	109,272	119,542	668,743	2,405	1,148,365
111	Ventura	1	160,854	4,031	332	988	368,364	534,570
	SCAG Region	**79,191**	**6,427,879**	**2,304,673**	**905,655**	**992,708**	**450,120**	**11,160,227**
	Forecast Difference (%), Trips vs. Worker Flow, County Normalized							
	County	**25**	**37**	**59**	**65**	**71**	**111**	**SCAG**
25	Imperial	-1.3%	0.2%	0.2%	0.8%	0.1%	0.0%	0.0%
37	Los Angeles	0.0%	-4.4%	3.5%	0.1%	0.4%	0.4%	0.0%
59	Orange	0.0%	6.4%	-7.7%	0.4%	0.9%	0.0%	0.0%
65	Riverside	0.1%	4.5%	5.5%	-13.9%	3.8%	0.0%	0.0%
71	San Bernardino	0.0%	5.7%	5.1%	2.3%	-13.2%	0.1%	0.0%
111	Ventura	0.0%	11.7%	0.4%	0.0%	0.1%	-12.2%	0.0%
	SCAG Region	**0.0%**	**-0.3%**	**1.7%**	**-0.7%**	**-0.5%**	**-0.3%**	**0.0%**

Table 5-7: Sub Air Basin To County HBW Trip Validation

Worker Flows, 2008-2012 ACS							
Sub Air Basin	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	SCAG
SCCAB (VENTURA COUNTY)	25	66683	1174	237	439	294158	362,716
SCAB (LOS ANGELES COUNTY)	197	3,927,389	180,183	14,943	55,685	35,216	4,213,613
MDAB (ANTELOPE VALLEY)	25	178,031	1,178,730	15,171	12,110	534	1,384,601
SCAB (ORANGE COUNTY)	233	47,652	65,357	429,554	86,634	363	629,793
SCAB (RIVERSIDE COUNTY)	60	114,887	32,196	55,712	420,546	627	624,028
MDAB (RIV DESERT)	0	121,681	616	217	1,354	1,322	125,190
MDAB (BLYTHE)	40	11,528	2,687	9,182	142,146	204	165,787
SSAB (COACHELLA VALLEY)	0	0	0	0	524	0	524
SCAB (SAN BERNARDINO CO)	0	50	35	84	6,288	0	6,457
MDAB (VICTOR VALLEY)	0	35	0	662	34	0	731
MDAB (SBD DESERT)	4	10	10	5,111	50	0	5,185
MDAB (SEALES VALLEY)	417	3,178	1,619	150,064	2,688	215	158,181
SSAB (IMPERIAL	3119	0	0	763	0	0	3,882

/WEST)							
SSAB (IMPERIAL /EAST)	575	0	0	60	0	0	635
SSAB (IMPERIAL PM2.5 NON-ATT)	47,376	123	58	412	100	10	48,079
SCAG Region	**52,071**	**4,471,247**	**1,462,665**	**682,172**	**728,598**	**332,649**	**7,729,402**

HBW Trips, 2012 Model Estimate

Sub Air Basin	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	SCAG
SCCAB (VENTURA COUNTY)	1	157,624	3,915	331	984	340,681	503,536
SCAB (LOS ANGELES COUNTY)	18	4,571,326	459,212	28,418	98,205	67,744	5,224,923
MDAB (ANTELOPE VALLEY)	9	373,861	1,422,327	29,620	34,762	1,505	1,862,083
SCAB (ORANGE COUNTY)	167	124,384	162,089	476,036	174,584	1,039	938,298
SCAB (RIVERSIDE COUNTY)	65	202,149	90,496	99,463	464,789	1,506	858,468
MDAB (RIV DESERT)	3	170,901	3,553	1,177	5,263	4,829	185,726
MDAB (BLYTHE)	84	38,538	17,843	19,445	159,510	891	236,312
SSAB (COACHELLA VALLEY)	0	26	13	6	439	1	485
SCAB (SAN BERNARDINO CO)	59	74	49	286	3,047	2	3,518
MDAB (VICTOR VALLEY)	39	88	74	642	52	2	897
MDAB	460	130	98	6,855	133	3	7,679

(SBD DESERT)							
MDAB (SEALES VALLEY)	1,032	5,056	4,360	195,055	7,214	98	212,813
SSAB (IMPERIAL /WEST)	3,782	193	163	1,805	151	4	6,099
SSAB (IMPERIAL /EAST)	1,150	5	4	61	6	0	1,226
SSAB (IMPERIAL PM2.5 NON-ATT)	64,580	122	79	707	117	3	65,608
SCAG Region	**71,448**	**5,644,478**	**2,164,274**	**859,907**	**949,256**	**418,308**	**10,107,670**

Forecast Difference (%), Trips vs. Worker Flow, Normalized

Sub Air Basin	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	SCAG
SCCAB (VENTURA COUNTY)	0.0%	12.9%	0.5%	0.0%	0.1%	-13.4%	0.0%
SCAB (LOS ANGELES COUNTY)	0.0%	-5.7%	4.5%	0.2%	0.6%	0.5%	0.0%
MDAB (ANTELOPE VALLEY)	0.0%	7.2%	-8.7%	0.5%	1.0%	0.0%	0.0%
SCAB (ORANGE COUNTY)	0.0%	5.7%	6.9%	-17.5%	4.9%	0.1%	0.0%
SCAB (RIVERSIDE COUNTY)	0.0%	5.1%	5.4%	2.7%	-13.3%	0.1%	0.0%
MDAB (RIV DESERT)	0.0%	-5.2%	1.4%	0.5%	1.8%	1.5%	0.0%
MDAB (BLYTHE)	0.0%	9.4%	5.9%	2.7%	-18.2%	0.3%	0.0%
SSAB (COACHELLA VALLEY)	0.0%	5.4%	2.6%	1.2%	-9.4%	0.3%	0.0%
SCAB	1.7%	1.3%	0.9%	6.8%	-10.8%	0.1%	0.0%

(SAN BERNARDINO CO)							
MDAB (VICTOR VALLEY)	4.3%	5.0%	8.2%	-19.0%	1.1%	0.3%	0.0%
MDAB (SBD DESERT)	5.9%	1.5%	1.1%	-9.3%	0.8%	0.0%	0.0%
MDAB (SEALES VALLEY)	0.2%	0.4%	1.0%	-3.2%	1.7%	-0.1%	0.0%
SSAB (IMPERIAL /WEST)	-18.3%	3.2%	2.7%	9.9%	2.5%	0.1%	0.0%
SSAB (IMPERIAL /EAST)	3.2%	0.4%	0.3%	-4.5%	0.5%	0.0%	0.0%
SSAB (IMPERIAL PM2.5 NON-ATT)	-0.1%	-0.1%	0.0%	0.2%	0.0%	0.0%	0.0%
SCAG Region	**0.0%**	**-2.0%**	**2.5%**	**-0.3%**	**0.0%**	**-0.2%**	**0.0%**

Figure 5-1: HBWD Trip Length Validation

Figure 5-2: HBSH Trip Length Validation

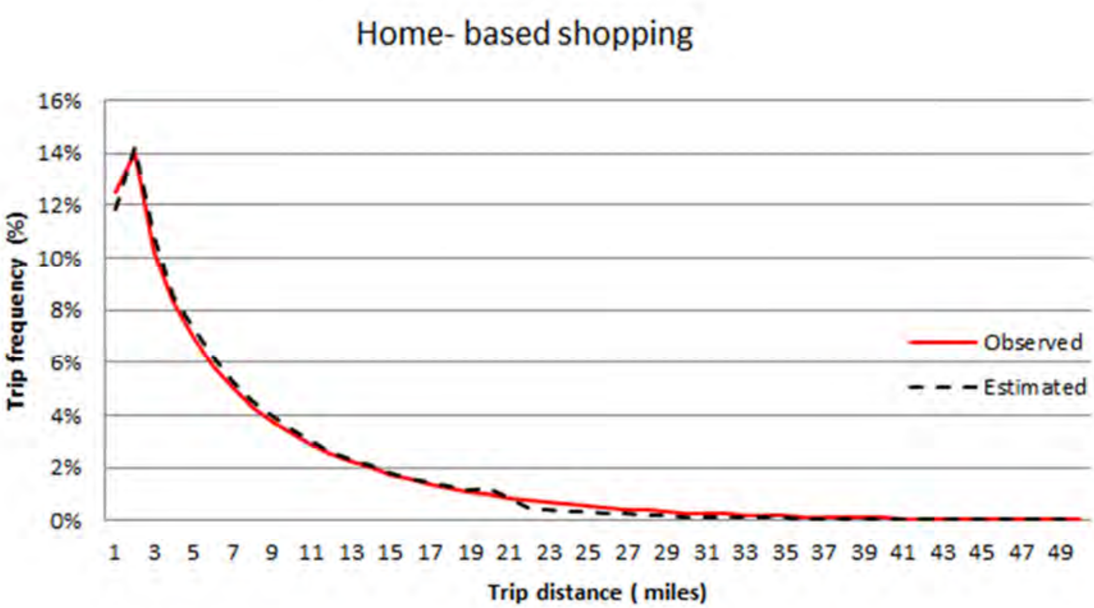


Figure 5-3: HBSR Trip Length Validation

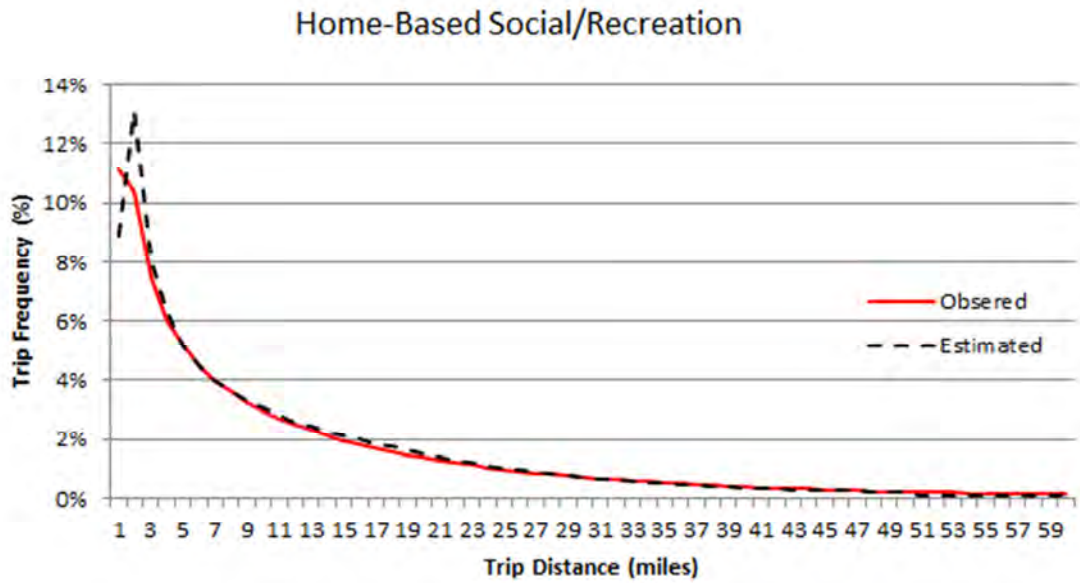


Figure 5-4: HBSP Trip Length Validation

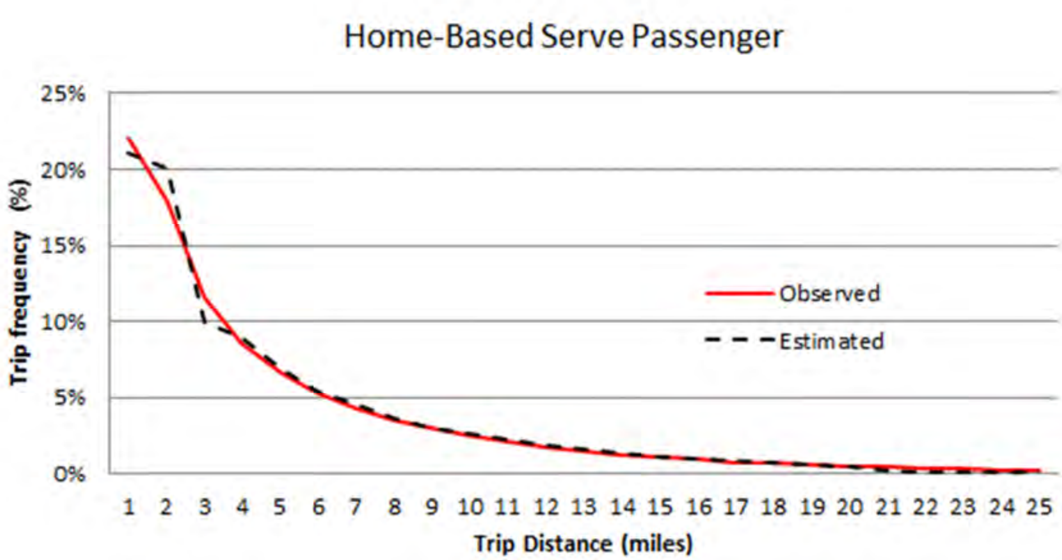


Figure 5-5: HBO Trip Length Validation

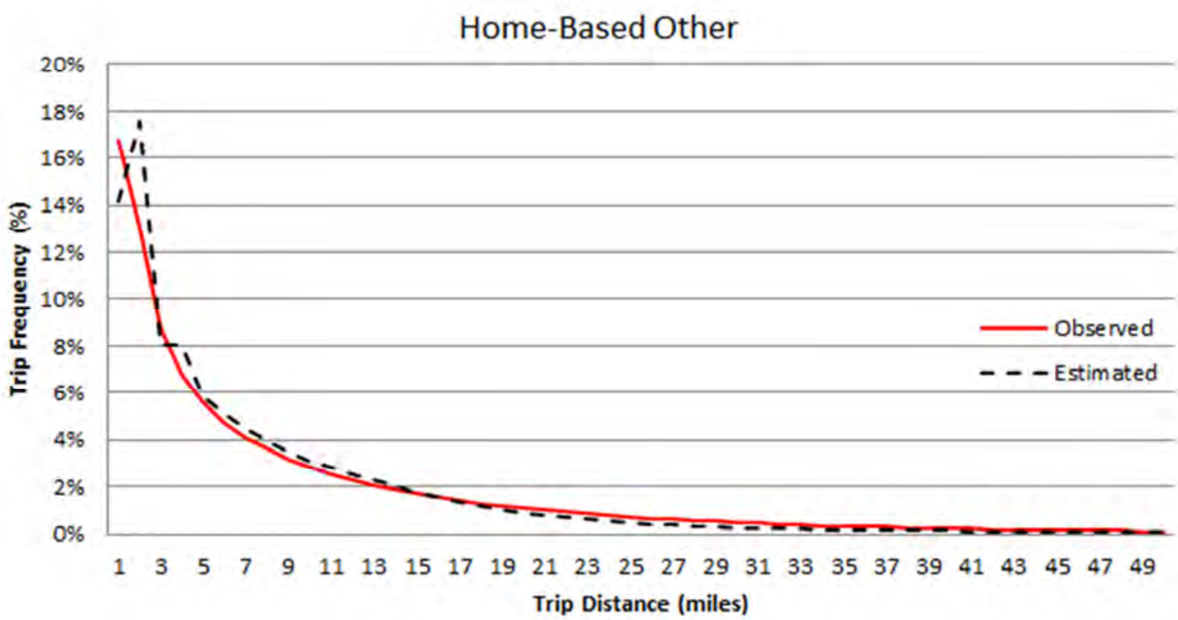


Figure 5-6: WBO Trip Length Validation

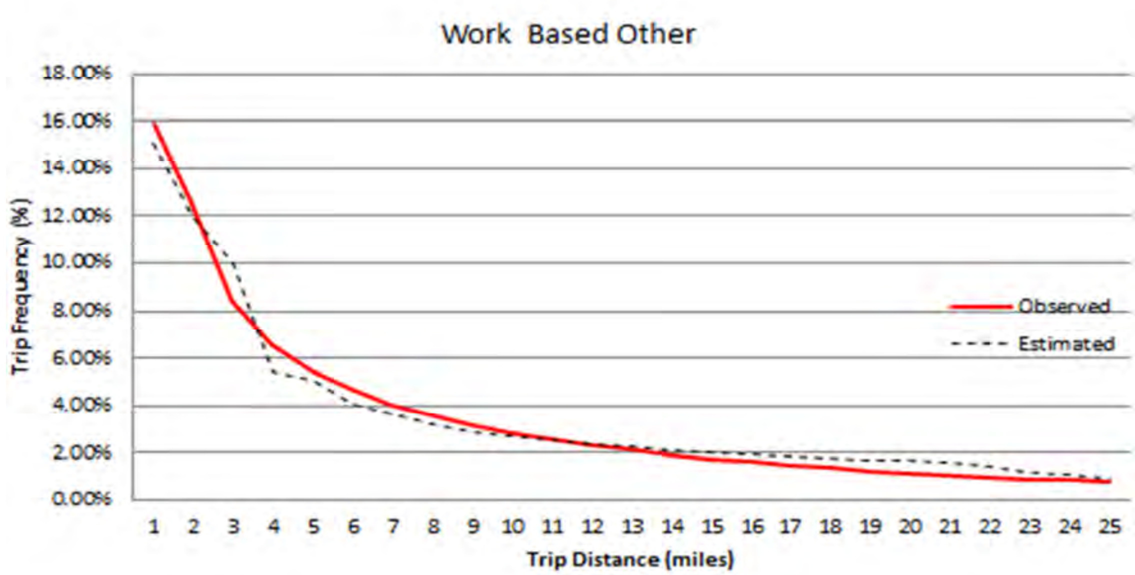


Figure 5-7: OBO Trip Length Validation

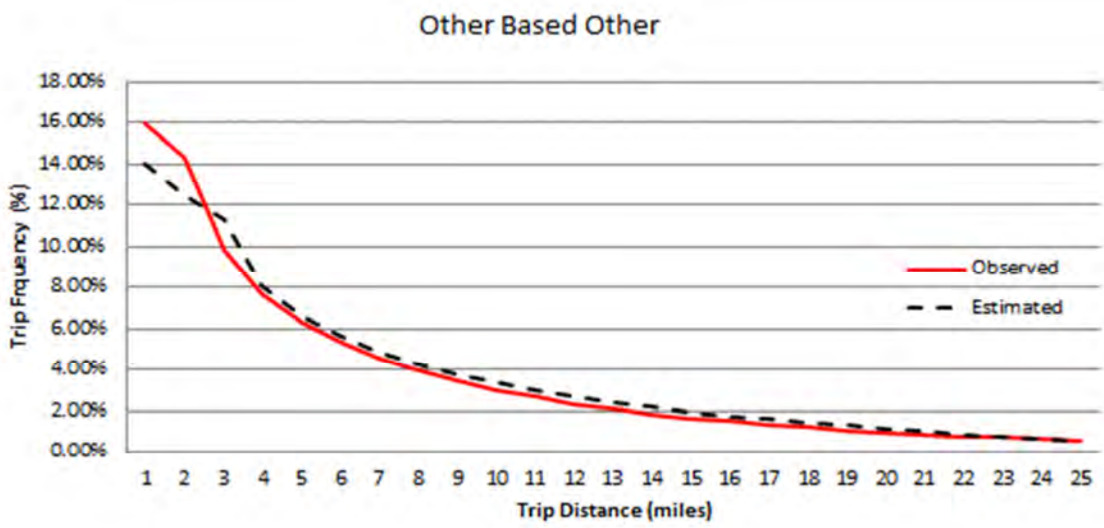
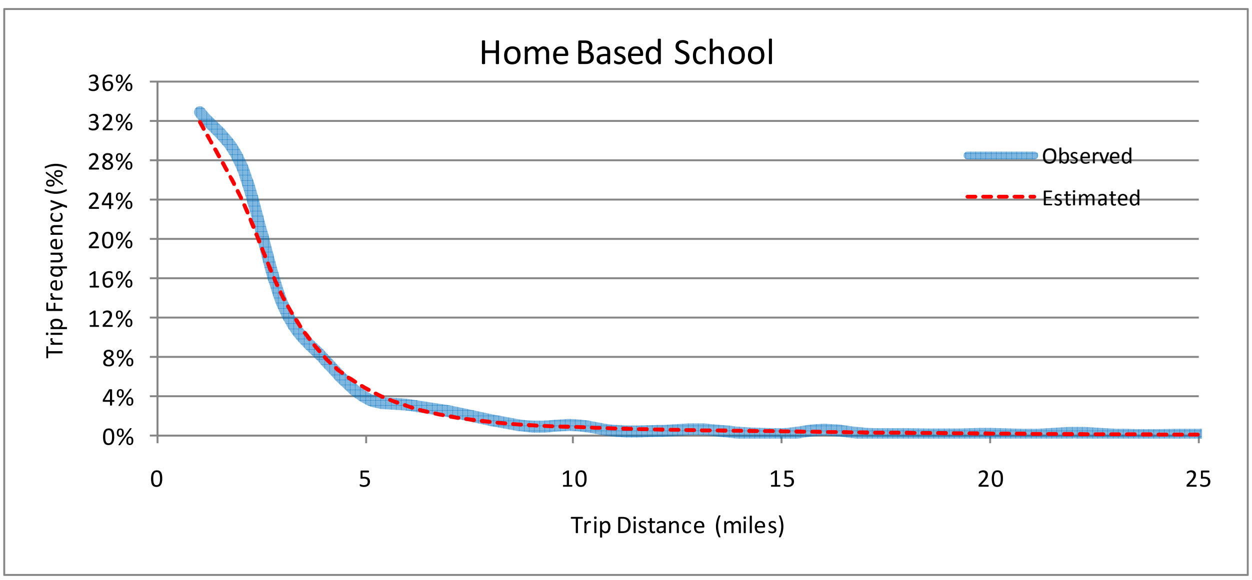


Figure 5-8: HBSC Trip Length Validation



Trip Distribution Model Results

Table 5-8: Year 2012 Home-Based Work Person Trip Distribution

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**77,255**	321	246	2,573	274	7.33	80,677
	95.76%	*0.40%*	*0.31%*	*3.19%*	*0.34%*	*0.01%*	*0.72%*
Los Angeles	21	**5,502,212**	475,992	29,761	105,550	76,668	6,190,204
	0.00%	***88.89%***	*7.69%*	*0.48%*	*1.71%*	*1.24%*	*55.47%*
Orange	9	384,405	**1,547,114**	29,877	34,822	1,533	1,997,761
	0.00%	*19.24%*	***77.44%***	*1.50%*	*1.74%*	*0.08%*	*17.90%*
Riverside	1,697	131,892	168,017	**723,570**	182,331	1,143	1,208,650
	0.14%	*10.91%*	*13.90%*	***59.87%***	*15.09%*	*0.09%*	*10.83%*
San Bernardino	208	248,195	109,272	119,542	**668,743**	2,405	1,148,365
	0.02%	*21.61%*	*9.52%*	*10.41%*	***58.23%***	*0.21%*	*10.29%*
Ventura	1	160,854	4,031	332	988	**368,364**	534,570
	0.00%	*30.09%*	*0.75%*	*0.06%*	*0.18%*	***68.91%***	*4.79%*
Total Attractions	**79,191**	**6,427,879**	**2,304,673**	**905,655**	**992,708**	**450,120**	**11,160,227**
	0.71%	**57.60%**	**20.65%**	**8.12%**	**8.90%**	**4.03%**	**100.00%**

Note: Shares displayed represent the distribution of attraction locations for residents of each county.

Table 5-9: Home-Based Work Person Trip Distribution (ACS*, Travel Survey and Model)

From\To	Source	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura
Imperial	ACS (2006-2010)	97.10%	0.20%	0.10%	2.30%	0.20%	0.00%
	Travel Survey (2012)	94.27%	2.03%	1.52%	2.19%	0.00%	0.00%
	Model (2012)	95.76%	0.40%	0.31%	3.19%	0.34%	0.01%
Los Angeles	ACS (2006-2010)	0.00%	93.30%	4.20%	0.30%	1.30%	0.80%
	Travel Survey (2012)	0.03%	90.23%	4.85%	0.79%	2.32%	1.78%
	Model (2012)	0.00%	88.89%	7.69%	0.48%	1.71%	1.24%
Orange	ACS (2006-2010)	0.00%	12.90%	85.10%	1.10%	0.90%	0.00%
	Travel Survey (2012)	0.07%	14.38%	79.78%	3.93%	1.81%	0.03%
	Model (2012)	0.00%	19.24%	77.44%	1.50%	1.74%	0.08%
Riverside	ACS (2006-2010)	0.10%	6.40%	8.40%	73.70%	11.30%	0.10%
	Travel Survey (2012)	0.13%	5.03%	7.75%	73.90%	13.12%	0.08%
	Model (2012)	0.14%	10.91%	13.90%	59.87%	15.09%	0.09%

San Bernardino	ACS (2006-2010)	0.00%	15.90%	4.40%	8.20%	71.50%	0.10%
	Travel Survey (2012)	0.00%	14.85%	3.53%	11.23%	70.00%	0.39%
	Model (2012)	0.02%	21.61%	9.52%	10.41%	58.23%	0.21%
Ventura	ACS (2006-2010)	0.00%	18.40%	0.30%	0.10%	0.10%	81.10%
	Travel Survey (2012)	0.00%	23.27%	0.14%	0.13%	0.00%	76.46%
	Model (2012)	0.00%	30.09%	0.75%	0.06%	0.18%	68.91%
SCAG Region	ACS (2006-2010)	**0.70%**	**57.80%**	**18.90%**	**8.80%**	**9.40%**	**4.30%**
	Travel Survey (2012)	**0.86%**	**56.95%**	**19.05%**	**8.98%**	**9.59%**	**4.56%**
	Model (2012)	**0.71%**	**57.60%**	**20.65%**	**8.12%**	**8.90%**	**4.03%**

(*) American Community Survey 2006-2010 Release

Table 5-10: Year 2012 Home-Based Non-Work Person Trip Distribution

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**299,423** ***96.42%***	**2,272** *0.73%*	**1,006** *0.32%*	**5,936** *1.91%*	**1,778** *0.57%*	**113** *0.04%*	310,528 *0.90%*
Los Angeles	823 *0.00%*	**17,393,491** ***94.26%***	593,074 *3.21%*	86,681 *0.47%*	265,268 *1.44%*	113,605 *0.62%*	18,452,942 *53.59%*
Orange	235 *0.00%*	587,624 *10.20%*	**5,050,109** ***87.68%***	67,965 *1.18%*	48,017 *0.83%*	5,541 *0.10%*	5,759,491 *16.72%*
Riverside	3,199 *0.07%*	114,497 *2.66%*	75,422 *1.75%*	**3,842,552** ***89.16%***	269,703 *6.26%*	4,305 *0.10%*	4,309,679 *12.51%*
San Bernardino	704 *0.02%*	271,064 *6.76%*	63,729 *1.59%*	276,647 *6.90%*	**3,391,855** ***84.59%***	5,793 *0.14%*	4,009,794 *11.64%*
Ventura	89 *0.01%*	165,427 *10.38%*	7,921 *0.50%*	4,167 *0.26%*	5,463 *0.34%*	**1,411,174** ***88.52%***	1,594,242 *4.63%*
Total Attractions	**304,474** **0.88%**	**18,534,377** **53.82%**	**5,791,262** **16.82%**	**4,283,949** **12.44%**	**3,982,084** **11.56%**	**1,540,530** **4.47%**	**34,436,676** **100.00%**

Note: Shares displayed represent the distribution of attraction locations for residents of each county.

Table 5-11: Year 2012 Non-Home Based Person Trip Distribution

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**100,639** ***98.65%***	**31** *0.03%*	**23** *0.02%*	**1,282** *1.26%*	**42** *0.04%*	**0** *0.00%*	102,017 *0.57%*
Los Angeles	1 *0.00%*	**9,496,284** ***94.42%***	383,076 *3.81%*	14,893 *0.15%*	104,404 *1.04%*	58,316 *0.58%*	10,056,974 *56.54%*
Orange	1 *0.00%*	407,804 *11.97%*	**2,952,331** ***86.65%***	24,132 *0.71%*	22,790 *0.67%*	291 *0.01%*	3,407,347 *19.16%*
Riverside	120 *0.01%*	26,427 *1.52%*	33,868 *1.95%*	**1,534,874** ***88.29%***	143,094 *8.23%*	91 *0.01%*	1,738,474 *9.77%*
San Bernardino	8 *0.00%*	130,267 *7.67%*	27,437 *1.62%*	125,674 *7.40%*	**1,414,137** ***83.30%***	213 *0.01%*	1,697,735 *9.54%*
Ventura	0 *0.00%*	80,955 *10.31%*	692 *0.09%*	92 *0.01%*	236 *0.03%*	**703,225** ***89.56%***	785,200 *4.41%*
Total Attractions	**100,769** **0.88%**	**10,141,767** **53.82%**	**3,397,425** **16.82%**	**1,700,947** **12.44%**	**1,684,703** **11.56%**	**762,136** **4.47%**	**17,787,747** **100.00%**

Note: Shares displayed represent the distribution of attraction locations for residents of each county.

Table 5-12: Year 2012 Total Person Trip Distribution

From\To	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Total Productions
Imperial	**477,318** **96.78%**	**2,624** *0.53%*	**1,275** *0.26%*	**9,791** *1.99%*	**2,094** *0.42%*	**120** *0.02%*	493,222 *0.78%*
Los Angeles	845 *0.00%*	**32,391,986** ***93.35%***	1,452,142 *4.18%*	131,335 *0.38%*	475,222 *1.37%*	248,589 *0.72%*	34,700,119 *54.75%*
Orange	245 *0.00%*	1,379,833 *12.36%*	**9,549,553** ***85.53%***	121,974 *1.09%*	105,629 *0.95%*	7,365 *0.07%*	11,164,599 *17.61%*
Riverside	5,017 *0.07%*	272,816 *3.76%*	277,307 *3.82%*	**6,100,996** ***84.07%***	595,129 *8.20%*	5,538 *0.08%*	7,256,804 *11.45%*
San Bernardino	920 *0.01%*	649,526 *9.47%*	200,439 *2.92%*	521,863 *7.61%*	**5,474,735** ***79.85%***	8,410 *0.12%*	6,855,893 *10.82%*
Ventura	90 *0.00%*	407,237 *13.98%*	12,645 *0.43%*	4,591 *0.16%*	6,687 *0.23%*	**2,482,763** ***85.20%***	2,914,012 *4.60%*
Total Attractions	**484,435** **0.76%**	**35,104,022** **55.38%**	**11,493,360** **18.13%**	**6,890,550** **10.87%**	**6,659,496** **10.51%**	**2,752,786** **4.34%**	**63,384,649** **100.00%**

Note: Shares displayed represent the distribution of attraction locations for residents of each county.

Table 5-13: Year 2012 Average Person Trip Lengths by County

AM-Peak Period:

County	Trip Purpose	Home-Based Work	Home-Based Non-Work	Home-Based School	Non-Home Based Others
Imperial	Time (minutes) Distance (miles)	14.11 11.17	9.97 7.49	5.01 3.37	5.93 3.96
Los Angeles	Time Distance	27.57 13.69	16.83 8.09	7.96 4.00	15.92 7.57
Orange	Time Distance	24.04 13.31	15.01 8.13	6.48 3.46	13.86 7.49
Riverside	Time Distance	41.21 24.10	15.95 9.45	8.64 5.49	12.45 7.13
San Bernardino	Time Distance	41.27 23.78	16.28 9.68	8.76 5.67	13.45 7.70
Ventura	Time Distance	29.32 17.05	14.80 8.60	6.51 3.80	10.46 6.10
All	**Time (min)** **Distance (mi)**	**29.81** **15.93**	**16.20** **8.47**	**7.82** **4.32**	**14.65** **7.44**

Table 5-13: Year 2012 Average Person Trip Lengths by County (continued)

Midday Period:

County	Trip Purpose	Home-Based Work	Home-Based Non-Work	Home-Based School	Non-Home Based Others
Imperial	Time (minutes)	13.45	11.83	12.55	5.94
	Distance (miles)	10.65	9.52	10.77	3.96
Los Angeles	Time	21.90	15.43	8.46	14.52
	Distance	12.55	8.54	4.97	7.72
Orange	Time	19.60	14.33	6.74	12.82
	Distance	12.26	8.69	3.97	7.64
Riverside	Time	29.85	15.51	12.49	11.55
	Distance	21.80	10.85	9.38	7.51
San Bernardino	Time	29.13	15.77	10.83	12.37
	Distance	21.89	11.09	7.78	8.16
Ventura	Time	22.07	14.28	10.30	9.86
	Distance	15.47	9.69	7.31	6.43
All	**Time (min)**	**23.04**	**15.21**	**9.13**	**13.44**
	Distance (mi)	**14.58**	**9.21**	**5.90**	**7.65**

Total Daily:

County	Trip Purpose	Home-Based Work	Home-Based Non-Work	Home-Based School	Non-Home Based Others
Imperial	Time (minutes)	13.88	10.95	7.24	5.94
	Distance (miles)	10.99	8.56	5.56	3.96
Los Angeles	Time	25.56	16.07	8.12	15.07
	Distance	13.28	8.34	4.30	7.66
Orange	Time	22.47	14.64	6.56	13.23
	Distance	12.94	8.44	3.62	7.58
Riverside	Time	37.21	15.71	9.80	11.91
	Distance	23.29	10.21	6.67	7.36
San Bernardino	Time	36.96	16.00	9.39	12.80
	Distance	23.11	10.45	6.31	7.98
Ventura	Time	26.75	14.52	7.68	10.10
	Distance	16.49	9.20	4.88	6.30
All	**Time (min)**	**27.41**	**15.66**	**8.23**	**13.92**
	Distance (mi)	**15.45**	**8.87**	**4.81**	**7.56**

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CHAPTER 6 – MODE CHOICE

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CHAPTER 6 – MODE CHOICE

Introduction

Mode choice is the process of taking the zone-to-zone person trips by trip purpose from the trip distribution model and determining how many of those person-trips are made by the various travel modes: non-motorized modes (walk and bike), auto modes (driver alone or carpool), and transit modes (drive or walk access and drive or walk egress). The 2012 model incorporates a redefined and recalibrated mode choice model for the region.

This Chapter describes the development of the updated mode choice model. The various travel modes estimated by the model are also summarized and explained.

Model Specification

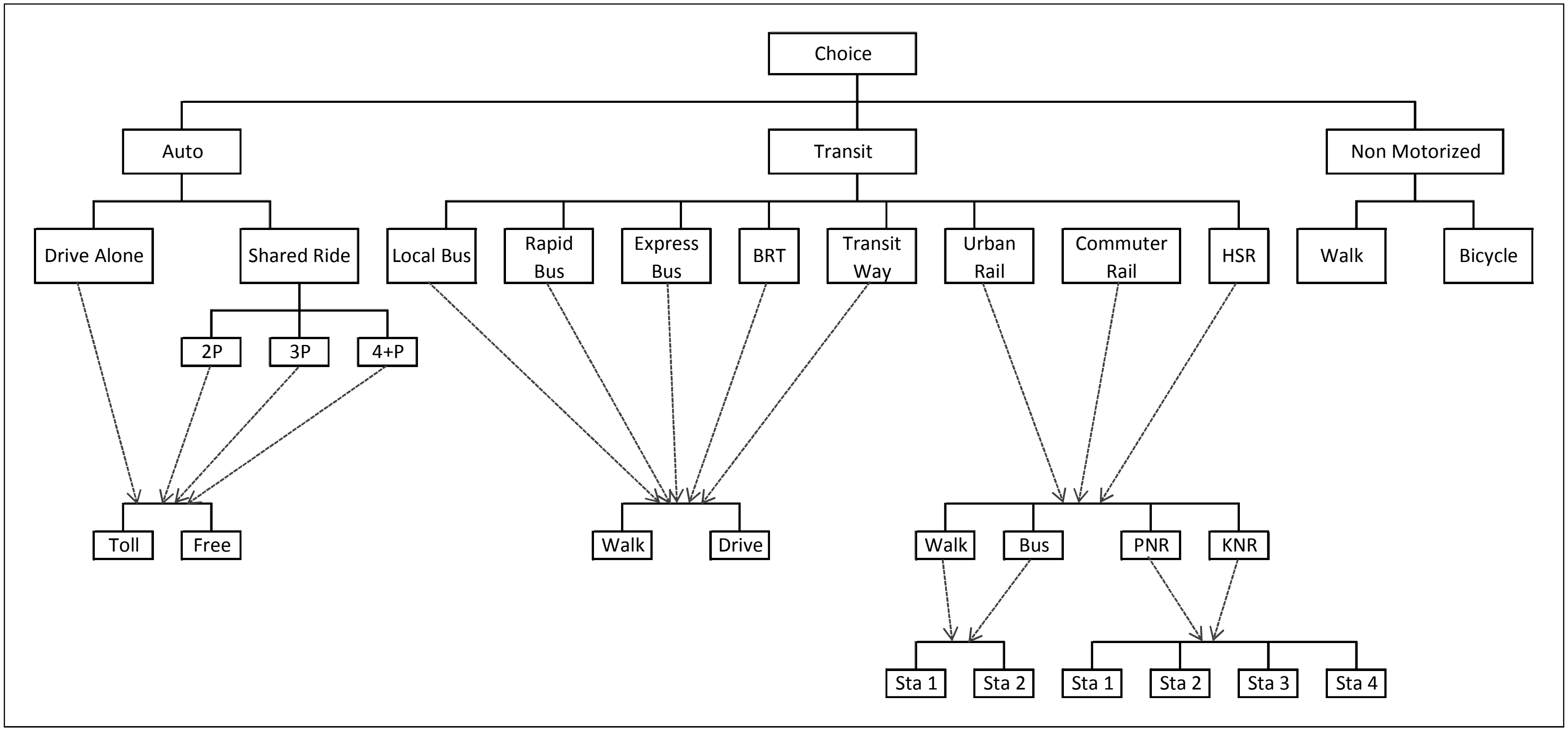
Elemental Choices

The SCAG mode choice model is a nested logit model, structured as shown in Figure 6-1. Among the auto choices, the model distinguishes four levels of occupancy (1, 2, 3 and 4 persons per vehicle) and includes a pre-route toll/no toll binary choice. Although not shown Figure 6-1, the model includes a HOV/non-HOV path subnest for the shared-ride choices. This model and the toll choice model may be used in lieu of the assignment-based diversion models, at the user's request. Currently the region includes over 400 centerline miles of HOV lanes restricted to 2+ person carpools, one 10-mile facility restricted to 3+ person carpools, and several toll facilities including two HOT lane facilities nearing full implementation.

The Southern California region comprises a wide variety of transit markets, ranging from the traditional transit-captive local bus market to choice travelers on the long distance commuter rail market. By 2040, it is expected that high-speed rail service will connect the region's main airports as well as serve Union Station and other cities in the region as part of the San Francisco-to-San Diego statewide line. The principal provider of transit services in the region is LACTMA, which operates a variety of transit technologies and services—local, limited stop (rapid) and express buses, bus rapid transit on a dedicated guideway, and urban rail (underground, at-grade and elevated lines). Two transitways, the El Monte Busway and the Harbor (I-110) Freeway HOV lanes separate express buses from the general purpose freeway traffic. The Harbor HOV facility provides elevated stations for fast boarding and alighting.

Commuter rail service is provided by Metrolink, and to a lesser extent Amtrak. Metrolink trains provide frequent peak period service from North Los Angeles, San Bernardino and Riverside into Los Angeles and Orange counties. Nearly 60 other transit agencies provide local and/or regional express bus services in the 6-county region, ranging from large fleets such as the Orange County Transportation Agency, Foothill Transit and the City of Los Angeles, to small city-run fleets. The elemental transit choices in the mode choice model have been defined to represent this wide variety of transit services, recognizing that for several markets these modes provide a competitive choice. In consultation with FTA, eight transit choices were defined on the basis of level of service characteristics and un-included mode attributes.

Figure 6-1: SCAG Mode Choice Model Nest Structure



Relative to local bus, key features considered in the definition of the transit modes include:

- Express bus: limited stop and limited span of service operating partly in mixed-flow freeway traffic
- Rapid bus: limited stops, more frequent service than express, distinctive branding; usually does not operate on freeways
- Transitway bus: limited stop service operating on semi-dedicated right of way (busway, HOV lanes)
- Bus Rapid Transit: limited stops, dedicated guideway, distinctive branding and vehicles
- Local (Urban) Rail: fixed-guideway transit (subways and light rail)
- Commuter Rail: fixed-guideway, long-distance rail, distinctive branding and vehicles, mostly commute market
- High Speed Rail: fixed-guideway, long-distance, distinctive branding and stops, commute and non-commute markets

Another feature of the SCAG mode choice model is the explicit modeling of station choice for all the rail modes. Station choice is modeled conditional on access mode. Rather than rely on the transit path builder to find the best combination of boarding and alighting stations, the mode choice model performs 'virtual' or 'on-the-fly' path building, explicitly trading off longer origin-to-station and/or station-to-destination paths with shorter station-to-station options (or vice-versa). For drive access, the model identifies the 10 best boarding stations and the 10 best alighting stations for a given origin-destination (OD) pair, considering the entire transit path utility. Of these, the top four stations become the drive-to-rail choice set for the station choice nest. OD trips are therefore distributed among all possible paths formed by the four access stations and four egress stations on the basis of their likelihoods. For walk and bus access trips, up to five boarding/alighting station combinations are identified, and the best two become part of the rail choice set. This specification of twelve stations (across the four access modes) for the choice set is a result of balancing the desire to capture the variations in travel behavior with the need to keep the computation time to a reasonable level.

The transit access and egress modes allowed for each primary transit mode are listed in Table 6-1. The commuter rail drive egress mode is unique to Southern California, where people keep a 'station' car at some Metrolink stations to drive to their final destination. Drive egress is also allowed for high-speed rail, since pick-up/drop-off and taxi patronage at the attraction station is likely to occur.

Table 6-1: Transit Access and Egress Modes

Primary Transit Mode	Access Modes						Egress Modes		
	Walk	Drive	Bus	PNR	KNR		Walk	Drive	Bus
Bus Modes	X	X					X		
Bus Rapid Transit	X	X	X				X		
Urban Rail	X		X	X	X		X		X
Commuter Rail	X		X	X	X		X	X	X
High Speed Rail	X		X	X	X		X	X	X

Note: PNR – Park-and-Ride, KNR – Kiss-and-Ride

Highway Path Building

A generalized cost function is used to build the highway travel time and cost matrices (skims). Up to eight different sets of skims are built for the mode choice model, one for each highway mode and time period combination. For each of these combinations, best path skims are built for the toll, no-toll and HOV paths, as appropriate.

$$GC_{ij} = Travel\ Time_{ij} + \left(AOC \times Distance_{ij} + Toll_{ij}\right)/VOT$$

The auto operating cost (AOC) is $0.27 per mile (in $2011), and the value of time (VOT) is $9.84 per hour.

Transit Path Building

Transit walk access paths are built using TransCAD's Pathfinder algorithm for each mode in the choice set. The model builds transit paths among an expanded set of transit origins and destinations, comprised of the TAZ centroids, rail stations and bus park-n-ride locations. The skims for the local bus and rapid bus modes are built in the usual zone-to-zone fashion. The skims for the express bus, transitway bus, BRT and the rail modes are built between zones and stations. The skim building process and method used to construct the entire path is described below, under Virtual Path Building.

A hierarchy of transit modes is assumed to identify the primary mode of a multimodal transit trip. At the bottom of the hierarchy is local bus; a local bus trip boards only local bus modes. At the top of the hierarchy is high-speed rail; a multimodal trip that includes at least one leg on high-speed rail modes is assumed to be a high-speed rail trip. The priority order of the transit modes and corresponding supporting modes are shown in Table 6-2.

Table 6-2: Primary and Support Transit Modes

Primary Transit Mode	Support Transit Mode(s)
Local Bus	None
Express Bus	Local, Rapid Bus
Rapid Bus	Local Bus
Transitway Bus	Local, Express, Rapid Bus
Bus Rapid Transit	Local, Rapid Bus, Express Bus
Local (Urban) Rail	Local, Express, Rapid, Transitway Bus and BRT
Commuter Rail	Local, Express, Rapid, Transitway Bus, BRT and Urban Rail
High Speed Rail	Local, Express, Rapid, Transitway Bus, BRT, Urban and Commuter Rail

For each primary mode, only the supporting modes are allowed when building its paths and skims. The path attributes and weights used to compute the generalized cost function are shown in Table 6-3. These weights are approximately consistent with the value of the HBW mode choice wait time and walk access time coefficients relative to the in-vehicle time coefficient. Travel time on the primary mode is always given a weight of 1.0, while travel time on the transit supporting modes is given a weight of 1.5. The exception is Rapid Bus; the local bus travel time is weighted only 1.1 when building Rapid Bus paths. All walk times (access, egress and transfer) are given a weight of 2.0, and similarly the wait time is weighted by 2.0.

Table 6-3: Transit Path Building Weights

Transit Mode	Run Time Factor		Wait Time Factor
	Primary Mode	Support Mode	
Walk access, egress, transfer	-	2.0	-
Local Bus	1.0	1.5 (1.1)	2.0
Rapid Bus	1.0	1.5	2.0
Express Bus, Transitway	1.0	1.5	2.0
BRT	1.0	1.5	2.0
Urban Rail	1.0	1.5	2.0
Commuter Rail	1.0	1.5	2.0
High-Speed Rail	1.0	1.5	2.0

Virtual Transit Path Building

The skims for the premium bus modes and for the rail modes are built to support the station choice nest of the mode choice model. For this reason, , the entire origin zone to destination zone path is broken into two or three parts-- zone to station, station to station, and station to zone for the rail modes, and zone to station and station to zone for the bus modes. Figure 6-2 shows a schematic of a rail skim core partitioned into these three parts, or trip legs. Paths and skims are built for each of these legs separately:

i. For the rail station-to-zone and zone-to-rail station legs, which represent the rail access and egress, the path is built by including only the transit supporting modes for each primary rail mode and the walk modes.

ii. For the rail station-to-station leg, which represents the primary mode line-haul component of the trip, the path is built including only the primary rail mode, and excluding all supporting and walk modes.

Figure 6-2: Rail Skim Core Schematic

		Destinations	
		Zones	Stations
Origins	Zones (1 thru 11500)	(Unused)	Access leg All transit modes allowed except the primary rail mode
	Stations (11501 thru 12000)	Egress leg All transit modes allowed except the primary rail mode	Station-to-Station leg Only the primary rail mode is allowed

The mode choice model builds the entire zone-to-zone trip on the fly, by combining the different access, line haul and egress legs into candidate entire journeys such that the total weighted travel time is minimized for each origin and destination station pair.

The bus paths are built in a similar fashion, with the exception that the 'station-to-station' leg is not relevant, since the nature of these modes is such that there is no destination station.

BRT is a special case. Analysis of the on-board survey data revealed that many riders drive to a BRT station, ride the BRT system and transfer to an local rail line before reaching their final destination. As such, the sequence of elements is zone to station, station to station (BRT), station to station (local rail) and station to zone. Therefore, the virtual path consists of up to four legs, instead of just the three used for rail modes.

No drive access skims are required for the mode choice model. Drive access to all modes except local and rapid bus is handled by the mode choice virtual path builder. As indicated above, the locations where drive-to-transit trips access the bus or rail system are explicitly identified so that park-n-ride to zone skims are available to the mode choice model. The drive leg (zone to PNR/KNR location) is obtained from the drive-alone skims. For local and rapid bus, park-n-ride behavior is dominated by informal parking; that is, trips that access the bus system at locations other than formal park-n-ride lots. These trips are modeled using the walk access skims, with the walk access time replaced by an appropriate drive access time, given the distance.

Choice Availability

The availability of any given elemental choice is defined by the following rules:

- Drive alone: Available to all trips. For the toll option, a toll link must be in the path. For the HOV lane option, an HOV lane link must be in the path.
- Shared ride: Available to all trips. For the toll options, a toll link must be in the path.
- Walk: Available to trips up to 3 miles long.
- Bicycle: Available to trips up to 12 miles long.
- Transit: Available to all inter-zonal trips with non-zero primary mode in-vehicle time. In addition, commuter rail is available only to work trips.

Utility Specification

The general form of the utility function for the auto modes is:

$$Utility_m^{mkt} = civt \times (in\ vehicle\ travel\ time) + covt \times (terminal\ time) + ccost^{mkt} \times \frac{(parking\ cost)}{2 \times occfac} ccost^{mkt} + \frac{(veh.operating\ cost \times distance)}{occfac} ccost^{mkt} + \frac{(toll\ cost)}{occfac} ccost^{mkt} + (HOT\ lane\ toll) \times \frac{distance}{occfac} + toll\ penalty_m + K_m$$

Where:

occfac is the factor to discount travel costs among occupants of a carpool; typically this factor is smaller than the average vehicle occupancy. For the drive alone modes *occfac* is 1.0.

$toll\ penalty = min\{0.0,\ ctollintcpt + ctollslope * (toll\ distance)\}$, s a utility penalty applied to discourage very short trips from using the toll roads. The toll penalty decreases with distance and is zero for a trip that is 2.5 miles or longer.

K_m is the alternative-specific constant. The alternative-specific constant itself consists of several components. A common constant, for example, is applied to all the shared-ride modes, while a different constant value is applied to the shared ride 3+ modes. The constants are applied so that the model is not over-specified, and each constant value can be readily interpreted in terms of the un-included attributes it represents. The mode choice coefficients are shown in Table 6-4.

Table 6-4: Mode Choice Utility Coefficients

Coefficient	HBW	HBO	NHB
In-Vehicle Travel Time	-0.02500	-0.01321	-0.01620
Terminal Time	-0.05300	-0.02853	-0.03500
Transit Walk Time (< 20 min)	-0.05300	-0.02853	-0.03500
Transit Walk Time (> 20 min)	-0.06200	-0.03276	-0.03500
Walk Mode Time (< 20 min)	-0.05300	-0.02853	-0.03500
Walk Mode Time (> 20 min)	-0.07950	-0.04280	-0.03500
Drive Time	-0.02500	-0.01321	-0.01620
First Wait Time (<5 min)	-0.06875	-0.03638	-0.04460
First Wait Time (>5 min)	-0.06875	-0.03638	-0.04460
Second Wait Time	-0.06875	-0.03638	-0.04460
Cost – zero cars	-0.00276	-0.00517	
Cost – insufficient cars	-0.00130	-0.00284	
Cost – low income, sufficient cars	-0.00426	-0.00681	-0.00551
Cost – medium income, sufficient cars	-0.00142	-0.00227	
Cost – high income, sufficient cars	-0.00086	-0.00134	
Primary Mode Logsum	0.75	0.75	0.75
Sub Mode Logsum	0.60	0.60	0.60
Access Mode Logsum	0.60	0.60	0.60

The general form of the utility function for the walk access bus transit modes is:

$$Utility^{mkt} = civt \times (in\ vehicle\ travel\ time) + cfw_1 \times first\ wait\ 1 + cfw_2 \times first\ wait\ 2 + cxw \times transfer\ wait + cwalk_1 \times walk\ time\ 1 + cwalk_2 \times walk\ time\ 2 + ccost^{mkt} \times fare + K$$

The computation of first wait time assumes that travelers know the schedule and consequently do not arrive at random. Wait time is computed as follows:

$$Wait\ Time = \sum_{n=1}^{N} \frac{min[hdwy - 15(n-1), 15]}{n+1}$$

where

$$N = \begin{cases} hdwy/15, & mod(hdwy/15) = 0 \\ hdwy/15 + 1, & mod(hdwy/15) > 0 \end{cases}$$

Since the wait time calculation accounts for non-random arrivals, the same coefficient is used for all wait time components, instead of applying different coefficients to differentiate between real time wait and wait time inconvenience. The walk time component is split into the first mile (less than 20 minutes) and subsequent walk time. The transit alternative specific constant consists of the sum of several terms, some of which are mode-specific and some that are market-specific. A more detailed description of the transit constants is provided below.

The general form of the utility function for the drive access bus transit modes is similar to the walk access utility, with drive access time replacing walk access time, and the inclusion of vehicle operating cost, parking cost, and a term that discourages drive access paths when the distance from origin to PNR lot is longer than the distance from origin to final destination. The best drive access station is found by the virtual path builder by searching for the best combination of access time and station-to-destination utility among the stations that are within 15 miles of the production zone.

Similar terms as those used in the walk access bus transit utilities are used in the rail utility functions. Note however that the rail utility function consists of three components—zone to station, station to station, and station to zone—and therefore the terms that apply to each leg of the trip will vary, as appropriate. The station choice coefficients are shown in Table 6-5. These coefficients are based on model estimation work performed for Chicago. These coefficient values are expressed at the station choice level. In other words, they are not scaled by the appropriate LogSum coefficients for interpretation at the multinomial level. However, after scaling they closely match the multinomial values for in-vehicle time.

Table 6-5: Station Choice Utility Coefficients

Attribute	Coefficient					
	HBW		HBO		NHB	
	Value	Ratio wrt IVT	Value	Ratio wrt IVT	Value	Ratio wrt IVT
In-Vehicle Time	-0.16650	--	-0.09756	--	-0.11964	--
Drive Access Time	-0.41292	2.5	-0.24195	2.5	-0.25842	2.2
First Wait Time	-0.35298	2.1	-0.21073	2.2	-0.25842	2.2
Transfer Wait Time	-0.35798	2.2	-0.24195	2.5	-0.29073	2.4
Number of Transfers	-1.44400	8.7	-0.84584	8.7	-1.03761	8.7
Walk Time	-0.25974	1.6	-0.21073	2.2	-0.25842	2.2
Parking Capacity	0.00023	--	0.00023	--	0.00023	--
Drive Egress Time	-0.41292	--	-0.24195	--	-0.25842	--
In-Vehicle Time (CRail only)	-0.12488	--	-0.07317	--	-0.08973	--

Note: IVT – In-Vehicle Time

Market Segmentation

The mode choice models were initially segmented by trip purpose, time period and four household income levels. This is the minimal level of segmentation required to expose trips to the correct transportation level of service and ensure that the model coefficients capture differences in travel behavior due to the type of trip and household wealth, in particular value of time. The final models are stratified by a combination of household income and car sufficiency, in order to better reflect the effect of transit-dependent users on mode and destination choice.

An important element of the market segmentation is the stratification of the alternative-specific constants (ASC). The specification of the ASCs responds to an understanding of the expected contribution of un-included attributes to the utility of each choice. Un-included attributes can be thought of as being a function of trip-maker characteristics, trip characteristics, or mode characteristics. The ASC can be considered as composed of two parts, one part that varies across demographic characteristics (for example, across household income groups or car ownership groups), and a second part that varies across mode and/or trip characteristics.

The transit constant is stratified by household income level, car sufficiency and trip distance, but not by primary transit mode. The stratification by household income and car sufficiency is recommended by FTA and responds to the higher likelihood of transit patronage among transit-dependent riders, all else equal. The stratification by trip distance is unique to the Southern California region and is based on analysis of the on-board survey data performed for LACMTA, as part of their model calibration and validation effort[2]. Specifically, three distinct transit markets were observed: a short distance market, primarily served by local and rapid bus and to a lesser extent local rail, a medium distance market served by local rail, express and transitway buses, and a long distance market served by commuter rail and a few express buses. The transit constant is therefore stratified into 5-mile distance ranges, and capped at 55 miles.

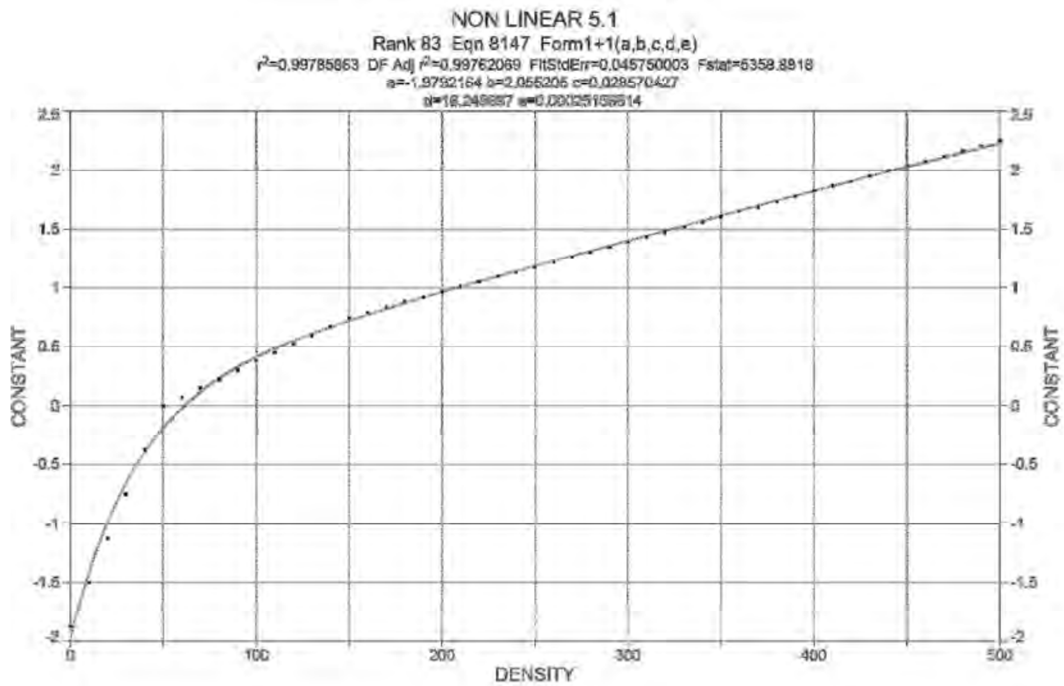
The primary transit mode constants are stratified by mode, but not by household income or car sufficiency. The rationale is that some un-included mode attributes are equally perceived by all riders, regardless of their income level. For example, the limited service span of express bus service is equally undesirable to all riders. The primary transit mode constants play a central role in an analysis of transit alternatives, because they contribute directly to the user benefits of each alternative mode as compared to the baseline alternative.

The transit constants also account for the effect of land use form. As part of the mode choice model calibration work performed for LACMTA, it was found that the level of service attributes and constants described above were insufficient to explain transit ridership in the more dense areas of the region. Functions of population and employment density were developed as part of this calibration work to further segment the transit constant. A sample urban form function is shown in Figure 6-3.

A CBD attraction constant that varies by mode was necessary to match observed HBW CBD transit attractions. A drive to transit constant, applied at the access mode level of the nest, captures the differences in the perception of drive and walk access across income and car sufficiency levels. Two additional constants werre needed to adequately match the proportion of commuter rail riders that park access commuter rail or local rail by bus.

[2] Los Angeles Mode Choice Model: Draft Calibration/Validation Report. Prepared for the Los Angeles Metropolitan Transit Authority, by Parsons Brinckerhoff. Los Angeles, CA: September 2010.

Figure 6-3: Density Component of the Transit Constant, HBWD Peak, Production End



Calibration Target Values

The mode choice calibration process consisted of adjusting the model constants to match observed transit travel patterns. These travel pattern summaries are called calibration target values; they are derived from the household travel survey and the on-board transit surveys, supplemented with ridership data. Calibration target values consist of various trip summaries, including:

- Number of trips by time period, trip purpose, mode and market segment (combined household survey and on-board surveys, expanded to validation year);
- On-board transit trip flows (for aggregate and district-level validation), by purpose, transit submode and time period;
- Trip length distribution (distance) by transit submode and market segment;
- Number of trips by access/egress mode (walk, bus, PNR, KNR) by transit submode;
- Station-to-station trips, station boardings (total, by transit submode and by access mode); and
- Transfer rates or transfer trips, by transit submode and by access mode.

Each data source made a specific contribution to the development of the calibration target values: the 2012 California Household Travel Survey provided the share of auto and non-motorized trips across purposes, time periods and household income markets, while the transit on-board surveys provided the number of transit trips by mode, access submode, and household income. The total number of trips was obtained from the trip generation model forecasts, and the targets as derived from the survey data were scaled so that the number of transit trips remains constant. School bus trips were removed from the

HBSC targets, since this mode is not part of the choice set. Tables 6-7 to 6-10 show the final calibration targets.

Table 6-6: HBW and HBO Mode Choice Calibration Targets, Peak Period

Household Segment	Mode	Trip Purpose					
		HBWD	HBWS	HBSh	HBSR	HBSP	HBO
No cars	Walk	10,248	6,554	53,106	23,946	115,695	37,359
	Bike	5,463	1,306	7,019	3,325	1,298	4,436
	Drive alone	3,400	4,598	2,530	2,406	5,963	3,767
	Shared ride 2	14,611	9,399	10,267	13,130	14,088	7,866
	Shared ride 3	6,088	8,203	4,838	4,346	23,173	2,314
	Shared ride 4+	3,653	5,656	3,327	2,240	19,470	3,663
	Walk to transit	72,898	-	17,968	11,552	-	36,978
	Kiss and ride	8,502	-	1,058	1,251	-	3,623
	Park and ride	1,212	-	-	-	-	-
	Total	**126,075**	**35,716**	**100,114**	**62,196**	**179,687**	**100,006**
Car competition	Walk	51,651	7,982	69,223	43,130	338,680	148,308
	Bike	5,971	1,322	4,445	7,798	1,931	11,989
	Drive alone	246,550	104,158	173,058	50,809	194,318	141,214
	Shared ride 2	123,682	31,475	72,370	112,438	271,491	223,758
	Shared ride 3	43,764	28,384	64,305	59,051	194,122	108,907
	Shared ride 4+	22,834	15,417	61,708	48,062	226,304	92,394
	Walk to transit	151,452	-	11,171	7,848	-	64,782
	Kiss and ride	5,629	-	413	561	-	1,836
	Park and ride	8,276	-	269	561	-	3,361
	Total	**659,808**	**188,737**	**456,962**	**330,258**	**1,226,845**	**796,549**
Income 0-35K	Walk	23,934	3,925	29,620	22,408	37,656	55,464
	Bike	2,853	699	1,444	925	368	5,921
	Drive alone	406,942	126,590	140,348	88,374	134,084	126,792
	Shared ride 2	47,379	17,680	38,986	44,480	184,121	98,115
	Shared ride 3	16,765	16,687	51,981	20,232	131,333	50,844
	Shared ride 4+	8,747	11,059	28,589	19,450	125,117	57,115
	Walk to transit	134,001	-	1,413	2,836	-	25,508
	Kiss and ride	4,443	-	82	199	-	797
	Park and ride	11,213	-	214	199	-	2,726
	Total	**656,276**	**176,639**	**292,678**	**199,104**	**612,678**	**423,282**
Income 35-75K	Walk	38,570	3,659	25,347	35,203	43,717	74,180
	Bike	4,168	422	685	1,622	404	8,064
	Drive alone	1,138,842	304,940	245,017	118,230	231,153	253,897
	Shared ride 2	89,331	30,808	38,020	104,546	288,130	179,958
	Shared ride 3	31,609	30,204	50,693	49,491	200,155	101,527
	Shared ride 4+	16,492	13,515	63,367	32,433	200,747	110,849
	Walk to transit	35,401	-	1,302	1,041	-	4,096
	Kiss and ride	2,540	-	38	41	-	70
	Park and ride	6,086	-	115	96	-	367
	Total	**1,363,039**	**383,548**	**424,584**	**342,703**	**964,306**	**733,008**
Income over 75K	Walk	42,276	8,791	18,185	42,109	44,887	122,464
	Bike	4,244	673	461	2,164	440	8,110
	Drive alone	2,918,200	892,298	527,834	211,532	473,235	632,911
	Shared ride 2	122,872	31,701	67,027	250,618	530,783	503,935
	Shared ride 3	24,574	52,073	100,540	117,688	386,091	303,909
	Shared ride 4+	6,144	23,249	125,675	82,258	345,542	222,206
	Walk to transit	18,222	-	516	304	-	1,673
	Kiss and ride	2,764	-	3	27	-	52
	Park and ride	28,734	-	23	70	-	617
	Total	**3,168,030**	**1,008,784**	**840,263**	**706,769**	**1,780,978**	**1,795,877**

Table 6-7: HBW and HBO Mode Choice Calibration Targets, Off-Peak Period

Household Segment	Mode	Trip Purpose					
		HBWD	HBWS	HBSh	HBSR	HBSP	HBO
No cars	Walk	5,893	4,373	82,377	47,747	62,333	36,756
	Bike	2,326	784	10,864	6,630	699	4,555
	Drive alone	1,448	2,761	3,733	4,797	3,213	3,157
	Shared ride 2	4,419	5,085	15,890	26,181	12,650	11,302
	Shared ride 3	2,946	4,557	7,489	8,665	10,404	4,987
	Shared ride 4+	1,473	3,882	5,150	4,467	7,518	5,262
	Walk to transit	34,773	-	20,889	11,298	-	52,740
	Kiss and ride	4,056	-	1,230	1,223	-	5,996
	Park and ride	578	-	-	-	-	-
	Total	**57,912**	**21,443**	**147,622**	**111,009**	**96,816**	**124,756**
Car competition	Walk	31,011	4,839	102,552	77,805	180,605	169,564
	Bike	3,585	801	6,585	14,067	3,025	15,231
	Drive alone	148,028	63,149	256,381	91,656	104,760	202,701
	Shared ride 2	74,258	19,083	107,214	202,833	182,958	295,383
	Shared ride 3	26,276	17,209	95,267	106,525	118,783	138,351
	Shared ride 4+	13,709	9,347	91,420	86,702	71,373	117,373
	Walk to transit	72,801	-	13,481	8,768	-	48,434
	Kiss and ride	3,309	-	499	627	-	1,469
	Park and ride	6,618	-	325	627	-	4,386
	Total	**379,596**	**114,428**	**673,724**	**589,611**	**661,504**	**992,891**
Income 0-35K	Walk	10,897	3,569	43,716	40,324	20,171	64,636
	Bike	1,233	424	2,132	1,664	330	6,908
	Drive alone	181,987	75,573	207,137	159,028	90,370	204,280
	Shared ride 2	21,169	10,718	57,538	80,042	103,246	126,767
	Shared ride 3	7,449	10,116	76,717	36,408	66,918	59,779
	Shared ride 4+	3,818	6,705	42,194	35,000	49,510	55,346
	Walk to transit	51,971	-	1,130	2,652	-	7,523
	Kiss and ride	1,018	-	85	213	-	786
	Park and ride	4,722	-	767	213	-	1,798
	Total	**284,263**	**107,105**	**431,416**	**355,545**	**330,546**	**527,823**
Income 35-75K	Walk	18,432	6,042	35,513	62,956	23,462	82,500
	Bike	2,004	326	2,888	2,901	322	10,065
	Drive alone	545,223	181,028	405,065	211,441	157,549	354,160
	Shared ride 2	42,716	18,683	62,318	186,968	161,535	226,521
	Shared ride 3	15,115	18,317	62,318	88,509	99,435	116,250
	Shared ride 4+	7,886	8,196	56,086	58,002	77,395	119,901
	Walk to transit	14,912	-	1,499	1,170	-	2,759
	Kiss and ride	175	-	38	92	-	334
	Park and ride	1,571	-	113	208	-	1,005
	Total	**648,032**	**232,592**	**625,838**	**612,247**	**519,698**	**913,495**
Income over 75K	Walk	22,178	15,633	24,691	76,485	19,568	125,300
	Bike	2,258	776	2,785	2,603	381	23,541
	Drive alone	1,532,862	530,548	802,467	377,876	318,934	880,998
	Shared ride 2	64,542	19,233	98,765	447,699	286,174	596,754
	Shared ride 3	12,908	31,594	148,148	210,234	187,347	356,097
	Shared ride 4+	3,227	14,106	160,493	146,943	146,911	253,440
	Walk to transit	9,329	-	1,059	529	-	1,414
	Kiss and ride	499	-	25	45	-	128
	Park and ride	6,181	-	74	123	-	437
	Total	**1,653,985**	**611,889**	**1,238,508**	**1,262,538**	**959,316**	**2,238,109**

Table 6-8: HBSC, HBCU and NHB Mode Choice Calibration Targets, Peak Period

Household Segment	Mode	Trip Purpose			
		HBSC	HBCU	WBO	OBO
All	Walk	889,863	43,174	71,513	471,901
	Bike	157,035	7,841	72,705	32,648
	Drive alone	111,328	201,529	1,561,008	2,315,953
	Shared ride 2	746,206	25,960	55,302	975,198
	Shared ride 3	649,432	8,971	117,782	1,062,786
	Shared ride 4+	618,179	12,606	74,352	1,361,955
	Walk to transit	20,980	68,943	43,358	27,533
	Kiss and ride	1,003	1,626	4,306	353
	Park and ride	974	4,804	2,375	1226
	School Bus	390,094	0	0	0
	Total	**3,585,093**	**375,455**	**2,002,701**	**6,249,554**

Table 6-9: HBSC, HBCU and NHB Mode Choice Calibration Targets, Off-Peak Period

Household Segment	Mode	Trip Purpose			
		HBSC	HBCU	WBO	OBO
All	Walk	403,825	36,458	135,680	545,463
	Bike	71,263	5,570	22,449	47,432
	Drive alone	59,171	171,872	1,317,194	3,870,404
	Shared ride 2	209,036	15,410	93,486	1,088,701
	Shared ride 3	176,191	10,917	72,151	1,188,226
	Shared ride 4+	161,886	7,278	62,443	1,216,102
	Walk to transit	10,138	58,181	31,518	27,419
	Kiss and ride	191	1,844	1,626	1,506
	Park and ride	756	1,434	2,194	1,628
	School Bus	175,653	0	0	0
	Total	**1,268,109**	**308,965**	**1,738,741**	**7,986,881**

Model Calibration and Validation

The calibration and validation of the mode choice model comprised an extensive, iterative effort that involved practically all model components, and in particular trip distribution, mode choice and transit path building. Mode-specific constants were first calibrated to match the household-based targets. The resulting relative values of these constants are examined for reasonableness, in particular the line-haul constants. Subsequently, the household stratified constants were recalibrated to the car sufficiency and income targets. The objective of the calibration is to determine the value of the alternative-specific constants. In addition, a set of coefficients were added to the transit utilities to reduce the number of premium mode trips that transfer to local bus at the destination end of the trip. The expected transfer frequency was established from the on-board survey data.

Table 6-10 shows the calibrated values of the transit line-haul constants, expressed as a constant and in equivalent minutes of in-vehicle time, relative to the local bus constant (the local bus constant is 0.0). Table 6-11 to Table 6-15 shows the estimated mode split and shares, compared to the target mode shares.

Table 6-10: Transit Line-Haul Constants (eq. in-vehicle time minutes)

Trip Purpose	Primary Transit Mode						
	Rapid Bus	Express Bus	Transitway Bus	BRT	Urban Rail	Commuter Rail	High Speed Rail *
HBWD PK	0.2980 (11.9)	-0.0899 (-3.6)	0.1623 (6.5)	0.1207 (4.8)	0.4125 (16.5)	1.2000 (48.0)	1.4400 (57.0)
HBWD OP	0.2000 (8.0)	-0.2601 (-10.4)	-0.2800 (-11.2)	0.1700 (6.8)	0.5500 (22.0)	0.6750 (27.0)	0.8100 (32.4)
HBCU	0.1213 (9.2)	-0.1500 (-11.3)	0.0750 (5.7)	0.0750 (5.7)	0.3115 (23.6)	0.3000 (22.7)	0.3600 (27.2)
HBSC	0.0641 (4.8)	-0.0793 (-6.0)	0.0396 3.0	0.0396 (3.0)	0 (0.0)	0 (0.0)	0 (0.0)
HBSH	0.0641 (4.8)	-0.0793 (-6.0)	0.0396 (3.0)	0.0396 (3.0)	0.1608 (12.2)	0.1585 (12.0)	0.1900 (14.4)
HBSR	0.0641 (4.8)	-0.0793 (-6.0)	0.0396 (3.0)	0.0396 (3.0)	0.1608 (12.2)	0.1585 (12.0)	0.1900 (14.4)
HBO	0.0660 (5.0)	-0.0764 (-5.8)	0.1020 (7.7)	0.0700 (5.3)	0.1584 (12.0)	0.1056 (8.0)	0.1280 (12.1)
WBO	0.0810 (5.0)	-0.2430 (-15.0)	-0.1620 -10.0	0.1620 (10.0)	0.1944 (12.0)	0.4050 (25.0)	0.4860 (29.4)
OBO	0.0810 (5.0)	-0.2430 (-15.0)	0.0810 (5.0)	0.0162 (10.0)	0.1944 (12.0)	0.1292 (7.8)	0.1550 (9.6)

(*) The high speed rail constants were asserted at 20% premium over commuter rail.

Table 6-11: HBW Peak Period Mode Choice Calibration Results

Estimated Trips							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	2,507	27,470	14,522	10,035	71,782	26,476	152,790
Car Competition	265,588	128,872	52,803	30,189	80,169	81,814	639,435
Income 0-35K	385,284	62,613	42,574	40,590	131,361	42,934	705,357
Income 35-75K	1,270,964	108,591	52,726	36,136	29,384	67,343	1,565,144
Income over 75K	2,639,318	111,375	26,615	7,454	17,872	64,592	2,867,227
Total	4,563,661	438,921	189,239	124,404	330,568	283,159	5,929,954
Estimated Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	1.6%	18.0%	9.5%	6.6%	47.0%	17.3%	100%
Car Competition	41.5%	20.2%	8.3%	4.7%	12.5%	12.8%	100%
Income 0-35K	54.6%	8.9%	6.0%	5.8%	18.6%	6.1%	100%
Income 35-75K	81.2%	6.9%	3.4%	2.3%	1.9%	4.3%	100%
Income over 75K	92.1%	3.9%	0.9%	0.3%	0.6%	2.3%	100%
Total	77.0%	7.4%	3.2%	2.1%	5.6%	4.8%	**100%**
Target Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	4.9%	14.8%	8.7%	5.7%	51.4%	14.5%	100%
Car Competition	41.3%	18.3%	8.5%	4.5%	19.5%	7.9%	100%
Income 0-35K	64.1%	7.8%	4.0%	2.4%	18.0%	3.8%	100%
Income 35-75K	82.9%	6.9%	3.5%	1.7%	2.3%	2.7%	100%
Income over 75K	91.2%	3.7%	1.8%	0.7%	1.2%	1.3%	100%
Total	**79.2%**	**6.7%**	**3.3%**	**1.6%**	**6.3%**	**2.9%**	**100%**

Table 6-12: HBW Off-Peak Period Mode Choice Calibration Results

Estimated Trips							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	2,008	12,429	10,828	6,371	65,326	18,852	115,813
Car Competition	181,941	86,684	35,927	21,149	54,407	48,098	428,207
Income 0-35K	229,445	32,615	19,467	17,479	82,757	27,044	408,808
Income 35-75K	733,940	59,061	27,165	18,513	27,268	38,189	904,136
Income over 75K	1,528,170	61,391	14,156	4,044	23,631	32,679	1,664,072
Total	2,675,505	252,179	107,543	67,557	253,390	164,861	3,521,036
Estimated Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	1.7%	10.7%	9.3%	5.5%	56.4%	16.3%	100%
Car Competition	42.5%	20.2%	8.4%	4.9%	12.7%	11.2%	100%
Income 0-35K	56.1%	8.0%	4.8%	4.3%	20.2%	6.6%	100%
Income 35-75K	81.2%	6.5%	3.0%	2.0%	3.0%	4.2%	100%
Income over 75K	91.8%	3.7%	0.9%	0.2%	1.4%	2.0%	100%
Total	76.0%	7.2%	3.1%	1.9%	7.2%	4.7%	**100%**
Target Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	5.0%	11.6%	9.0%	6.3%	51.5%	16.6%	100%
Car Competition	43.1%	18.8%	9.0%	4.8%	16.3%	8.1%	100%
Income 0-35K	66.2%	8.1%	4.3%	2.6%	14.6%	4.1%	100%
Income 35-75K	82.7%	7.0%	3.7%	1.8%	1.8%	3.0%	100%
Income over 75K	91.1%	3.7%	2.0%	0.8%	0.7%	1.8%	100%
Total	**79.5%**	**6.7%**	**3.5%**	**1.7%**	**5.2%**	**3.3%**	**100%**

Table 6-13: HBNW Peak Period Mode Choice Calibration Results

Estimated Trips							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	21,301	74,807	48,530	59,167	106,828	330,432	641,066
Car Competition	640,727	733,064	526,867	579,656	56,973	812,658	3,349,945
Income 0-35K	423,063	275,691	243,022	322,624	23,300	209,476	1,497,176
Income 35-75K	1,095,195	732,254	521,233	567,992	6,054	275,169	3,197,898
Income over 75K	1,973,826	1,406,825	966,743	897,567	2,517	312,965	5,560,443
Total	4,154,112	3,222,640	2,306,395	2,427,006	195,672	1,940,701	14,246,528
Estimated Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	3.3%	11.7%	7.6%	9.2%	16.7%	51.5%	100%
Car Competition	19.1%	21.9%	15.7%	17.3%	1.7%	24.3%	100%
Income 0-35K	28.3%	18.4%	16.2%	21.5%	1.6%	14.0%	100%
Income 35-75K	34.2%	22.9%	16.3%	17.8%	0.2%	8.6%	100%
Income over 75K	35.5%	25.3%	17.4%	16.1%	0.0%	5.6%	100%
Total	29.2%	22.6%	16.2%	17.0%	1.4%	13.6%	**100%**
Target Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	3.3%	10.3%	7.8%	65%	16.4%	55.7%	100%
Car Competition	19.9%	24.2%	15.2%	15.2%	3.2%	22.3%	100%
Income 0-35K	32.0%	23.9%	16.7%	15.1%	2.2%	10.1%	100%
Income 35-75K	34.4%	24.8%	16.3%	16.5%	0.3%	7.7%	100%
Income over 75K	36.0%	26.4%	17.7%	15.1%	0.1%	4.7%	100%
Total	**30.4%**	**24.7%**	**16.4%**	**15.1%**	**1.7%**	**11.8%**	**100%**

Table 6-14: HBNW Off-Peak Period Mode Choice Calibration Results

Estimated Trips							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	30,373	123,113	84,841	91,978	93,261	440,062	863,627
Car Competition	875,994	887,666	632,204	605,685	35,298	908,184	3,945,031
Income 0-35K	613,289	319,118	292,887	389,246	11,274	257,109	1,882,923
Income 35-75K	1,585,308	823,577	557,267	548,750	4,642	326,328	3,845,873
Income over 75K	2,787,340	1,573,289	1,079,494	920,406	2,038	394,829	6,757,397
Total	5,892,303	3,726,764	2,646,692	2,556,065	146,515	2,326,511	17,294,851
Estimated Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	3.5%	14.3%	9.8%	10.7%	10.8%	51.0%	100%
Car Competition	22.2%	22.5%	16.0%	15.4%	0.9%	23.0%	100%
Income 0-35K	32.6%	16.9%	15.6%	20.7%	0.6%	13.7%	100%
Income 35-75K	41.2%	21.4%	14.5%	14.3%	0.1%	8.5%	100%
Income over 75K	41.2%	23.3%	16.0%	13.6%	0.0%	5.8%	100%
Total	34.1%	21.5%	15.3%	14.8%	0.8%	13.5%	**100%**
Target Mode Shares							
Household Segment	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**Total**
No Cars	3.1%	13.7%	6.6%	4.7%	19.4%	52.5%	100%
Car Competition	22.5%	27.0%	15.7%	12.6%	2.7%	19.5%	100%
Income 0-35K	40.2%	22.3%	14.6%	11.1%	0.9%	10.9%	100%
Income 35-75K	42.2%	23.9%	13.7%	11.7%	0.3%	8.3%	100%
Income over 75K	41.8%	25.1%	15.8%	12.4%	0.1%	4.8%	100%
Total	**36.1%**	**24.5%**	**14.9%**	**11.9%**	**1.5%**	**11.2%**	**100%**

Table 6-15: HBSC and NHB Mode Choice Calibration Results

Estimated Trips								
Trip Purpose	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**School Bus**	**Total**
HBSC Peak	181,290	694,324	623,753	636,087	129,355	980,341	372,461	**3,617,613**
HBSC Off-Peak	302,893	190,354	175,296	179,771	92,219	525,140	164,211	**1,629,887**
NHB Peak	3,192,592	729,787	1,102,478	1,694,324	193,667	780,766	-	**7,693,615**
NHB Off-Peak	6,182,540	1,017,207	1,538,377	1,991,194	120,285	899,845	-	**11,749,49**
Estimated Mode Shares								
Trip Purpose	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**School Bus**	**Total**
HBSC Peak	5.0%	19.2%	17.2%	17.6%	3.6%	27.1%	10.3%	100.0%
HBSC Off-Peak	18.6%	11.7%	10.8%	11.0%	5.7%	32.2%	10.1%	100.0%
NHB Peak	41.5%	9.5%	14.3%	22.0%	2.5%	10.1%	-	100.0%
NHB Off-Peak	52.6%	8.7%	13.1%	16.9%	1.0%	7.7%	-	100.0%
Target Mode Shares								
Trip Purpose	**Drive Alone**	**Shared Ride 2**	**Shared Ride 3**	**Shared Ride 4+**	**Transit**	**Non-Motorized**	**School Bus**	**Total**
HBSC Peak	7.9%	19.4%	16.6%	15.9%	2.5%	27.7%	10.1%	**100%**
HBSC Off-Peak	14.7%	14.2%	11.9%	10.7%	4.6%	32.8%	11.1%	**100%**
NHB Peak	47.0%	12.5%	14.3%	17.4%	1.0%	7.9%	0.0%	**100%**
NHB Off-Peak	53.2%	12.2%	13.0%	13.2%	0.7%	7.7%	0.0%	**100%**

Mode Choice Model Results

Table 6-16: Year 2012 Mode Choice Summary Statistics (Home-Based Work)

Mode Choice	Imperial		Los Angeles		Orange		Riverside		San Bernardino		Ventura		Total	
Vehicle Trips	68,151	84.47%	4,902,340	79.20%	1,693,519	84.77%	1,045,887	86.53%	987,223	85.97%	472,538	88.40%	9,169,658	82.16%
Drive Alone	64,865	80.40%	4,568,558	73.80%	1,579,836	79.08%	975,845	80.74%	918,443	79.98%	451,619	84.48%	8,559,165	76.69%
2 Person Carpool	2,294	2.84%	218,131	3.52%	77,313	3.87%	41,049	3.40%	40,435	3.52%	14,240	2.66%	393,463	3.53%
3+ Person Carpool	992	1.23%	115,652	1.87%	36,370	1.82%	28,993	2.40%	28,345	2.47%	6,679	1.25%	217,031	1.94%
Auto Passenger Trips	4,782	5.93%	508,317	8.21%	168,570	8.44%	113,802	9.42%	111,563	9.71%	30,998	5.80%	938,032	8.41%
Vehicle Occupancy	1.07		1.10		1.10		1.11		1.11		1.07		1.10	
Transit Trips	540	0.67%	465,343	7.52%	43,454	2.18%	8,773	0.73%	10,983	0.96%	5,679	1.06%	534,772	4.79%
Non-Motorized Person Trips	7,203	8.93%	314,204	5.08%	92,218	4.62%	40,188	3.33%	38,595	3.36%	25,355	4.74%	517,763	4.64%
Total Person Trips	**80,677**	**100%**	**6,190,203**	**100%**	**1,997,761**	**100%**	**1,208,650**	**100%**	**1,148,365**	**100%**	**534,570**	**100%**	**11,160,22**	**100%**

Table 6-17: Year 2012 Mode Choice Summary Statistics (Home-Based Non-Work)

Mode Choice	Imperial		Los Angeles		Orange		Riverside		San Bernardino		Ventura		Total	
Vehicle Trips	130,972	52.10%	7,746,889	49.29%	2,610,083	53.10%	1,983,361	54.90%	1,823,991	54.73%	756,685	55.90%	15,051,982	51.58%
Drive Alone	88,077	35.04%	4,571,441	29.09%	1,591,875	32.39%	1,272,593	35.23%	1,163,692	34.92%	494,276	36.51%	9,181,953	31.46%
2 Person Carpool	25,426	10.11%	1,703,766	10.84%	567,548	11.55%	401,478	11.11%	372,429	11.17%	150,244	11.10%	3,220,892	11.04%
3+ Person Carpool	17,469	6.95%	1,471,682	9.36%	450,660	9.17%	309,290	8.56%	287,870	8.64%	112,166	8.29%	2,649,137	9.08%
Auto Passenger Trips	69,992	27.84%	5,458,945	34.73%	1,717,444	34.94%	1,190,645	32.96%	1,106,942	33.21%	436,443	32.24%	9,980,411	34.20%
Vehicle Occupancy	1.53		1.70		1.66		1.60		1.61		1.58		1.66	
Transit Trips	529	0.21%	241,454	1.54%	25,015	0.51%	6,539	0.18%	6,198	0.19%	2,601	0.19%	282,335	0.97%
Non-Motorized Person Trips	49,890	19.85%	2,269,110	14.44%	562,705	11.45%	432,213	11.96%	395,629	11.87%	158,016	11.67%	3,867,564	13.25%
Total Person Trips	**251,384**	**100%**	**15,716,39**	**100%**	**4,915,247**	**100%**	**3,612,757**	**100%**	**3,332,760**	**100%**	**1,353,746**	**100%**	**29,182,291**	**100%**

Does not include home-based school trips.

Table 6-18: Year 2012 Mode Choice Summary Statistics (Non-Home-Based)

Mode Choice	Imperial		Los Angeles		Orange		Riverside		San Bernardino		Ventura		Total	
Vehicle Trips	70,273	68.88%	5,776,510	57.44%	2,103,957	61.75%	1,169,828	67.29%	1,147,771	67.61%	525,659	66.95%	10,793,999	60.68%
Drive Alone	59,297	58.12%	4,353,670	43.29%	1,627,632	47.77%	949,955	54.64%	931,857	54.89%	432,058	55.03%	8,354,470	46.97%
2 Person Carpool	5,139	5.04%	433,294	4.31%	157,712	4.63%	85,435	4.91%	82,129	4.84%	36,675	4.67%	800,385	4.50%
3+ Person Carpool	5,837	5.72%	989,546	9.84%	318,613	9.35%	134,438	7.73%	133,785	7.88%	56,926	7.25%	1,639,144	9.22%
Auto Passenger Trips	20,566	20.16%	3,048,852	30.32%	999,853	29.34%	440,766	25.35%	435,736	25.67%	187,136	23.83%	5,132,908	28.86%
Vehicle Occupancy	1.29		1.53		1.48		1.38		1.38		1.36		1.48	
Transit Trips	65	0.06%	240,754	2.39%	20,273	0.60%	2,408	0.14%	2,457	0.14%	2,108	0.27%	268,065	1.51%
Non-Motorized Person Trips	11,113	10.89%	990,857	9.85%	283,263	8.31%	125,472	7.22%	111,771	6.58%	70,297	8.95%	1,592,774	8.95%
Total Person Trips	**102,017**	**100%**	**10,056,973**	**100%**	**3,407,347**	**100%**	**1,738,474**	**100%**	**1,697,734**	**100%**	**785,200**	**100%**	**17,787,746**	**100%**

Table 6-19: Year 2012 Mode Choice Summary Statistics (Home-Based School)

Mode Choice	Imperial		Los Angeles		Orange		Riverside		San Bernardino		Ventura		Total	
Vehicle Trips	14,757	24.95%	745,615	27.25%	235,500	27.89%	184,006	26.40%	192,525	28.44%	67,326	27.99%	1,439,729	27.40%
Drive Alone	4,076	6.89%	248,720	9.09%	87,492	10.36%	57,925	8.31%	66,630	9.84%	24,461	10.17%	489,305	9.31%
2 Person Carpool	5,103	8.63%	230,334	8.42%	70,493	8.35%	57,188	8.21%	58,050	8.57%	20,301	8.44%	441,468	8.40%
3+ Person Carpool	5,579	9.43%	266,561	9.74%	77,515	9.18%	68,893	9.89%	67,845	10.02%	22,563	9.38%	508,956	9.69%
Auto Passenger Trips	21,523	36.39%	1,020,697	37.30%	342,600	40.58%	306,503	43.98%	276,082	40.78%	95,483	39.70%	2,062,888	39.26%
Vehicle Occupancy	2.46		2.37		2.45		2.67		2.43		2.42		2.43	
Transit & School Bus Trips	869	1.47%	167,664	6.13%	23,182	2.75%	10,095	1.45%	8,409	1.24%	5,408	2.25%	215,627	4.10%
Non-Motorized Person Trips	21,994	37.19%	802,565	29.33%	242,960	28.78%	196,316	28.17%	200,017	29.54%	72,279	30.05%	1,536,131	29.24%
Total Person Trips	**59,143**	**100%**	**2,736,541**	**100%**	**844,243**	**100%**	**696,920**	**100%**	**677,033**	**100%**	**240,495**	**100%**	**5,254,375**	**100%**

Table 6-20: Year 2012 Mode Choice Summary Statistics (all trip purposes)

Peak Periods	Imperial		Los Angeles		Orange		Riverside		San Bernardino		Ventura		Total	
Vehicle Trips	140,215	55.09%	9,092,198	53.65%	3,144,056	57.84%	2,097,268	58.14%	1,981,038	58.24%	871,062	60.67%	17,325,838	55.74%
Drive Alone	103,409	40.63%	6,389,357	37.70%	2,267,933	41.72%	1,517,237	42.06%	1,425,396	41.91%	658,361	45.86%	12,361,693	39.77%
2 Person Carpool	20,329	7.99%	1,286,241	7.59%	434,263	7.99%	297,570	8.25%	283,626	8.34%	111,376	7.76%	2,433,404	7.83%
3+ Person Carpool	16,477	6.47%	1,416,600	8.36%	441,861	8.13%	282,462	7.83%	272,017	8.00%	101,325	7.06%	2,530,741	8.14%
Auto Passenger Trips	64,176	25.21%	4,986,818	29.42%	1,625,874	29.91%	1,072,385	29.73%	1,004,634	29.54%	385,815	26.87%	9,139,703	29.40%
Vehicle Occupancy	1.46		1.55		1.52		1.51		1.51		1.44		1.53	
Transit Trips	1,108	0.44%	666,951	3.94%	66,997	1.23%	15,668	0.43%	15,809	0.46%	9,244	0.64%	775,778	2.50%
Non-Motorized Person Trips	49,040	19.27%	2,202,802	13.00%	599,034	11.02%	422,132	11.70%	399,981	11.76%	169,541	11.81%	3,842,529	12.36%
Total Person Trips	**254,539**	**100%**	**16,948,769**	**100%**	**5,435,961**	**100%**	**3,607,453**	**100%**	**3,401,462**	**100%**	**1,435,662**	**100%**	**31,083,847**	**100%**
Off-Peak Periods	**Imperial**		**Los Angeles**		**Orange**		**Riverside**		**San Bernardino**		**Ventura**		**Total**	
Vehicle Trips	143,939	60.31%	10,079,155	56.78%	3,499,004	61.08%	2,285,814	62.64%	2,170,473	62.83%	951,146	64.34%	19,129,531	59.22%
Drive Alone	112,906	47.30%	7,353,031	41.42%	2,618,902	45.72%	1,739,082	47.65%	1,655,226	47.92%	744,053	50.33%	14,223,200	44.03%
2 Person Carpool	17,634	7.39%	1,299,284	7.32%	438,804	7.66%	287,580	7.88%	269,418	7.80%	110,084	7.45%	2,422,803	7.50%
3+ Person Carpool	13,399	5.61%	1,426,841	8.04%	441,298	7.70%	259,152	7.10%	245,829	7.12%	97,009	6.56%	2,483,528	7.69%
Auto Passenger Trips	52,687	22.07%	5,049,993	28.45%	1,602,594	27.98%	979,331	26.84%	925,687	26.80%	364,245	24.64%	8,974,537	27.78%
Vehicle Occupancy	1.37		1.50		1.46		1.43		1.43		1.38		1.47	
Transit Trips	895	0.37%	448,263	2.53%	44,926	0.78%	12,146	0.33%	12,238	0.35%	6,553	0.44%	525,020	1.63%
Non-Motorized Person Trips	41,161	17.25%	2,173,934	12.25%	582,113	10.16%	372,057	10.20%	346,032	10.02%	156,405	10.58%	3,671,702	11.37%
Total Person Trips	**238,682**	**100%**	**17,751,345**	**100%**	**5,728,637**	**100%**	**3,649,348**	**100%**	**3,454,429**	**100%**	**1,478,349**	**100%**	**32,300,790**	**100%**

Table 6-20: Year 2012 Mode Choice Summary Statistics (continued)

All Time Periods	Imperial		Los Angeles		Orange		Riverside		San Bernardino		Ventura		Total	
Vehicle Trips	284,154	58.14%	19,171,354	55.60%	6,643,060	60.08%	4,383,082	61.26%	4,151,511	61.21%	1,822,208	63.12%	36,455,369	58.00%
Drive Alone	216,315	44.26%	13,742,388	39.86%	4,886,835	44.19%	3,256,319	45.51%	3,080,622	45.42%	1,402,414	48.58%	26,584,892	42.30%
2 Person Carpool	37,963	7.77%	2,585,525	7.50%	873,067	7.90%	585,150	8.18%	553,044	8.15%	221,460	7.67%	4,856,207	7.73%
3+ Person Carpool	29,876	6.11%	2,843,441	8.25%	883,158	7.99%	541,614	7.57%	517,845	7.63%	198,334	6.87%	5,014,269	7.98%
Auto Passenger Trips	112,355	22.99%	9,815,314	28.47%	3,121,807	28.23%	1,949,504	27.25%	1,857,096	27.38%	723,057	25.05%	17,579,133	27.97%
Vehicle Occupancy	1.40		1.51		1.47		1.44		1.45		1.40		1.48	
Transit Trips	2,003	0.41%	1,115,214	3.23%	111,923	1.01%	27,815	0.39%	28,046	0.41%	15,796	0.55%	1,300,798	2.07%
Non-Motorized Person Trips	90,201	18.46%	4,376,736	12.69%	1,181,147	10.68%	794,189	11.10%	746,013	11.00%	325,946	11.29%	7,514,232	11.96%
Total Person Trips	**488,714**	**100%**	**34,478,618**	**100%**	**11,057,937**	**100%**	**7,154,589**	**100%**	**6,782,666**	**100%**	**2,887,008**	**100%**	**62,849,531**	**100%**

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CHAPTER 7 - HEAVY DUTY TRUCK MODEL

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CHAPTER 7 – HEAVY DUTY TRUCK MODEL

Introduction

[3] This Chapter addresses the various elements of the Heavy Duty Truck (HDT) Model, including internal and external HDT trips, Port HDT trips and Intermodal HDT trips. Included is a description of the model inputs, an overview of the various model components, and a summary of the 2012 HDT Model results.

HDT Model Structure

Figure 7-1 provides a flow chart of the overall structure of the HDT model. The model forecasts trips for three HDT weight classes: light-heavy (8,500 to 14,000 lbs. gross vehicle weight (GVW); medium-heavy (14,001 to 33,000 lbs. GVW); and heavy-heavy (>33,000 lbs. GVW). The key components of the new HDT Model are the following:

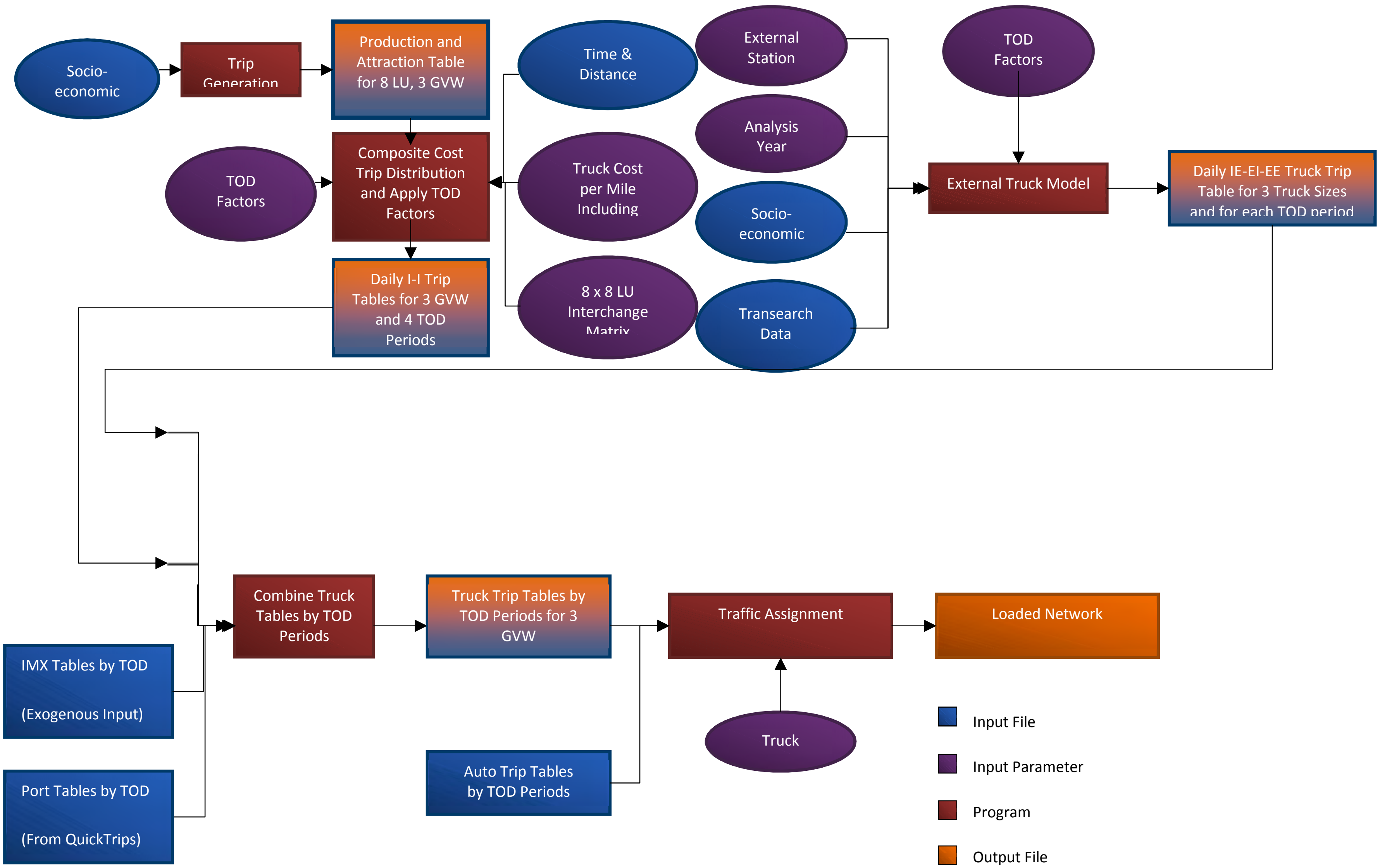
- ***External Trip Generation and Distribution Model.*** This component estimates the trip table for all interregional truck trips based on commodity flow patterns that link Southern California with the rest of the nation. The previous model used a commodity flow database obtained from outside sources, and included procedures for converting annual tonnage flows at the county level to daily truck trips at the TAZ level. The updated model replaces the older Caltrans Intermodal Transportation Management System (ITMS) commodity flow database with a new TRANSEARCH database from IHS/Global Insight. Adjustments were made to the TransCAD scripts that convert annual tonnage flows into daily truck trip tables. These modifications are a result of differences in data formats between TRANSEARCH and ITMS.

- ***Internal Trip Generation and Distribution Models.*** This component of the HDT Model estimates trip tables for intraregional trips. Trip generation is based on trip rates (number of trips per employee or household) for different land uses/industry sectors at the trip ends. This basic structure was retained, although all of the current trip rates were updated with new survey data. Other trip generation specifications (e.g., trip rates as a function of size of firm or more detailed industry/land use classifications) were reviewed, but it was determined that these specifications were not supported by currently available forecast data from SCAG.

  The trip distribution process was modified by developing a matrix of factors that indicate the trip interchange relationships among different land use types (i.e., what fraction of trips originating at a land use such as manufacturing sites go to warehouses vs. other manufacturing sites, etc.). The GPS survey data was used to develop a series of gravity models for each truck class. This offers some of the benefits of tour-based models by directing trips from zone to zone based on logical relationships amongst land use types without the extensive data requirements (typically difficult to collect from trip diary surveys) that are required to support development of a full tour-based model.

[3] Cambridge Systematics, Inc., *SCAG Task 4 Data Verification and Analysis – Final Report*, October 2010.

Figure 7-1: Final HDT Model Structure (TOD = Time-of-Day)



- ***Special Generator Trip Generation and Distribution Models.*** These models include the port model and the intermodal rail model. All of the input parameters to the port trip generation model were updated to reflect current port capacity improvements and throughput forecasts. This model update also implements a procedure to incorporate two types of secondary port truck trips. Transload secondary trips are cargo trips from intermediate handling locations (i.e., transloading sites where cargo is moved from international to domestic containers) to final destinations. Additionally there are secondary repositioning movements of trucks associated with port truck trips. These movements include trips made by trucks that originated at a port but do not immediately return to a port. Similarly, secondary repositioning movements also include trips that travel to a location from a non-port zone prior to traveling to a port. Secondary transload trips are distributed by the port model using a combination of a gravity model and an intermodal railyard model. Secondary repositioning trips are allocated to other zones in the region using the gravity model distribution.

- ***Trip Assignment.*** The model incorporates a multiclass assignment combining the truck trip tables with the passenger trip tables. Prior to assignment, the truck trip tables are converted to PCEs. The PCE factors were adapted from the Transportation Research Board (TRB) Highway Capacity Manual[4] (HCM), and are a function of the percent truck volume and length and steepness of grades. Five time periods are used to assign truck trips, consistent with the auto trip assignment. Updated time-of-day factors were developed using data from permanent classification count stations, weigh-in-motion (WIM), and vehicle classification counts.

Internal HDT Model

Internal HDT Trip Generation Model

The internal truck trip generation model is land use-based, where trip rates are multiplied by employment by industry sector to obtain internal truck trip productions and attractions. All the internal truck travel in the region is associated with ten broad but distinct land uses, namely, households, agriculture/mining/construction, retail, government, manufacturing, transportation/utility, general warehousing, high cube warehousing, wholesale, and other (service). The trip rates (i.e., truck trips per employee) were updated based on recent data collection efforts –establishment surveys and third-party truck GPS data. Trip rates for the general warehousing and high cube warehousing were updated using a combination of establishment surveys and independent trip generation studies.

Land Use and Socioeconomic Data

The socioeconomic data used by the Internal HDT Model is consistent with those data used by the passenger model, except that the employment data are stratified into more employment categories. The 22 two-digit NAICS categories of employment were mapped to 11 categories to account for truck trip generation similarities. This employment category mapping is shown in Table 7-1. These stratified employment types, plus households, support ten land use purposes for the HDT trip generation models: Households, Agriculture/Mining/Construction, Retail, Governments, Manufacturing, Transportation and Utility, General Warehousing, High Cube Warehousing, Wholesale, and Other (service). The warehousing land use categories were separated from the transportation and utility category using data from secondary establishment surveys and warehousing studies.

[4] Highway Capacity Manual. Volume 2: Uninterrupted Flow. Transportation Research Board: Washington D.C., 2010.

Table 7-1: Aggregated Two-Digit NAICS Categories

	Two-Digit	Two-Digit Description		Aggregate Categories for Trip Generation Models
1	11	Agriculture, Forestry, Fishing, and Hunting	1	Agriculture, Forestry, Fishing, and Hunting
2	21	Mining	2	Mining
3	22	Utilities	3	Utilities
4	23	Construction	4	Construction
5	31	Manufacturing	5	Manufacturing
6	42	Wholesale Trade	6	Wholesale Trade
7	44	Retail Trade	7	Retail Trade
8	45	Retail Trade	7	Retail Trade
9	48	Transportation and Warehousing	8	Transportation and Warehousing
10	49	Transportation and Warehousing	8	Transportation and Warehousing
11	51	Information Services	9	FIRES
12	52	Finance and Insurance	9	FIRES
13	53	Real Estates, and Rental and Leasing	9	FIRES
14	54	Professional, Scientific, and Technical Services	9	FIRES
15	55	Management of Companies and Enterprises	9	FIRES
16	56	Administrative and Support, and Waste Management and Remediation Services	9	FIRES
17	61	Educational Services	10	EDU
18	62	Health Care, and Social Assistance	9	FIRES
19	71	Arts, Entertainment, and Recreation	9	FIRES
20	72	Accommodation, and Food Services	9	FIRES
21	81	Other Services (Except Public Administration)	9	FIRES
22	92	Public Administration	11	GOVT

Note: FIRES - Finance/Insurance/Real Estate/Services, EDU – Educational, GOVT – Government.

Internal HDT Trip Rates

Trip rates derived from establishment surveys and GPS data for each truck type and land use are shown in Table 7-2. A second set of warehousing trip rates based on thousand square feet (KSF) is included to facilitate studies of proposed warehouses where only square footage data are available. All other rates are defined per employee.

Table 7-2: Internal HDT Trip Rates

Category	Light HDT Trip Rate	Medium HDT Trip Rate	Heavy HDT Trip Rate
Households	0.0147	0.0046	0.0072
Agriculture/Mining/Construction	0.0804	0.0778	0.0715
Retail	0.0663	0.0662	0.0703
Government	0.0296	0.0150	0.0148
Manufacturing	0.0613	0.0655	0.0924
Transportation/Utility	0.158	0.181	0.319
General Warehousing (Employment)	0.161	0.185	0.327

High Cube Warehousing (Employment)	0.184	0.211	0.372
General Warehousing (KSF)	0.2819	0.2434	0.5421
High Cube Warehousing (KSF)	0.0948	0.1272	0.3380
Wholesale	0.0916	0.0968	0.1316
Other (Service)	0.0095	0.0111	0.0151

Table 7-3 shows the 2012 HDT trip generation estimates. As expected, households in the region generate a high number of trip ends, especially for Light HDT. This is mostly due to the fact that land uses such as transportation and warehousing, utilities, service and retail deliver goods and provide services to residential neighborhoods. The largest HDT trip generator is the transportation and utility land use that includes trucks involved in power generation, water supply and sewage treatment, all kinds of transportation (trucking industry, taxi, and chartered services), and postal and courier services. The second highest generators of HDT trips are retail and manufacturing land uses, which account for a major share of employment in the region and serve the vast area and population of the six-county SCAG region.

Table 7-3: 2012 Internal HDT Trip Generation Estimates

Land Use	Light HDT Trip Ends	Medium HDT Trip Ends	Heavy HDT Trip Ends	Total Trip Ends	Percent of Total Trip Ends
Households	86,236	27,018	42,545	155,799	16%
Ag/Mining/Construction	30,611	29,634	27,246	87,491	9%
Retail	52,071	51,996	55,204	159,270	16%
Governments	7,710	3,922	3,855	15,487	2%
Manufacturing	40,302	43,051	60,796	144,149	15%
Transportation/Utility	55,393	63,672	112,215	231,279	24%
General Warehousing	7,591	8,729	15,418	31,738	3%
High Cube Warehousing	3,741	4,300	7,578	15,619	2%
Wholesale	34,208	36,159	49,147	119,513	12%
Other	2,990	3,484	4,748	11,222	1%
Total	**320,851**	**271,964**	**378,752**	**971,567**	

Internal HDT Trip Distribution Model

The trip distribution process was modified by developing a matrix of factors that indicate the trip interchange relationships among different land use types (i.e., what fraction of trips originating at a land use such as manufacturing sites go to warehouses vs. other manufacturing sites, etc.). The internal HDT trip distribution model uses a gravity formulation, stratified by land use type at both the production and the attraction end of the trip. This results in a total of 100 gravity models for each truck type: Light-Heavy Duty Truck (LHDT), Medium-Heavy Duty Truck (MHDT) and Heavy-Heavy Duty Truck (HHDT). After trip distribution, the 100 different trip matrices are combined into a single matrix for each truck type, so that only three matrices are passed on to time-of-day factoring and trip assignment.

Truck trips are distributed using composite cost impedances that account for time and distance-based monetary costs in addition to travel time. Based on a review of the literature, the appropriate distance-based costs for the SCAG model are identified in a report commissioned by the Minnesota Department of Transportation (DOT)[5]. These costs account for fuel, tires, maintenance and repair, and depreciation.

The link composite cost is calculated as shown in the equation below. The corresponding unit costs are shown in Table 7-4.

*Composite Cost = Cost per hour * Congested time +*
*[Fuel Price / Fuel efficiency + Cost per mile (excluding fuel)] * Distance*

Table 7-4: Composite Truck Unit Costs

Truck Type	Cost per Hour	Fuel Efficiency (MPG)	Cost per Mile (excluding fuel)	Fuel Price per Gallon (a)
LHDT	$14.31	8.5	$0.14	$4.08
MHDT	$19.86	7.0	$0.24	$4.21 (b)
HHDT	$19.86	6.0	$0.27	$4.21 (b)

(a) Assumes all MHDT and HHDT trucks are diesel a fleet mix of 60% gasoline and 40% diesel powered trucks for LHDT.
(b) Fuel prices based on average 2012 California gasoline and diesel prices.

The GPS survey of truck trips provided the data to calibrate the model friction factors. These data were used to build observed truck trip flow matrices, stratified by truck type (LHDT, MHDT and HHDT). The TransCAD gravity model calibration utility was used to calibrate the fraction factors that best matched the observed truck flow matrices, given the composite cost impedances and land-use based trip productions and attractions. Figures 7-2 to 7-4 show the trip length calibration performed for the 2008 HDT model update, respectively for each truck class. Model parameters calibrated for the 2008 base year have been retained in the 2012 base year model.

[5] Levinson, David Matthew, Corbett, Michael J. and Hashami, Maryam, *Operating Costs for Trucks*, (2005) http://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID1736159_code807532.pdf?abstractid=1736159&mirid=1.

Figure 7-2 LHDT Internal Truck Trip Length Calibration

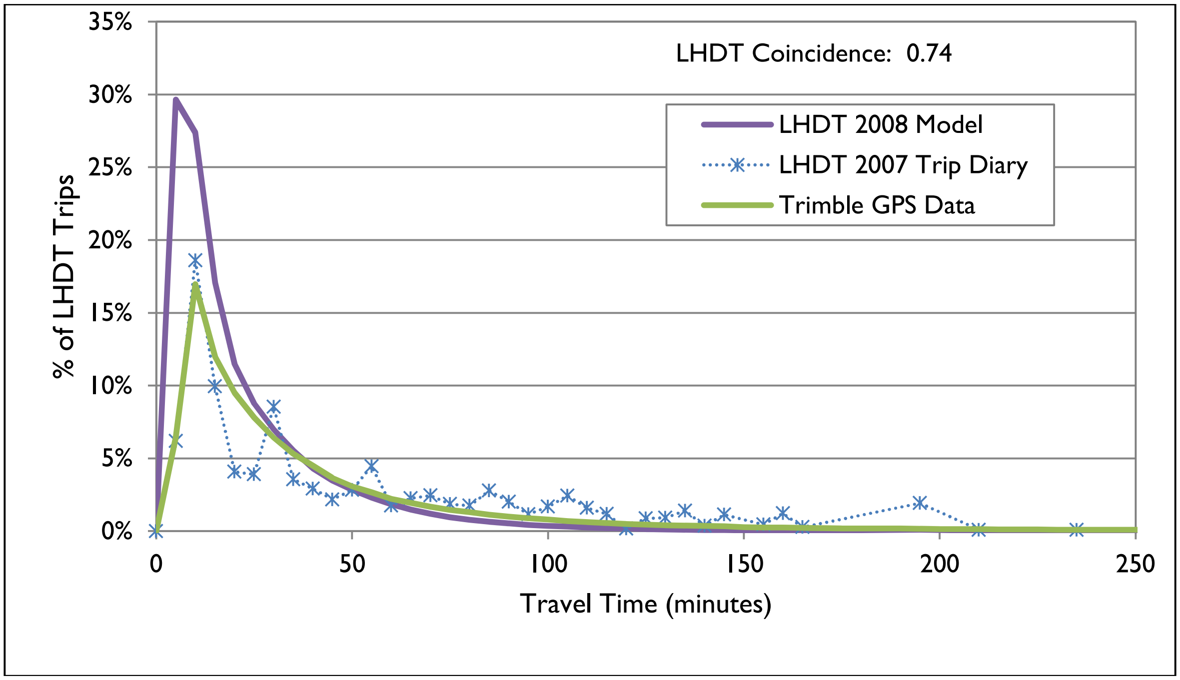


Figure 7-3 MHDT Internal Truck Trip Length Calibration

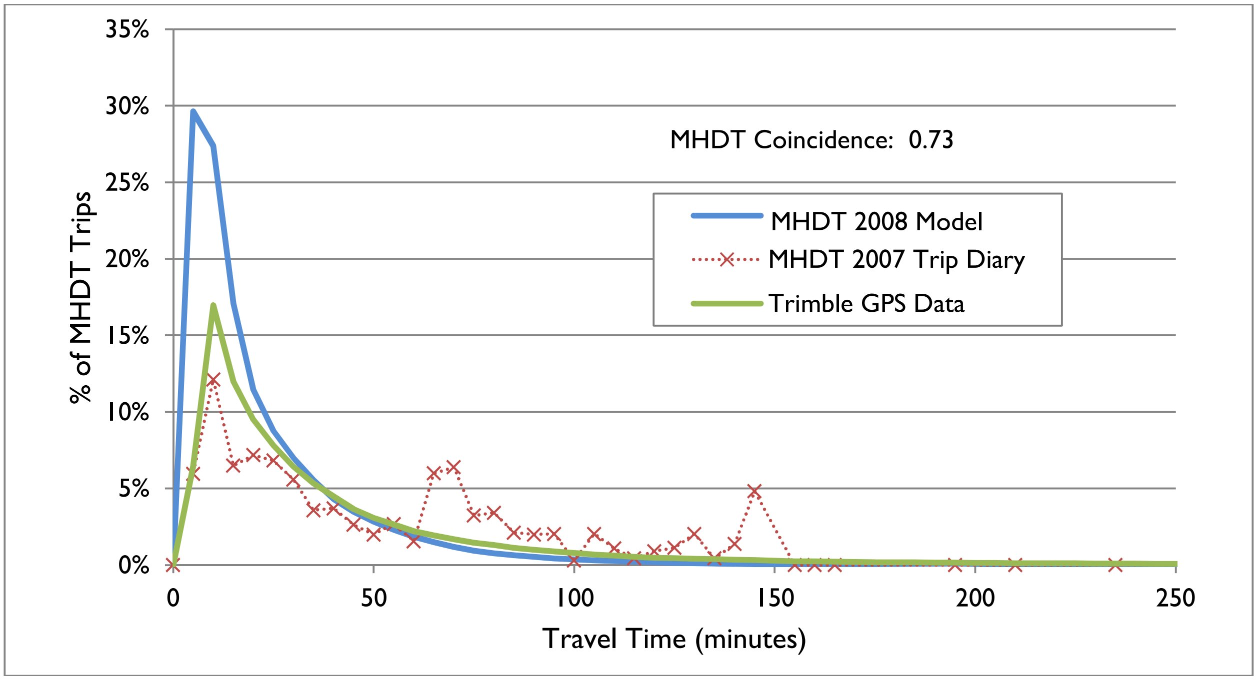
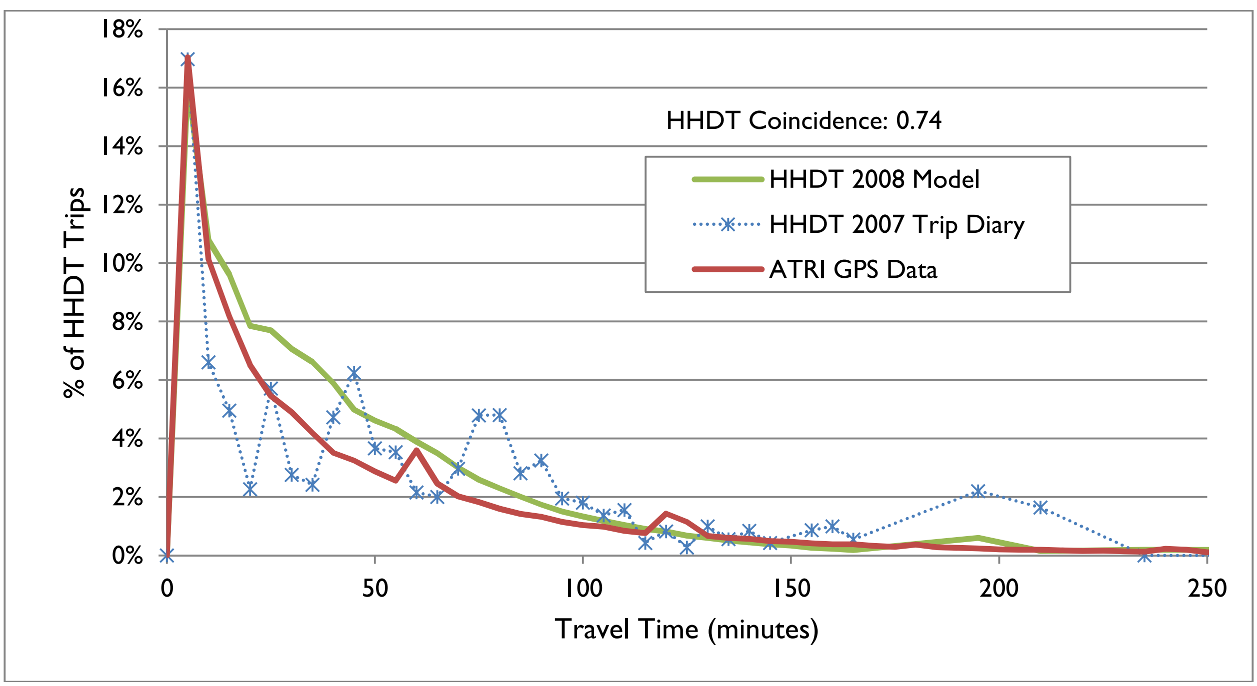


Figure 7-4 HHDT Internal Truck Trip Length Calibration



External HDT Model

The external HDT Model consists of internal-external and external-internal truck trips, and external-external (EE) truck trips. The IE/EI HDT trips are generated and distributed using a combination of commodity flow data at the county level and 2-digit NAICS employment data for allocating county data to TAZs. Growth factors developed using the commodity flow data at a county level and external cordon are used to forecast future year external HDT trips from the base year trip flow matrices.

The external HDT Model is based on the 2007 TRANSEARCH commodity flow table. The TRANSEARCH data are provided as annual flows in tons and are converted to daily weekday flows using an annualization factor of 306 (6 days per week for 51 weeks) for all commodities. The flows are converted from tons to trucks using the payload factors shown in Table 7-5. These payload factors were developed using data from the 2002 Vehicle Inventory and Use Survey (VIUS).

The methodology that converts commodity flows to annual HDT trips at the TAZ level is described below for various direction, commodity and shipment type combinations.

Outbound Truck Load (TL) and Private Carrier Shipments

The external trip end of the outbound commodity flows are allocated to external cordon stations using survey data from the SCAG region. The internal trip end of the outbound commodity flows is disaggregated from counties to TAZs based on shares of employment in the manufacturing, agricultural, mining industries, or warehousing land use acreage, depending on the type of commodity.

Inbound Truck Load and Private Carrier Shipments

The external trip end of the inbound commodity flows are allocated to cordon stations as described above for outbound flows. To establish the internal TAZ trip end, flows of each commodity destined to warehouses are estimated using Reebie data, and then disaggregated to TAZs based on the share of warehousing land use acreage. The remaining non-warehouse destination flows are assumed to be destined directly to manufacturing facilities. To disaggregate these flows, the fraction of each commodity consumed by different industries is determined using an Input-Output table, and then disaggregated to TAZs based on shares of employment in the corresponding industry.

Less than Truck Load (LTL) Shipments

SCAG inbound and outbound LTL shipments typically move through LTL terminals at the origin and destination so the same methodology is used for both directions. Also, since LTL shipments could carry any commodity, the approach is the same for all commodities. Truck load payload factors are used because payloads for LTL shipments cannot be determined (each LTL shipment carries many commodities with varying payloads). The external trip end of the LTL commodity flow is allocated to cordon stations as described above for truck load shipments. The internal trip end is disaggregated from county to TAZ based on the share of LTL trucking employment.

Table 7-5: External HDT Commodity Payload Factors

Commodity		Payload Factors (Tons per Truck)		
STCC	**Description**	**LHDT**	**MHDT**	**HHDT**
1	Farm Products	1	2	16
8	Forest Products	3	6	14
9	Fresh Fish or Other Marine Products	2	2	10
10	Metallic Ores	3	3	24
11	Coal	3	3	18
13	Crude Petroleum, Natural Gas, or Gasoline	3	6	15
14	Non-metallic Minerals	4	5	16
19	Ordinance or Accessories	2	5	14
20	Food or Kindred Products	3	4	15
21	Tobacco Products, excluding Insecticides	3	6	15
22	Textile Mill Products	1	4	11
23	Apparel or Other Finished Textile Products	5	6	9
24	Lumber or Wood Products, excluding Furniture	4	6	16
25	Furniture or Fixtures	2	3	9
26	Pulp, Paper, or Allied Products	2	7	13
27	Printed Matter	2	7	15
28	Chemicals or Allied Products	2	5	14
29	Petroleum or Coal Products	3	6	11
30	Rubber or Miscellaneous Plastics Products	3	5	12
31	Leather or Leather Products	3	6	13
32	Clay, Concrete, Glass, or Stone Products	3	7	14
33	Primary Metal Products	5	6	15
34	Fabricated Metal Products	5	5	11
35	Machinery, excluding Electrical	2	3	9
36	Electrical Machinery, Equipment, or Supplies	2	5	8
37	Transportation Equipment	2	7	11
38	Instruments, Photographic Goods, Optical Goods, Watches, or Clocks	2	4	10
39	Miscellaneous Products of Manufacturing	2	6	8
40	Waste or Scrap Materials	2	3	14
43	Mail	3	4	14
44	Freight Forwarder Traffic	3	1	7
45	Shipper Association or Similar Traffic	3	6	9
46	Freight All Kinds	3	5	12
47	Small Packages, LTC or LTL	3	6	10
48	Waste Hazardous Materials or Waste Hazardous Substances	3	6	15

Note: STCC – Standard Transportation Commodity Classification

External – External HDT Trips

The 2007 TRANSEARCH data identify EE truck freight flows passing through the SCAG region. To assign the cordon station to each EE trip end, a method similar to the one used for the external end of the IE/EI trips was used.

Empty Truck Trips

To account for all external truck trips in the SCAG region, empty truck are added to the loaded truck trips estimated from the commodity flows. Empty truck trip percentages at each external cordon location were generated from survey data. Assuming the empty truck fractions to be the same for all O-D pairs for an external cordon, empty truck trips are added to the loaded truck trips between SCAG TAZs and external TAZs.

Port HDT Model

Ports TAZ Development

The SCAG Tier 1 Zone System consists of 4,192 TAZs, including 42 TAZs that represent the Ports areas. The Port HDT Model was updated to use a more refined set of port TAZs, developed by the Ports of Los Angeles and Long Beach. This zone system, called Port TAM, includes a total of 90 Port area TAZs, for a total of 4,253 Tier 1 TAZs. Table 7-6 below provides a summary breakdown of the 4,253 TAZ system.

Table 7-6: PortTAM 4,253 TAZ System

from Zone ID	To Zone ID	Zone Type	Total
1	4109	Internal zones	4,109
4110	4149	External zones	40
4150	4161	Airport zones	12
4162	4251	Port zones	90
4251	4253	Extra zones	2
Total Zones			**4,253**

Terminal Gate Surveys

Origin-destination truck surveys were conducted in early 2010 at the Ports of Los Angeles and Long Beach Marine Terminals. The marine terminals are distribution points where international cargo is loaded onto trucks and rail. The survey was conducted to obtain OD pattern information by truck type. Surveys were conducted at six Port of Long Beach terminals (ITS, PCT, LBCT, CUT, SSA, and HANJIN) and six Port of Los Angeles terminals (YTI, MAERSK, EVERGREEN, TRAPAC, YANG MING, and APL).

A total of 23,030 survey sheets were distributed and 3,559 were returned. From the returned surveys, 2,981 origin trips were fully completed and geo-coded, and another 2,593 destination trips were also fully completed and geo-coded for a total of 5,574 trips. Tables 7-7 and 7-8 present the survey sample origins and destinations by container type.

The marine terminal truck trips exhibited the following OD patterns:

- 12% traveled to the Ports areas & nearby locations
- 30% traveled to Gateway cities locations
- 20% traveled to off-dock yards
- 33% traveled to locations within the rest of the SCAG region
- Less than 5% traveled to out of state locations
- 98% of the off-dock intermodal yard traffic went to the four main intermodal yards (ICTF, Hobart, East LA, and LATC). Almost no traffic was recorded from yards at Industry and San Bernardino.

Table 7-7: Survey Sample Origins

Terminal	Bobtails	Chassis	Containers	Total
ITS	121	45	259	**425**
PCT	98	33	215	**346**
LBCT	165	14	282	**461**
CUT	94	45	151	**290**
SSA	75	26	73	**174**
HANJIN	142	13	198	**353**
YTI	9	3	21	**33**
MAERSK	107	31	80	**218**
EVERGREEN	59	21	104	**184**
TRAPAC	163	13	166	**342**
YANG MING	48	10	69	**127**
APL	13	1	14	**28**
Total	**1,094**	**255**	**1,632**	**2,981**

Table 7-8: Survey Sample Destinations

Terminal	Bobtails	Chassis	Containers	Total
ITS	116	22	246	**384**
PCT	77	22	173	**272**
LBCT	115	15	258	**388**
CUT	89	18	141	**248**
SSA	30	14	94	**138**
HANJIN	85	31	187	**303**
YTI	15	1	16	**32**
MAERSK	35	31	140	**206**
EVERGREEN	55	6	103	**164**
TRAPAC	86	14	213	**313**
YANG MING	23	10	81	**114**
APL	10	3	18	**31**
Total	**736**	**187**	**1670**	**2,593**

Port Truck Trip Generation

The port trip generation model was developed in 2008 based on a detailed port area zone system and specialized trip generation rates for autos and trucks by type (Bobtail, Chassis, and Containers). Port truck trip generation has two components: 1) container terminal truck trips, and 2) non-container terminal truck trips.

Container Terminal Truck Trip Generation

The container terminal truck trip generation model for the ports is referred to as the QuickTrip Model. QuickTrip was originally developed for the Ports of Los Angeles and Long Beach. The Model includes detailed input variables such as mode split (rail versus truck moves), time-of-day factoring, weekend moves, empty return factors, and other characteristics that affect the number of trucks entering and exiting through the terminal gates. The relevant input data for each container terminal include the following:

- Peak monthly Twenty-Foot Equivalent Units (TEU) throughput.
- TEU-to-lift conversion factor: factor determining the average number of TEUs associated with each lift at the terminal.
- TEU land-side throughput distributions: percent of TEU throughput associated with on-dock intermodal imports, on-dock intermodal exports, off-dock intermodal imports, off-dock intermodal exports, local imports, local exports, empties, and trans-shipments across the wharf.
- Number of operating days during the week.
- Percent of throughput moved during each terminal operating shift (for the day, second and hoot shifts).

QuickTrip produces the following truck trip outputs for each terminal:

- Monthly gate transactions
- Peak week truck trip volume
- Daily truck trips, and truck trips by each hour of the day by type of truck trip (bobtail, chassis, container, empty), and direction (arrival at and departure from the terminal)

QuickTrip can be used to generate base as well as future year truck trips by truck type and direction for each terminal, using the model inputs described earlier for each specific year. The inputs that are particularly expected to change for different years include the peak monthly TEU throughput, and the TEU land-side throughput distributions (based on expected increase in on-dock intermodal capacity at the port terminals in the future). Additionally, the model has the capability to analyze the impacts of other port truck trip reduction strategies such as virtual container yards and off-peak truck diversions, using specific inputs associated with these strategies.

The Model was enhanced to allow the user to assess whether the estimated capacity of each rail yard has been exceeded. If so, traffic is iteratively re-allocated to other yards that are not over capacity. The enhanced model also allows the user to choose different efficiency factors, such as "percent double cycle trucks," for different off-dock yards. In the original version, the user had to use the same variables for the entire off-dock market.

Non-Container Terminal Truck Trip Generation

Non-container terminal truck trip generation estimates were also developed for the Ports as part of the Port truck trip generation process. This includes trips to and from all of the other types of marine terminals (automobile terminals, dry bulk terminals, liquid bulk terminals and break-bulk terminals). In addition, there are many non-terminal land uses located throughout the ports (e.g., administrative offices, recreation, commercial, government buildings) that potentially generate truck traffic.

Existing non-container terminal truck trips were developed by conducting a series of driveway and midblock truck counts throughout the Ports. A number of specific terminals were counted at their driveways, while other terminals and miscellaneous land use activities were reflected via the use of downstream roadway truck counts. In some cases, a roadway truck count was used to represent the trip generation of a group of non-container terminals and other land uses.

Port Trip Table Distribution

The zone to zone distribution of port truck trips is based on a fixed OD matrix. A detailed and comprehensive truck driver survey was undertaken by the ports at the marine container terminals. The survey was used to develop detailed origin-destination trip tables for use in the Port area travel demand model. The stated trip OD from every valid survey was correlated with the travel demand model TAZ system. The survey results were then used to develop port truck OD frequency distributions by truck type for use in the model. Distribution patterns were developed separately for arrival trips and departure trips for each terminal. A total of 15 Port Truck Trip Tables were developed (5 time periods by 3 vehicle classes): AM, MD, PM, EV and NT time periods, and Bobtails, Chassis and Container truck trips. The time periods are consistent with those used by the passenger model, but combine the night and evening periods into a single night time period. Empty container and loaded container truck types are combined into one truck type called container truck type.

For terminals with few or no observations (Pier C, YTI and APL) an average distribution of all surveyed records was used. Before creating survey frequency distribution vectors, survey sample trips were adjusted to exclude trips that have both OD within the same terminal.

Base Year Port Trip Tables Summary

Summaries of 2012 Port truck trips are shown in Tables 7-9 and 7-10.

Table 7-9: 2012 Port HDT Trips by Truck Type

Time Period	Bobtails	Chassis	Containers	Total
AM	1,339	415	1,858	3,612
MD	7,756	2,439	11,037	21,232
PM	3,669	1,159	5,248	10,076
EV	1,888	596	2,696	5,180
NT	2,832	895	4,045	7,772
Daily	**17,484**	**5,504**	**24,884**	**47,872**

Table 7-10: 2012 Port HDT Trips by Time Period and County

County	Time Period					
	AM	MD	PM	EV	NT	Total
Imperial	0	0	0	0	0	**0**
Los Angeles	3,276	19,752	9,430	4,846	7,269	**44,573**
Orange	108	475	206	106	159	**1,055**
Riverside	46	204	89	46	69	**455**
San Bernardino	153	675	295	153	230	**1,506**
Ventura	6	26	12	7	10	**62**
External Stations	23	100	44	23	34	**224**
Total	**3,612**	**21,233**	**10,076**	**5,182**	**7,772**	**47,875**
% of Daily Trips	**7.5%**	**44.4%**	**21.0%**	**10.8%**	**16.2%**	

Intermodal HDT Trips

Intermodal Trip Tables

Intermodal (IMX) trucks trips are heavy HDT movements generated at the six regional intermodal facilities in the SCAG region. These intermodal facilities are shown in Figure 7-5. The intermodal (IMX) trip tables were developed from the IMX surveys conducted for LACMTA in 2005[6]. These surveys collected the following data on truck movements at these facilities: total inbound and outbound trains by month, including origin, destination, and number of containers by type; weekly train schedule; number of "lifts" (loading/unloading rail cars) by month split by containers versus trailers; and gate transactions by day by type (inbound, outbound, loaded, empty and bobtail).

The data obtained from the six IMX terminals were used to put together matrices of annual shipment flows at the zip code level. Trips to or from the ports were excluded, as they are modeled by the Port HDT Model. Four customer data matrices were developed: TL inbound, TL outbound, LTL inbound, and LTL outbound. A summary of these truck movements is shown in Table 7-11. These truck trips were all assumed to be HHDTs. The daily truck trips were developed assuming an annualization factor of 306. A summary of the IMX daily trip tables by terminal and county, as derived from the 2005 IMX surveys, is presented in Table 7-12.

[6] Cambridge Systematics, Inc. LACMTA Cube Cargo Model Development. 2005.

Figure 7-5: Intermodal Facilities in the SCAG Region

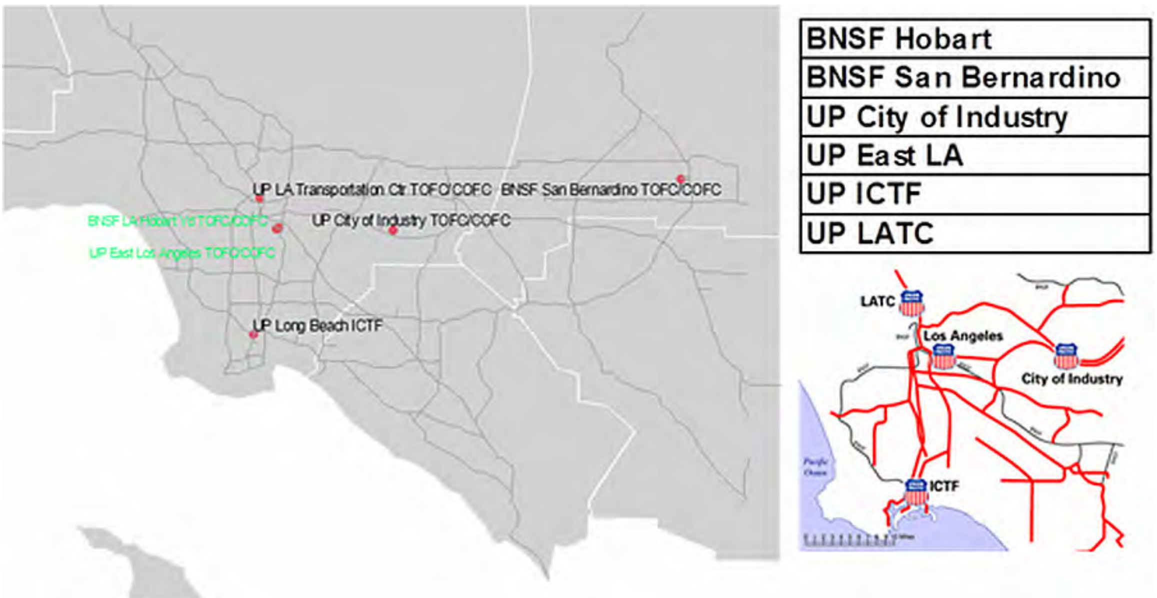


Table 7-11: 2005 Domestic IMX (Non-Port) Annual Truck Trips

Domestic	BNSF Hobart	BNSF San Bernardino	UP City of Industry	UP East LA	UP ICTF	UP LATC	Total
Inbound	444,204	433,333	93,789	96,757	2,463	21,812	1,092,357
TL/IMC	273,495	300,654	81,789	85,567	2,276	18,781	762,562
LTL	170,708	132,679	12,000	11,190	187	3,031	329,795
Outbound	445,011	458,677	78,431	69,837	662	21,353	1,073,970
TL/IMC	280,997	331,201	66,901	59,086	482	18,441	757,108
LTL	164,014	127,476	11,530	10,751	180	2,912	316,862
Total	889,214	892,009	172,220	166,594	3,125	43,165	2,166,327
TL/IMC	554,492	631,855	148,690	144,653	2,758	37,222	1,519,670
LTL	334,722	260,154	23,530	21,941	367	5,943	646,657

Table 7-12: 2012 Intermodal HHDT Trips by Terminal and County

IMX Terminal	IMX Terminal TAZ	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	Grand Total	Share by Terminal
UP ICTF	1,360	0	9	1	1	1	0	**13**	**0%**
UP LATC	1,591	0	84	22	24	15	1	**147**	**2%**
BNSF Hobart	1,679	10	1,722	280	327	532	36	**2,905**	**40%**
UP East LA	1,702	2	322	110	78	73	4	**589**	**8%**
UP City of Industry	2,304	6	283	152	112	49	3	**606**	**8%**
BNSF San Bernardino	3,773	19	516	1,687	687	50	2	**2,961**	**41%**
Grand Total		**37**	**2,937**	**2,252**	**1,228**	**720**	**47**	**7,221**	
Share by County		**1%**	**41%**	**31%**	**17%**	**10%**	**1%**		

Secondary Transload HDT Trips

In addition to trips to and from the Ports and intermodal railyards, the PortTAM model accounts for secondary trips associated with transloading of container cargo. Transloading occurs when cargo in 20- and 40-foot international containers is moved to larger (usually 53-foot) domestic containers. The loaded domestic containers are drayed to intermodal railyards, trucked to other warehouse or wholesale locations, or trucked outside of the SCAG region.

The HDT model incorporates secondary transload trip tables generated by PortTAM. Transload studies show that 27% of all containers imported to the ports are transloaded and then transported to intermodal railyards, while 13% of imported containers are transloaded and transpoted to other zones within or outside of the SCAG region. The share of cargo transloaded to rail is expected to increase to 30% by 2035. The share of cargo that will be transloaded and transported to non-railyard facilities is expected to remain constant at 13%.

The trip tables passed from the PortTAM model to the SCAG HDT model include transloaded cargo, as well as empty container and bobtail trips required to support transloading of cargo.

Secondary Repositioning HDT Trips

The truck trip table generated by PortTAM (i.e., the Port, IMX, and transload models) include trips that have at least one end at a Port, transload, or intermodal zone. The trip tables generated by these trips give rise to additional secondary repositioning trips to and from these locations. For example, the first leg of an HDT trip chain would be from a port zone to a wholesale or warehouse facility, then the second leg would be from the wholesale or warehouse facility to a different TAZ in the six-county SCAG region. While some trucks may return directly to another port zone, this is not the case for all port-related trips. Secondary repositioning trips are calculated based on the imbalance of inbound and outbound port-related trucks in each TAZ.

Secondary repositioning trips are added to the internal truck trip tables after trip distribution, and therefore use distribution patterns consistent with the gravity model used for trip distribution. Table 7-13 presents a summary of the total wholesale HHDT trips in the region that are computed from three models – internal HDT, Port and IMX.

Table 7-13: 2012 Wholesale and Warehousing HDT Trips

Truck Type/PA	Internal HDT	Port Model HHDT	IMX HHDT Trips	Total Wholesale/Warehuose HHDT
LHDT Productions	34,208	n/a		
LHDT Attractions	34,208			
MHDT Productions	36,159			
MHDT Attractions	36,159			
HHDT Productions	49,147	12,885	3,405	65,437
HHDT Attractions	49,147	12,254	3,570	64,971

HDT Time-of-Day Factoring & Assignment

The HDT Model uses fixed time-of-day factors derived from observed truck counts. The HDT time of time periods are consistent with the passenger model periods, namely:

- AM Peak: 6:00 AM – 9:00 AM
- Mid-day: 9:00 AM - 3:00 PM
- PM Peak: 3:00 PM - 7:00 PM
- Evening: 7:00 PM – 9:00 PM
- Night: 9:00 PM – 6:00 AM

The HDT diurnal factors were derived from the 2007 Vehicle Travel Information System (VTRIS)[7] database. VTRIS is maintained by the FHWA Office of Highway Policy Information to track traffic trends, vehicle distributions and weight of vehicles to meet data needs specified in highway legislation. The VTRIS database contains truck classification counts spanning nearly half a year at many locations on SCAG interstate and state highways. The HDT time of day factors are shown in Table 7-14.

Table 7-14: HDT Time-of-Day Factors

Time Period	Diurnal Factors		
	LHDT	MHDT	HHDT
AM Peak (6 AM - 9AM)	18.8%	18.0%	13.9%
Midday (9 AM-3PM)	42.9%	46.5%	35.3%
PM Peak (3 PM- 7PM)	20.3%	15.5%	16.7%
Evening (7 PM - 9 PM)	4.8%	3.5%	7.2%
Night (9 PM - 6AM)	13.2%	16.5%	26.9%

HDT trips are assigned simultaneously with the auto trips as part of a user equilibrium multiclass assignment. The assignment methodology is described in detail in Chapter 8 – Trip Assignment. Truck volumes are converted to PCEs following the procedures recommended in the 2010 Highway Capacity Manual. The PCE factors are a function of grade, length of the climb segment, and percent of truck volume, and vary by truck type (LHDT, MHDT and HHDT). These factors are shown in Table 7-15.

[7] http://www.fhwa.dot.gov/ohim/ohimvtis.cfm

Table 7-15: HDT Passenger Car Equivalent Factors

Percent Trucks	Length of Grade in miles	Light -Heavy				Medium-Heavy				Heavy-Heavy			
		% Grade				% Grade				% Grade			
		< 2	2 - 4	4 - 6	> 6	< 2	2 - 4	4 - 6	> 6	< 2	2 - 4	4 - 6	> 6
0-5%	< 1	1.3	1.5	3.0	4.0	1.5	2.0	3.5	5.0	2.5	2.5	4.5	6.0
	1 - 2	1.3	2.5	4.0	5.0	1.5	3.5	5.0	6.5	2.5	5.0	7.5	12.5
	> 2	1.3	2.5	4.0	5.0	1.5	3.5	5.0	6.5	2.5	5.0	7.5	12.5
5-10%	< 1	1.3	1.5	2.5	3.0	1.5	2.0	3.0	4.0	2.5	2.5	4.5	5.5
	1 - 2	1.3	2.0	3.5	4.0	1.5	3.0	4.0	5.5	2.5	4.0	8.0	11.5
	> 2	1.3	2.0	3.5	4.0	1.5	3.0	4.0	5.5	2.5	4.0	8.0	11.5
>10%	< 1	1.3	1.5	2.0	2.5	1.5	2.0	2.5	3.0	2.5	2.5	4.0	4.0
	1 - 2	1.3	2.0	3.0	3.5	1.5	2.5	3.5	4.0	2.5	3.5	6.0	9.0
	> 2	1.3	2.0	3.0	3.5	1.5	2.5	3.5	4.0	2.5	3.5	6.0	9.0

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Chapter 8 – Time of Day Choice

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Chapter 8 – Time of Day Choice

Introduction

This Chapter describes the methodologies available to segment the peak and off-peak demand into finer time periods, in preparation for assigning the auto trips to the highway network.

In the highway assignment, vehicle trips for all trip purposes are assigned, or loaded, onto each of five time period highway networks. The five time periods are:

- AM Peak (AM) - 6:00 AM to 9:00 AM,
- Midday (MD) - 9:00 AM to 3:00 PM,
- PM Peak (PM) - 3:00 PM to 7:00 PM,
- Evening (EV) - 7:00 PM to 9:00 PM, and
- Night (NT) - 9:00 PM to 6:00 AM.

Prior to assignment, the mode choice output is converted from peak/off-peak production-attraction (PA) format to time-of-day OD format. Two procedures are available to accomplish this conversion. The standard procedure, employed for the 2016 RTP/SCS development, is based on trips-in-motion diurnal factors. The second, optional procedure is based on a time-of-day choice model. Both procedures are described next.

Diurnal Factors

Trips-in-motion diurnal factors were derived from the 2012 California Household Travel Survey. These diurnal factors allocate the production-attraction trips by purpose to each of the five time periods. There are two sets of factors. The first set is applied at the end of trip generation to subdivide trips by purpose into "peak" and "off-peak" categories prior to the application of the trip distribution model. These factors are shown in Table 8-1. The second set is applied prior to trip assignment to allocate peak trips into the AM and PM peak periods by direction of travel, and off-peak trips into MD, EV and NT by direction of travel. These factors are displayed in Table 8-2. Once all of the factors are applied, OD trip tables by mode are summed for all trip purposes, combined with the internal-external, external-external and heavy duty truck trips, and then assigned by time period.

Table 8-1: Peaking Factors

Trip Purpose	Peak	Off-Peak
HBWD	0.6628	0.3372
HBWS	0.6224	0.3776
HBCU	0.5483	0.4517
HBSC	0.7390	0.2610
HBSH	0.4042	0.5958
HBSR	0.3574	0.6426
HBSP	0.6497	0.3503
HBO	0.4451	0.5549
WBO	0.5353	0.4647
OBO	0.4350	0.5651

Table 8-2: Time-of-Day Factors

Trip Purpose	Peak Period				Off Peak Period					
	AM		PM		MD		EV		NT	
	PA	AP	PA	AP	PA	AP	PA	AP	PA	AP
HBWD	45.0	1.4	3.4	50.3	27.5	18.2	1.5	15.2	24.3	13.6
HBWS_HBI	29.7	0.2	2.4	67.6	27.8	14.5	0.1	30.1	7.6	19.9
HBWS_IBW	33.4	1.4	3.4	61.8	34.0	45.7	0.7	8.8	7.4	3.4
HBCU	47.9	1.2	18.3	31.3	34.3	31.3	0.2	13.8	1.9	18.5
HBSC	68.8	0.0	1.0	30.2	8.7	82.0	0.8	4.5	1.3	2.6
HBSH	12.5	2.8	23.8	60.9	35.8	35.1	5.5	13.0	3.3	7.4
HBSR	16.8	2.2	37.9	43.0	27.7	15.0	5.4	17.7	5.3	28.9
HBSP	36.8	14.0	17.0	32.1	38.8	29.6	3.8	9.3	7.5	10.9
HBO	29.0	3.2	25.8	42.1	41.5	30.3	4.1	10.1	4.1	9.9
WBO	5.3	26.9	62.7	5.1	60.4	26.5	5.4	0.6	2.9	4.1
OBO	11.5	11.5	38.5	38.5	40.4	40.4	5.8	5.8	3.9	3.9

Time of Day Choice Model

The time of day choice model was introduced to give the model system the ability to shift demand among time periods, in response for example to increasing peak period congestion, or due to variable time of day road pricing.

Model Specification

The time-of-day choice model is a multinomial logit model that estimates the probability that travelers choose a specific trip departure time based on the characteristics of the trips, the characteristics of the drivers, and the characteristics of the highway network. The models predict travel for 31 time periods, representing 30-minute time intervals from 6:00AM to 9:00PM, and an overnight time period.

The models were developed using the 2012 California Household Travel Survey. Other data used in the model estimation, such as distance and travel time skims, employment and population density, were obtained from a current, fully-equilibrated version of the SCAG travel demand model.

In total, nine models are developed, corresponding to each direction of the home-based trips (from home, to home), and one model for the non-home based trips. The HBSR and HBO trips are combined into a single purpose when applying the time of day choice model. The final segments are:

- Home-based work direct trips (HBWD) from home
- Home-based work direct trips (HBWD) to home
- Home-based work strategic trips (HBWS) from home
- Home-based work strategic trips (HBWS) to home
- Home-based shopping trips (HBSH) from home
- Home-based shopping trips (HBSH) to home
- Home-based other (HBO) from home

- Home-based other (HBO) to home
- Non-home-based other (OBO) trips

The utility that a trip chooses time interval *t* is given by:

$$U(t) = \alpha_t + \sum_{i=0}^{2} \beta^i \times Dist \times Shift^i \quad + \sum_{i=0}^{2} \gamma^i \times Delay \times Shift^i + \sum \delta^i \times A^i$$

That is, the likelihood of choosing a given time period is a function of the travel distance (*dist*), the travel time measured as delay relative to the travel time during the night time period (*delay*), and attributes of the tripmaker or trip such as household income, age, household size, mode, and population density of the origin or destination zone (*A*).

The distance and delay variables are interacted with shift variables, which measure the propensity to choose times earlier or later than the middle of the AM, PM, or MD time periods. Two shift variables are used, to measure the early and late shift relative to the middle interval, respectively. A positive coefficient on the early shift variables indicates that the trip is likely to shift early, while a positive coefficient on the late shift variable indicates that the trip is likely to shift late.

The following household, person and zone attributes were found to be significant:

- Median household income
  - Less than $35,000
  - $35,000 to $74,999
  - $75,000 to $149,999
  - $150,000 or more
- Average household size
- Median age of people living in the trip origin TAZ
- Origin TAZ population density
- Destination TAZ population density
- Origin CBD dummy
- Destination CBD dummy

The model estimation results indicate that, on the journey from home to work, the longer the distance between home and work, the earlier the chosen time interval, all else equal. The same effect of distance on time-of-day choice is observed on the journey from work to home. On the other hand, the effect of delay is to increase the likelihood of choosing intervals away from the peak interval within each peak period, as delay increases. That is, some trips will choose earlier travel times, while others will choose later travel times. No pattern emerged as to whether earlier times are generally preferable to later times, but clearly there is a response towards moving away from the most congested time interval.

Model Application

The nine time-of-day choice models developed are applied to their respective production-attraction (PA) matrices output from the mode choice model. The time of day split for HBSC, HBSP, HBU and WBO trips is performed using the diurnal factors described above.

Effect of Pricing on Time-of-Day Choice

Because there are few trips in the SCAG region that are currently exposed to tolls, the effect of road pricing on time of day choices was measured using a stated preference (SP) survey and models derived from these survey data.

The stated preference survey was administered in 2011 to 3,500 travelers in the SCAG region. Information about a recent auto trip was gathered from each respondent, and was used to customize a series of hypothetical scenarios where travelers were asked to choose a departure time period given choices characterized by different travel times and road prices.

The stated preference results were used to develop models to estimate the likelihood of shifting departure time when all alternative times are tolled. Time-of-day shift multinomial logit models were estimated for work commute trips, business-related trips and non-work trips. Table 8-3 shows the model estimation results.

Table 8-3: Time-of-Day Shift Models

Trip Segment	Alternative	Variable Coefficients				
		Travel Time (min)	Cost[1]	Time Shift Early	Time Shift Late	Constant
Work Commute	Travel in Peak	-0.0568	-2.2000			
	Travel Earlier			-0.0149		0.2340
	Travel Later				-0.0184	0.3830
Business Travel	Travel in Peak	-0.0481	-0.8320			
	Travel Earlier			-0.0134		0.0179
	Travel Later				-0.0090	0.2420
Non-Work Travel	Travel in Peak	-0.0309	-2.1800			
	Travel Earlier			-0.0083		0.3290
	Travel Later				-0.0077	0.7690

Within the model flow, the time-of-day choice models are applied first, followed by the time-of-day shift models. The former models are intended to predict the general propensity to choose a time period, while the latter predict the specific response given a variable road pricing schedule.

SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

CHAPTER 9 – TRIP ASSIGNMENT

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CHAPTER 9 – TRIP ASSIGNMENT

Introduction

This Chapter describes the various trip assignment methodologies and 2012 validation results. Assignments used in the 2012 model include a static, multiclass user equilibrium highway assignment to the highway network, and a multi-path (Pathfinder) transit assignment to the transit network.

Highway assignment validation is one of the crucial steps in the modeling process. The ability of the model to produce base year volume estimates within acceptable ranges of tolerance compared to actual ground counts is essential to validate the entire travel demand model. The screenline analysis for the 2012 validation year is presented in this Chapter. Also, key to highway assignment validation is the comparison of model estimated VMT to estimates from the Highway Performance Monitoring System. An acceptable tolerance level is mandatory for regional air quality planning and conformity purposes. Specifics regarding the comparative analyses are summarized in this Chapter and assignment statistics for the SCAG region are also presented.

The multi-class highway assignment simultaneously loads the vehicle forecasted by the mode choice model, the internal-external and external-external vehicle trips, and the three classes of heavy duty trucks (light, medium and heavy). The OD trip tables loaded to the highway network include the following vehicle classes:

- Drive Alone
- Shared Ride 2 No HOV
- Shared Ride 3+ No HOV
- Shared Ride 2 HOV
- Shared Ride 3+ HOV
- Light Trucks
- Medium Trucks
- Heavy Trucks

The internal-external and external-external trips are included in the Drive Alone trip tables. The next section briefly describes the methodology used to generate these trips, while the rest of the chapter discuss the highway assignment process, validation results and transit assignment process.

External Trips

External trips (cordon trips) are trips with one or both ends outside the modeling area. External trips for the light-and-medium duty vehicles are estimated independently from heavy-duty vehicles (trucks). The following provides a brief description of the methodology used to estimate light-and-medium duty (auto) vehicle external trips.

Traffic counts were obtained for each cordon location to estimate Year 2012 cordon volumes. Previous cordon survey results were then used to split total external trips into: 1) through trips - External-to-External, and 2) External-to-Internal and Internal-to-External. The resulting through trip table (E-E) and the IE/EI trip table were combined with trip tables from previous steps to form final OD vehicle trip tables for highway assignment.

Highway Assignment Procedures

Highway assignment is the process of loading vehicles onto the appropriate highway facilities to produce traffic volumes, congested speeds, vehicle-miles traveled, and vehicle-hours traveled (VHT) estimates, for each of the five time periods. Link or segment assignments by time period are added to produce average daily traffic volumes (ADT) for the model network. The 2012 model assignments consist of a series of multi-class simultaneous equilibrium assignments for the eight classes of vehicles listed above, and for each of the five time periods. During the assignment process, trucks are converted to passenger-car equivalents for each link based on the percentage of trucks, grade, link length and level of congestion. Transit vehicles are pre-loaded to the highway links.

To achieve travel time convergence between the highway assignment and the demand model, a five loop feedback procedure is used in the 2012 model. The following describes the travel time feedback process:

- **Step 1**: Auto ownership, trip generation, trip distribution and mode choice are run using the speeds coded on the input highway networks. These coded speeds represent observed speeds, where available. The resulting trip tables for each vehicle class and time period are assigned to the highway networks, which yields the first pass loaded volumes and congested speeds.

- **Step 2**: These congested speeds are fed back into the demand model (auto ownership, trip generation, etc.) to produce a second set of congested speeds for the AM peak, PM peak, and midday periods. An averaging process is used to smooth the volume variation between the first and second pass assignments. These averaged speeds are again fed back to the demand model, and the process is repeated three more times for a total of five feedback loops.

- **Step 3**: During the final, 5th loop assignment, all highway assignments are performed: AM peak, midday, PM peak, evening and night time.

The averaging process used to smooth volume variations across feedback loops is the method of successive averages, with a 1/n step, where n is the number of iterations. Convergence for each assignment process (as opposed to model-wide convergence) is achieved when the bi-conjugate user equilibrium assignment achieves a relative gap of 0.001or 200 iterations, whichever occurs first.

Generalized Cost Function

The 2012 model uses a generalized cost function during highway assignment to measure and compare the travel time and cost associated with alternative highway paths. The equation of this cost function is as follows:

$$GenCost = travel\ time + HOT\ penalty + {}^{(auto\ operating\ cost + tolls)}\Big/_{cost\ conversion\ factor}$$

Each of the terms of this equation in turn is calculated as follows:

a. Travel time is computed using volume-delay functions, described in detail in the next section

b. The tolls are a model input, specified by the user as appropriate

c. The high occupancy toll (HOT) lane penalty represents a perceived cost of accessing and exiting the HOT lanes. This penalty applies only when the toll flag identifies a HOT lane. It defaults to a value of 0.5 minutes per mile for drive alone vehicles, as shown in Table 9-1.

d. The auto operating cost measures the contribution of distance to the generalized cost; for 2012 the auto operating cost is 26.78 cents per mile (in constant $2011); its derivation is shown in Appendix B.

e. The cost conversion factor, which may be interpreted as a value of time, varies by vehicle class and time period, as shown in the equation and Table 9-1 below.

$$Cost\ conversion\ factor = Distance\ cost\ conversion\ factor * cost\ multiplier * VOT\ multiplier$$

Table 9-1: Generalized Cost Function Parameters

Vehicle Class	HOT Penalty (min/mile)	Distance Cost Conversion Factor ($/hr)		Time Period	Multiplier		VOT Multiplier				
					Auto Cost	Truck Cost	AM Toll/HOT	Midday Toll/HOT	Peak Toll/HOT	Evening Toll/HOT	Night Toll/HOT
Drive Alone	0	33.9		AM Peak	0.9	1	1.5/2.5	1.25/2	1.5/2.5	1.5/2.5	1/1.5
Shared Ride 2	0	40.5		Midday	0.55	1	1.5/2.5	1.25/2	1.5/2.5	1.5/2.5	1/1.5
Shared Ride 3+	0.2	40.5		PM Peak	0.75	1	1.5/2.5	1.25/2	1.5/2.5	1.5/2.5	1/1.5
Light-Duty Trucks	0	52.4		Evening	0.55	1	1	1	1	1	1
Medium Duty Trucks	0	65.8		Night	0.55	1	1	1	1	1	1
Heavy Duty Trucks	0	70.7					1	1	1	1	1

Volume-Delay Function

The volume delay function (VDF) utilized for the traffic assignment portion of the Regional Model is the Bureau of Public Roads (BPR) function. The volume-delay function is used in assignment to simulate the relationship between traffic volume, congestion delay, and congested speeds. The equation of the function is as follows:

$$t_i \cdot \left[1 + \alpha_i \left(\frac{x_i}{C_i}\right)^{\beta_i}\right]$$

where:

t_i = Free flow travel time on link i

C_i = Capacity of link i

x_i = Flow on link i

α = Constant

β = Constant

If $\frac{x_i}{C_i}$ <= 1 then β is set to the specific value of 5.0. If $\frac{x_i}{C_i}$ > 1, then α and β are set to values that vary by link facility type, posted speed, and area type according to the values in Table 9-2.

Table 9-2: Volume-Delay Function Parameters

Facility Type	Posted Speed	Area Type	Alpha	Beta
Freeways and HOV	All	All	0.60	8.0
Expressways	<=45mph	1-5	0.60	5.0
Expressways	<=45mph	6-7	0.60	6.0
Expressways	>45mph	All	0.60	8.0
All Others	All	1-5	0.60	5.0
All Others	All	6-7	0.60	6.0

Freeway on-ramps (facility types 82 and 84) have a separate volume-delay function. The function is as follows:

$$\frac{L_i}{FFS_i} + \frac{\left[\frac{PLPHx_i}{120} * 5.0 * \left(1 + \frac{x_i}{C_i}\right)^8\right]}{60}$$

where:

L_i	=	Length on link i in miles
FFS_i	=	Free Flow Speed on link i in miles/hour
C_i	=	Capacity of link i
x_i	=	Flow on link i
$PLPHx_i$	=	Per-Lane-Per-Hour Flow on link i

HOV Diversion

A binomial diversion model is applied prior to highway assignment to split carpool trips between vehicles that use the HOV lanes and vehicles that remain on the general purpose flow lanes. The probability of choosing the HOV facility is given by the function below:

$$P(HOV) = \frac{b}{b + e^{at}}$$

Where t represents the travel time savings from using the HOV facility, $t = HOV\ time - GP\ time + access\ penalty$, and a and b are calibrating factors. The HOV access penalty measures the inconvenience of entering and exiting the lanes, given that many of them are buffer or barrier-separated with limited opportunities for access and egress. The access penalty is 5.0 minutes across all time periods. The calibrating factor a determines the steepness of the logistic curve, while b determines the likelihood of using the HOV lanes at zero travel time savings. To encourage carpool trips to stay on the HOV lanes, a factor of 1.1 is used on the mainline travel times. All the parameters of the HOV diversion function can be specified by time period, however, currently the same parameters are used for all time periods.

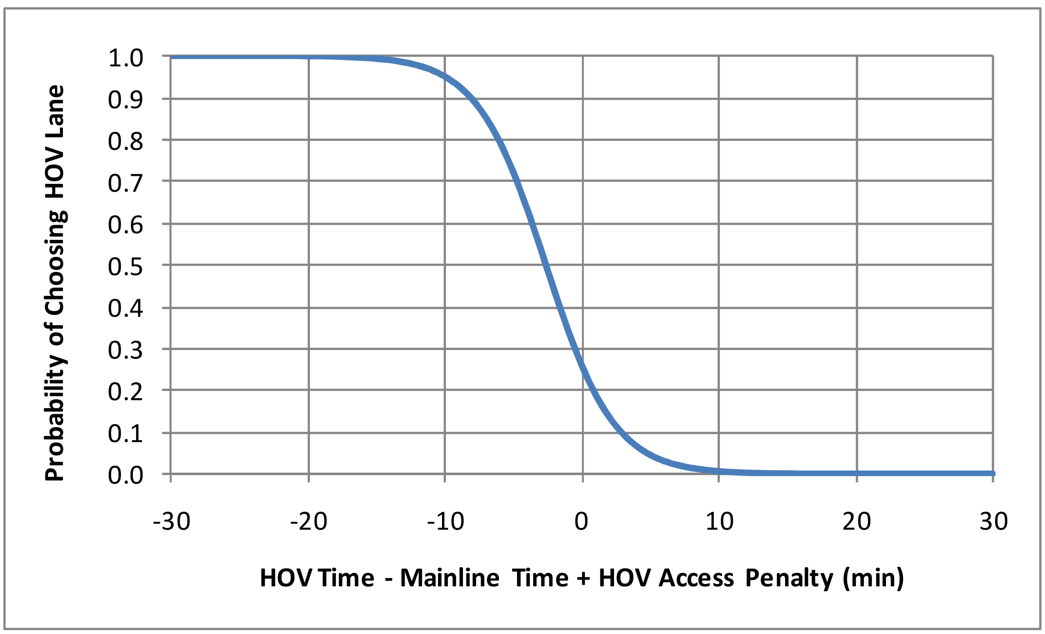


Figure 9-1: HOV Diversion Function

HPMS Factoring

After the entire model has converged, the estimated link volumes are factored prior to performing the emission calculations. Although the model achieves a good match to HPMS estimates without any factoring, as shown in the tables below, HPMS factoring is used to overcome the small remaining discrepancies and ensure consistency among the emission calculations and HPMS. The adjustment factors are calculated by comparing model VMT estimates to HPMS estimates by air basin, county and vehicle type (light vehicles and heavy duty trucks).

Highway Assignment Validation and Summary

This section describes how the 2012 Regional Model's highway trip assignment module has been validated to observed conditions. It includes results for Heavy Duty Truck and mixed-flow components of the trip assignment model. Figures 9-2 and 9-3 provide a visual representation of the SCAG regional screenlines.

Figure 9-2: Screenlines (Regional)

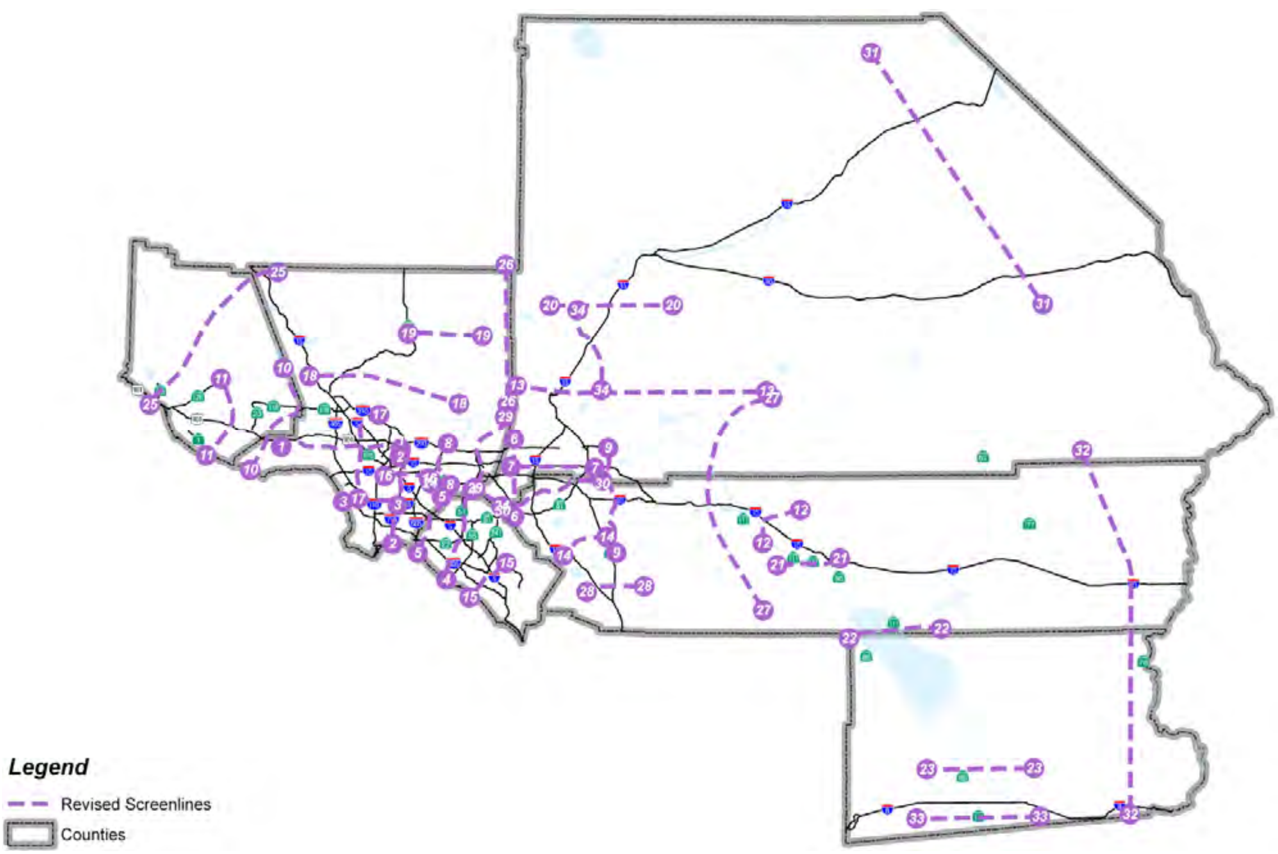
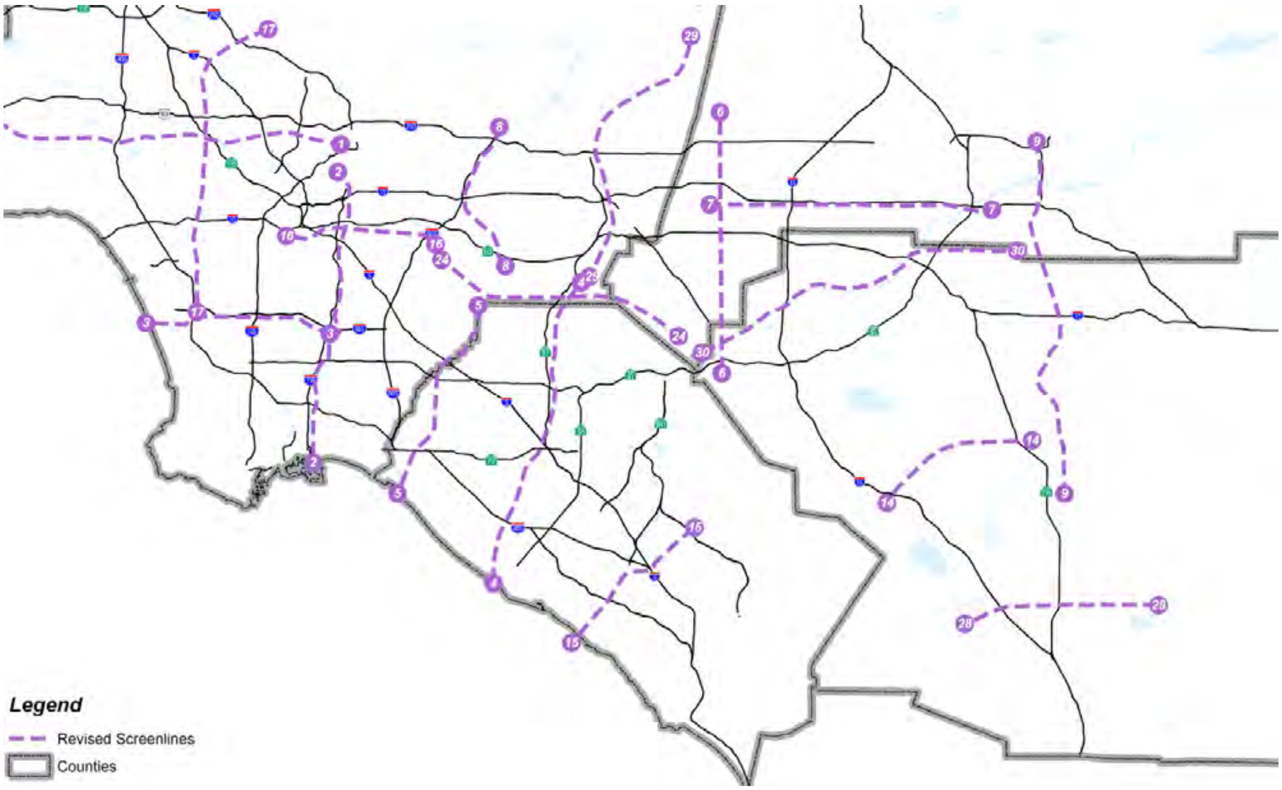


Figure 9-3: Screenlines (Detail)



Validation of the Mixed-Flow Trip Assignment Model

Tables 9-3 through 9-8 present an overview of the highway assignment statistics for each model time period and daily total. After the HPMS volume adjustment, the 2012 model forecasts 417,169,000 VMT on an average weekday in 2012 within the model area for light and medium duty vehicles. In addition, the model forecasts 30,425,000 VMT for heavy-duty vehicles in the expanded model area. The total for all vehicle types combined is 447,594,000 VMT.

A comparison of 2012 model speeds to PeMS speed data is shown in Figures 9-5 to 9-8.

Table 9-3: Year 2012 Loaded Highway Network Summary

From Assignment						
Light and Medium Duty Vehicles	**AM Peak**	**PM Peak**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	32.3	30.3	37.7	42.7	48.6	**35.0**
Vehicle Miles Traveled (,000)	81,299	124,534	135,654	31,118	38,335	**410,940**
Vehicle Hours Traveled (,000)	2,517	4,113	3,596	728	789	**11,743**
Vehicle Hours Delay (,000)	726	1,307	529	50	5	**2,617**
Heavy Duty Vehicles	**AM PEAK**	**PM PEAK**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	40.8	38.8	48.4	55.2	59.2	**47.4**
Vehicle Miles Traveled (,000)	4,392	5,165	11,285	1,903	6,713	**29,457**
Vehicle Hours Traveled (,000)	108	133	233	34	113	**622**
Vehicle Hours Delay (,000)	29	41	37	2	1	**110**
All Vehicles Combined	**AM PEAK**	**PM PEAK**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	32.7	30.5	38.4	43.3	49.9	**35.6**
Vehicle Miles Traveled (,000)	85,691	129,699	146,939	33,020	45,048	**440,397**
Vehicle Hours Traveled (,000)	2,625	4,246	3,830	763	902	**12,365**
Vehicle Hours Delay (,000)	755	1,348	566	52	6	**2,727**
After HPMS Adjustment						
Light and Medium Duty Vehicles	**AM PEAK**	**PM PEAK**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	33.0	31.2	38.3	42.9	48.1	**35.7**
Vehicle Miles Traveled (,000)	82,545	126,466	137,753	31,574	38,831	**417,169**
Vehicle Hours Traveled (,000)	2,498	4,050	3,600	736	808	**11,693**
Vehicle Hours Delay (,000)	665	1,158	452	43	2	**2,321**
Heavy Duty Vehicles	**AM PEAK**	**PM PEAK**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	40.5	38.9	48.6	55.0	58.7	**47.3**
Vehicle Miles Traveled (,000)	4,549	5,343	11,628	1,964	6,941	**30,425**
Vehicle Hours Traveled (,000)	112	137	239	36	118	**643**
Vehicle Hours Delay (,000)	32	43	39	3	3	**120**
All Vehicles Combined	**AM PEAK**	**PM PEAK**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	33.4	31.5	38.9	43.5	49.4	**36.3**
Vehicle Miles Traveled (,000)	87,094	131,809	149,381	33,538	45,772	**447,594**
Vehicle Hours Traveled (,000)	2,611	4,187	3,840	772	926	**12,336**
Vehicle Hours Delay (,000)	697	1,201	491	45	5	**2,440**

Table 9-4: Year 2012 VMT Comparison by County and by Air Basin (in Thousands)

County		VC SCCAB		SCAB		MDAB		SSAB		Total		County Total
		Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck	
Imperial	Model	-	-	-	-	-	-	4,221	520	4,221	520	4,740
	HPMS							4,466	796	4,466	796	5,261
Los Angeles	Model	-	-	202,147	12,847	7,259	348	-	-	209,406	13,195	222,601
	HPMS			204,952	11,581	8,470	605			213,422	12,186	225,608
Orange	Model	-	-	70,106	3,481	-	-	-	-	70,106	3,481	73,587
	HPMS			73,180	3,366					73,180	3,366	76,546
Riverside	Model	-	-	44,995	2,840	1,404	750	9,504	1,248	55,902	4,837	60,740
	HPMS			41,253	3,496	1,495	632	9,636	1,697	52,383	5,824	58,208
San Bernardino	Model	-	-	35,197	2,405	19,159	3,612	-	-	54,355	6,017	60,372
	HPMS			36,584	3,396	18,424	3,909			55,007	7,306	62,313
Ventura	Model	16,949	1,407	-	-	-	-	-	-	16,949	1,407	18,356
	HPMS	18,719	954							18,719	954	19,673
Total	**Model**	**16,949**	**1,407**	**352,444**	**21,573**	**27,822**	**4,710**	**13,725**	**1,767**	**410,940**	**29,457**	**440,397**
	HPMS	**18,719**	**954**	**355,969**	**21,839**	**28,388**	**5,146**	**14,101**	**2,492**	**417,178**	**30,431**	**447,609**
	Ratio	**0.905**	**1.476**	**0.990**	**0.988**	**0.980**	**0.915**	**0.973**	**0.709**	**0.985**	**0.968**	**0.984**

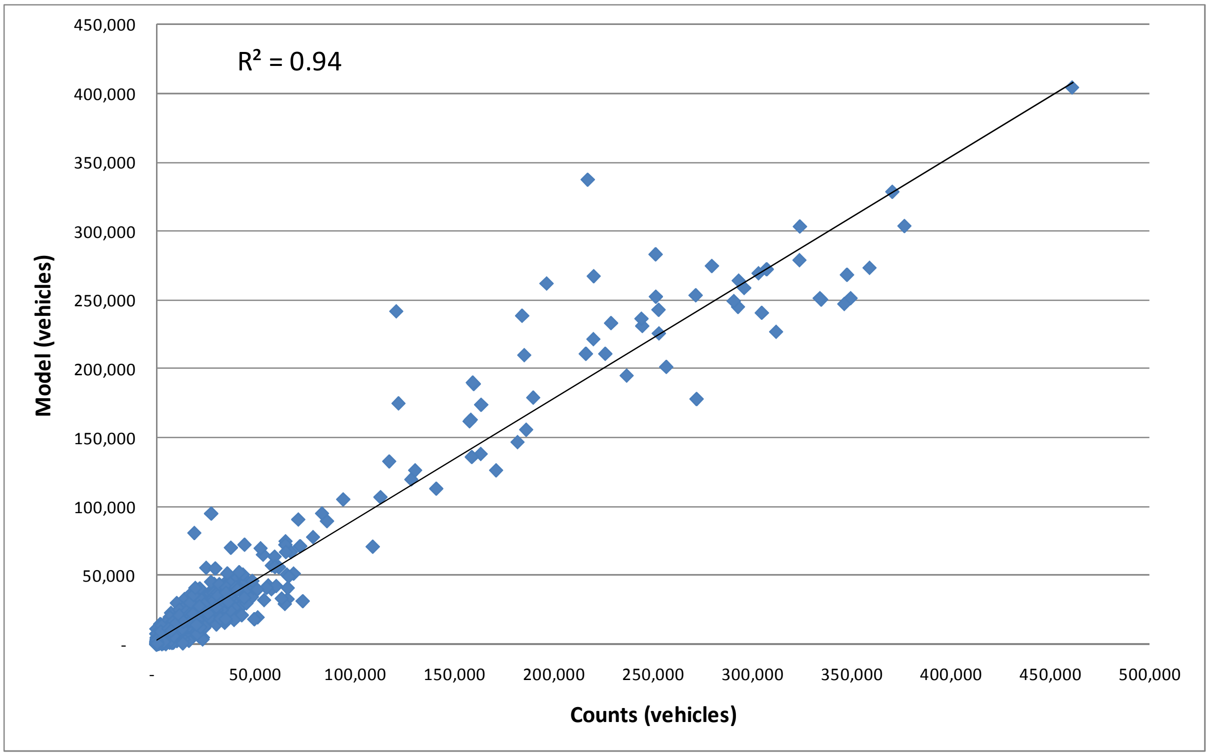


Figure 9-4: Year 2012 Screenline Location Volumes

Table 9-5: Year 2012 Screenline Comparison of Model Weekday ADT and Ground Counts

Screen line	Location	Direction	Obs	Light & Medium Duty Vehicles				Heavy Duty Vehicles				Total		
				Model	Count	Ratio	RMSE	Model	Count	Ratio	RMSE	Model	Count	Ratio
1	Los Angeles	EW	36	1,643,333	1,438,447	1.142	30.868	91,875	65,230	1.408	120.927	**1,738,207**	**1,503,677**	**1.156**
2	Los Angeles	NS	69	2,757,913	2,479,594	1.112	29.400	187,455	174,090	1.077	75.051	**2,954,142**	**2,653,684**	**1.113**
3	Los Angeles	EW	42	1,233,089	1,251,723	0.985	32.720	81,210	80,719	1.006	79.769	**1,318,358**	**1,332,442**	**0.989**
4	Orange	NS	51	1,992,150	1,968,557	1.012	49.033	105,089	117,808	0.892	88.436	**2,100,100**	**2,086,365**	**1.007**
5	Los Angeles/ Orange	NS	31	1,592,584	1,303,352	1.222	36.493	99,192	80,031	1.239	115.247	**1,692,604**	**1,383,383**	**1.224**
6	San Bernardino/ Riverside	NS	48	1,310,620	1,134,768	1.155	41.941	120,293	100,851	1.193	116.516	**1,431,634**	**1,235,619**	**1.159**
7	San Bernardino	EW	28	907,580	859,811	1.056	37.711	48,686	110,899	0.439	91.306	**957,194**	**970,710**	**0.986**
8	Los Angeles	NS	26	1,221,830	1,173,315	1.041	20.077	100,738	88,082	1.144	80.645	**1,324,788**	**1,261,397**	**1.050**
9	San Bernardino/ Riverside	NS	32	497,705	505,972	0.984	33.996	32,337	52,180	0.620	103.841	**530,924**	**558,152**	**0.951**
10	Ventura/ Los Angeles	NS	11	436,046	433,715	1.005	20.553	37,852	27,905	1.356	143.725	**474,044**	**461,620**	**1.027**
11	Ventura	NS	9	267,843	203,148	1.318	37.501	28,295	23,937	1.182	160.184	**296,226**	**227,085**	**1.304**
12	Riverside	NS	8	167,197	169,701	0.985	33.817	20,154	32,627	0.618	45.010	**187,635**	**202,328**	**0.927**
13	San Bernardino	EW	8	190,147	132,663	1.433	62.510	26,186	28,318	0.925	16.848	**216,333**	**160,981**	**1.344**
14	Riverside	EW	10	299,214	246,044	1.216	28.953	21,861	28,782	0.760	53.863	**321,380**	**274,826**	**1.169**
15	Orange	NS	16	664,897	596,392	1.115	53.163	39,654	20,934	1.894	217.601	**704,970**	**617,326**	**1.142**
16	Los Angeles	EW	34	1,442,630	1,191,469	1.211	30.058	107,992	110,648	0.976	41.293	**1,554,546**	**1,302,117**	**1.194**
17	Los Angeles	NS	69	2,454,877	2,245,764	1.093	34.703	125,354	116,299	1.078	91.059	**2,588,035**	**2,362,063**	**1.096**
18	Los Angeles	EW	17	410,115	437,970	0.936	38.533	35,493	38,436	0.923	48.820	**446,216**	**476,406**	**0.937**
19	Los Angeles	EW	28	195,827	215,730	0.908	62.226	8,252	11,614	0.711	111.600	**204,453**	**227,344**	**0.899**
20	San Bernardino	EW	7	80,479	64,055	1.256	39.760	19,588	24,965	0.785	41.800	**100,082**	**89,020**	**1.124**
21	Riverside	EW	12	163,429	156,929	1.041	39.130	17,703	27,049	0.654	51.955	**181,319**	**183,978**	**0.986**
22	Riverside/ Imperial	EW	4	16,916	13,360	1.266	45.265	2,371	4,073	0.582	50.013	**19,288**	**17,433**	**1.106**
23	Imperial	EW	13	43,411	33,207	1.307	92.566	2,653	6,801	0.390	103.634	**46,105**	**40,008**	**1.152**
24	Los Angeles/ San Bernardino	EW	10	534,551	360,431	1.483	63.230	23,481	30,259	0.776	41.390	**558,119**	**390,690**	**1.429**
25	Ventura/ Los Angeles	NS	8	157,646	157,349	1.002	12.767	30,662	27,654	1.109	35.148	**188,418**	**185,003**	**1.018**

26	Los Angeles	NS	5	40,105	21,278	1.885	98.227	4,058	4,084	0.994	57.511	**44,163**	**25,362**	**1.741**
27	San Bernardino/ Riverside	NS	5	124,606	90,138	1.382	46.684	22,269	21,525	1.035	11.436	**146,875**	**111,663**	**1.315**
28	Riverside	EW	12	278,858	258,358	1.079	29.858	17,003	23,527	0.723	48.210	**295,990**	**281,885**	**1.050**
29	Los Angeles	NS	28	988,848	981,540	1.007	35.732	94,223	95,072	0.991	36.743	**1,083,906**	**1,076,612**	**1.007**
30	Riverside	EW	22	890,353	711,855	1.251	39.024	50,349	72,789	0.692	40.300	**941,046**	**784,644**	**1.199**
31	San Bernardino	NS	10	46,886	41,990	1.117	33.146	16,777	15,148	1.108	37.679	**63,664**	**57,138**	**1.114**
32	San Bernardino/ Riverside/ Imperial	NS	6	29,614	29,924	0.990	18.655	16,216	13,252	1.224	40.434	**45,853**	**43,176**	**1.062**
33	Imperial	EW	24	60,348	64,447	0.936	86.136	1,269	6,828	0.186	149.925	**61,672**	**71,275**	**0.865**
34	San Bernardino	NS	7	187,091	169,409	1.104	15.275	20,358	20,776	0.980	67.065	**207,587**	**190,185**	**1.092**
35	Los Angeles	NS	15	259,714	260,876	0.996	27.558	6,786	21,536	0.315	86.592	**267,481**	**282,412**	**0.947**
Total			**761**	**23,588,454**	**21,403,281**	**1.102**	**39.466**	**1,663,73**	**1,724,72**	**0.965**	**86.327**	**25,293,35**	**23,128,00**	**1.094**

Table 9-6: Year 2012 Screenline Comparison of Model Weekday ADT and Ground Counts by Volume Group

	Volume Group By Facility	OBS	Daily Vehicle Volumes				Daily Vehicle Volumes				Daily Vehicle Volumes		
			Light And Medium Duty Vehicles				Heavy-Duty Vehicles				Total		
			Model	Count	Ratio	RMSE	Model	Count	Ratio	RMSE	Model	Count	Ratio
1	0 - 4,999	165	649,131	355,779	1.82	220.94	18,509	35,908	0.52	121.92	669,227	391,687	1.71
2	5,000 - 24,999	347	5,838,727	4,880,627	1.20	58.53	214,858	332,581	0.65	85.30	6,074,760	5,213,208	1.17
3	25,000 - 49,999	126	4,408,278	4,005,656	1.10	37.07	232,551	339,376	0.69	58.47	4,656,540	4,345,032	1.07
4	50,000 - 99,999	68	5,471,221	5,326,238	1.03	19.81	544,995	531,663	1.03	48.18	6,017,848	5,857,901	1.03
5	100,000 - 199,999	54	7,031,635	6,654,035	1.06	19.93	636,192	478,906	1.33	55.01	7,668,887	7,132,941	1.08
6	200,000 or More	1	189,463	180,946	1.05	4.71	16,632	6,294	2.64	164.25	206,094	187,240	1.10
Total		**761**	**23,588,454**	**21,403,281**	**1.10**	**39.47**	**1,663,737**	**1,724,728**	**0.96**	**86.33**	**25,293,356**	**23,128,009**	**1.09**

Notes: RMSE - root mean square error, OBS - number of observed roadway facilities in the group.

Table 9-7: Year 2012 Screenline Comparison of Model Weekday ADT and Ground Counts by Facility Type

	Area Type	OBS	Light And Medium Duty Vehicles				Heavy-Duty Vehicles				Total		
			Model	Count	Ratio	RMSE	Model	Count	Ratio	RMSE	Model	Count	Ratio
10	Freeway	154	13,262,810	12,639,864	1.05	21.54	1,372,178	1,139,928	1.20	50.99	14,636,800	13,779,792	1.06
20	HOV	59	784,232	787,718	1.00	46.85	0	0	0.00	0.00	785,594	787,718	1.00
30	Expressway/Parkway	14	216,746	197,889	1.10	37.70	14,222	21,182	0.67	42.49	231,044	219,071	1.05
40	Principal Arterial	195	5,839,590	4,847,640	1.20	49.87	183,258	367,387	0.50	91.81	6,047,111	5,215,027	1.16
50	Minor Arterial	204	2,935,438	2,454,815	1.20	59.74	81,591	159,798	0.51	95.42	3,029,349	2,614,613	1.16
60	Major Collector	114	530,181	454,804	1.17	114.46	12,002	34,981	0.34	122.70	542,988	489,785	1.11
70	Minor Collector	21	19,456	20,551	0.95	146.88	487	1,452	0.34	142.03	20,470	22,003	0.93
Total		**761**	**23,588,454**	**21,403,281**	**1.10**	**39.47**	**1,663,737**	**1,724,728**	**0.96**	**86.33**	**25,293,356**	**23,128,009**	**1.09**

Notes: RMSE - root mean square error, OBS - number of observed roadway facilities in the group.

Table 9-8: Year 2012 Screenline Comparison of Model Weekday ADT and Ground Counts by Area Type

	Area Type	OBS	Light And Medium Duty Vehicles				Heavy-Duty Vehicles				TOTAL		
			Model	Count	Ratio	RMSE	Model	Count	Ratio	RMSE	Model	Count	Ratio
1	Core	-	-	-	-	-	-	-	-	-	-	-	-
2	Central Business District	5	140,412	101,786	1.38	62.96	3,589	3,630	0.99	30.85	144,529	105,416	1.37
3	Urban Business District	132	5,275,194	4,988,142	1.06	35.40	355,223	344,644	1.03	102.61	5,643,847	5,332,786	1.06
4	Urban	263	9,132,038	8,386,906	1.09	36.76	606,964	594,608	1.02	65.47	9,758,857	8,981,514	1.09
5	Suburban	227	7,123,999	6,353,633	1.12	37.84	447,082	515,996	0.87	97.45	7,577,711	6,869,629	1.10
6	Rural	119	1,646,327	1,393,316	1.18	60.60	222,643	234,572	0.95	76.44	1,869,691	1,627,888	1.15
7	Mountain	15	270,485	179,498	1.51	89.17	28,237	31,278	0.90	27.89	298,721	210,776	1.42
Total		**761**	**23,588,454**	**21,403,281**	**1.10**	**39.47**	**1,663,737**	**1,724,728**	**0.96**	**86.33**	**25,293,356**	**23,128,009**	**1.09**

Notes: RMSE - root mean square error, OBS - number of observed roadway facilities in the group.

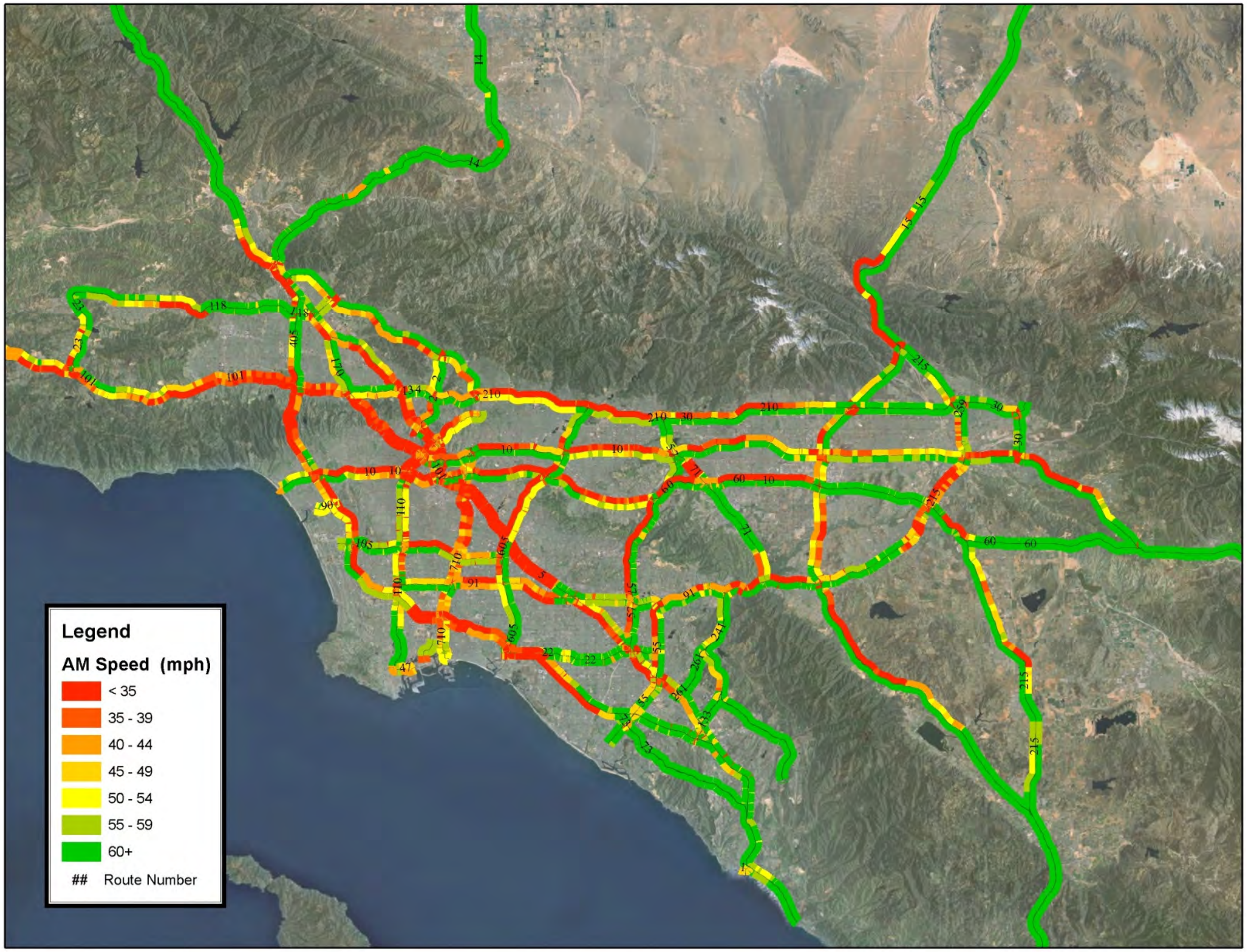


Figure 9-5: Year 2012 Model Estimated AM Peak Period Speeds

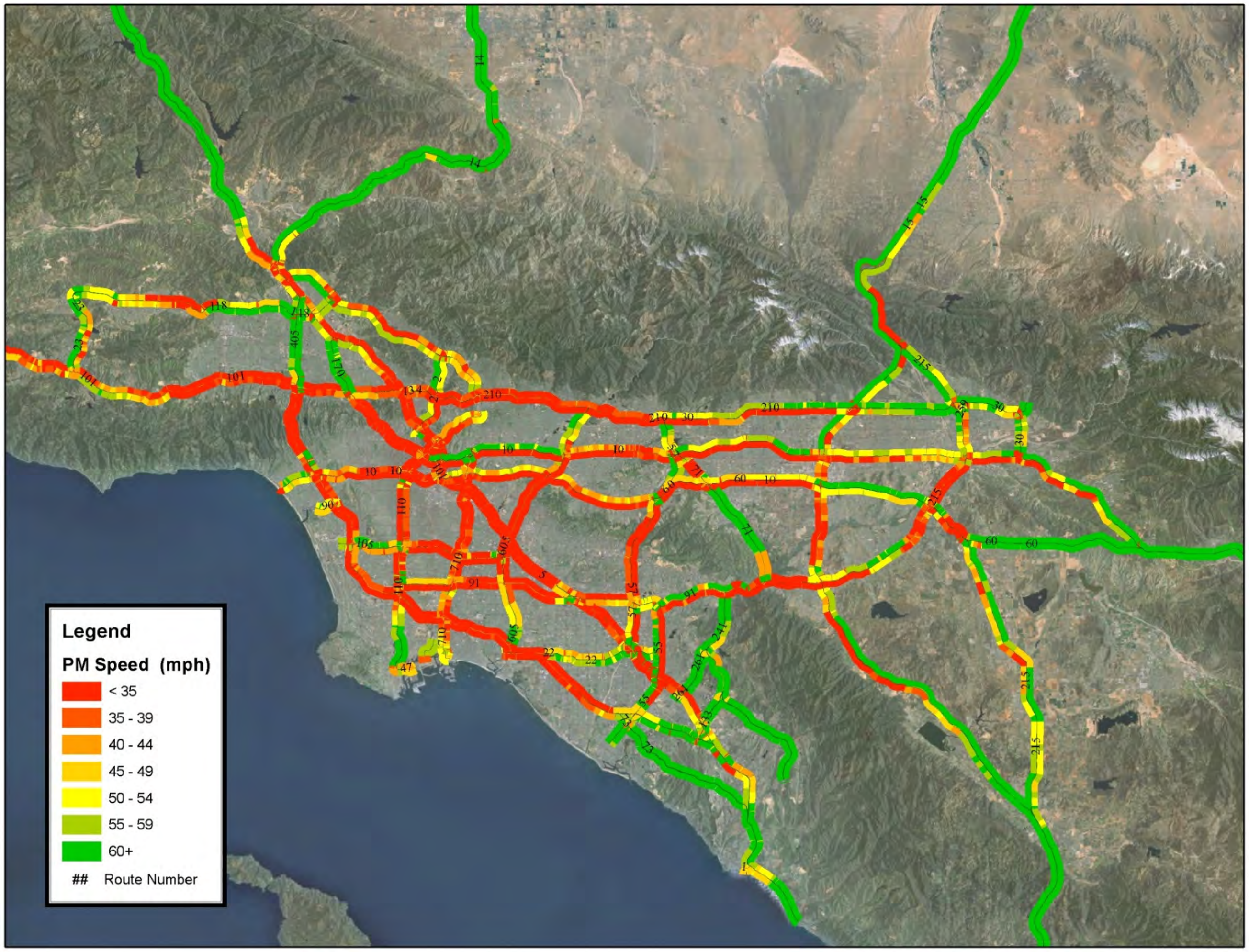


Figure 9-6: Year 2012 Model Estimated PM Peak Speeds

Figure 9-7: PeMS AM Peak Speeds

Figure 9-8: PeMS PM Peak Speeds

Transit Assignment Procedures

Transit assignment is the process of loading the transit trips onto the appropriate routes, to produce boardings on each route, by station, etc. Transit trips are assigned in production-attraction format, and for two time periods, peak and off-peak.

Transit trips estimated by the model choice model on the final feedback loop are aggregated across trip purposes to create linked transit trips for each primary line-haul mode, resulting in two transit trip tables: peak and off-peak linked trips. For drive access trips, only the portion from the park-n-ride location to the final attraction zone is included in the transit trip table. The rail trips are assigned in a manner consistent with the station choice estimates generated by the mode choice models. These trips are split into three parts:

- Production zone to boarding station (bus access trips only)
- Boarding station to alighting station (all trips)
- Alighting station to attraction zone (all trips)

The production zone to boarding station leg of walk access and drive access rail trips is not assigned to the transit network because it does not comprise any bus loadings.

The resulting peak and off-peak loaded transit network files are aggregated to create total daily loaded trips.

Transit Assignment Validation and Summary

The 2012 transit assignment loaded 2,612,100 unlinked passenger trips (boardings) on the transit network. Table 9-9 compares the model estimated daily transit boardings for the four predominant transit modes, to actual transit boarding statistics for 2012.

Table 9-9: Year 2012 Daily Transit Boardings - Model vs. Actual Counts

Transit Mode	Model Estimated Boardings	Actual Boardings	Ratio
Commuter Rail	46,914	44,472	**1.05**
Urban Rail	376,751	356,648	**1.06**
MTA Bus *	1,241,494	1,190,314	**1.04**
Other Transit **	946,598	763,648	**1.24**
Total Boarding	**2,611,757**	**2,355,082**	**1.11**

** MTA Bus: Local bus, Rapid bus, Express bus operated by LACMTA*
*** Other Transit: Local bus, Rapid bus, Express bus operated by other transit carriers in SCAG region*

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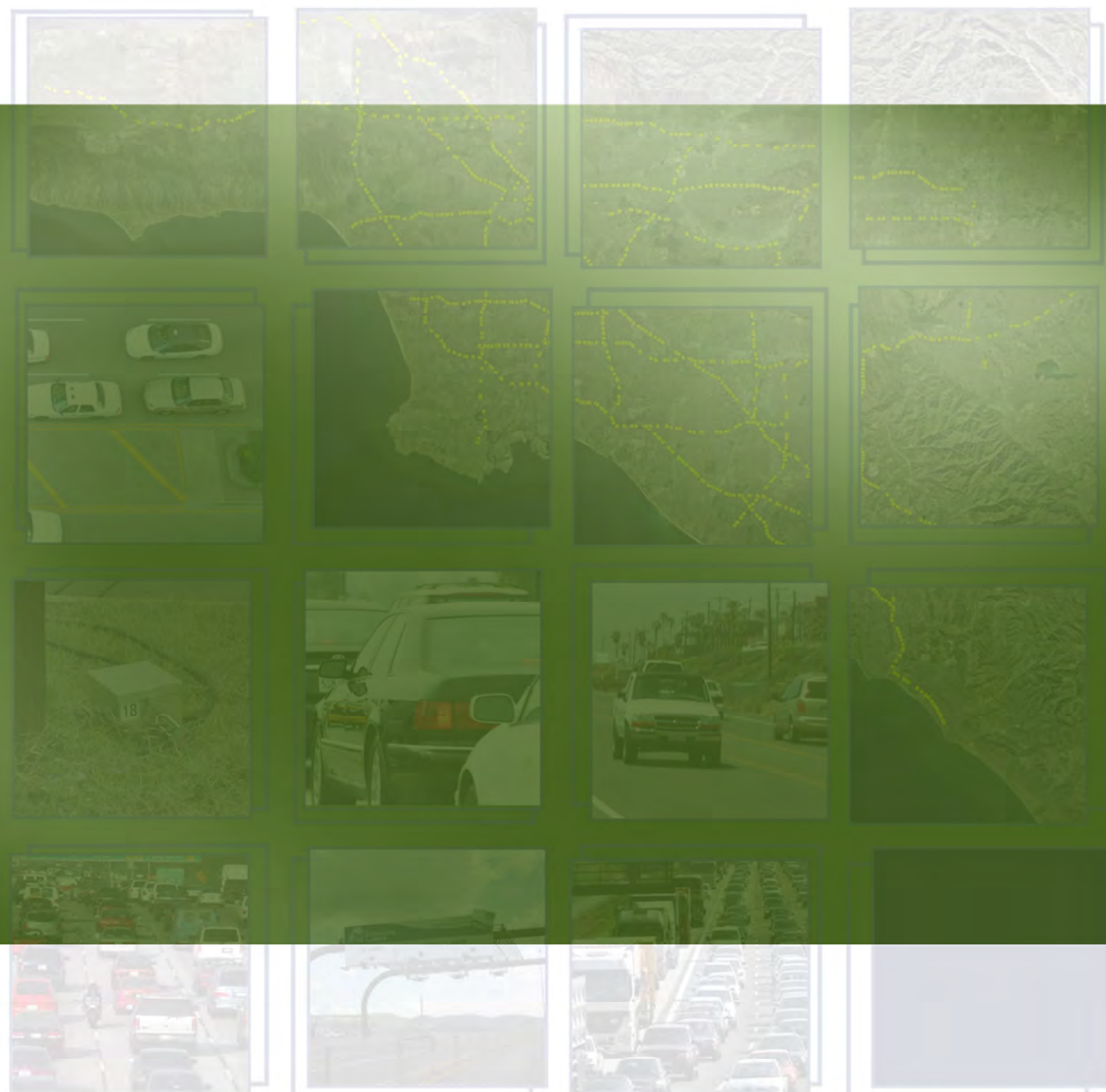
Appendix A: Highway Network Coding Conventions



Appendix A: Highway Network Coding Conventions

Facility Type

1 – Freeways

10 – Freeway

2 – HOV

20 – HOV 2
21 – HOV 3+
22 – HOV – HOV Connector

3 - Expressway/Parkway

30 – Undivided
31 – Divided, Interrupted
32 – Divided, Uninterrupted

4 - Principal Arterial

40 – Undivided
41 – Divided
42 – Continuous Left Turn

5 - Minor Arterial

50 – Undivided
51 – Divided
52 – Continuous Left Turn

6 – Major Collector

60 – Undivided
61 – Divided
62 – Continuous Left Turn

7 - Minor Collector

70 – Undivided
71 – Divided
72 – Continuous Left Turn
73 – Posted Speed 25
74 – Posted Speed 15

8 – Ramps

80 – Freeway to Freeway Connector
81 – Freeway to arterial
82 – Arterial to freeway
83 – Ramp Distributor
84 – Ramp from Arterial to HOV
85 – Ramp from HOV to Arterial
86 – Collector distributor
87 – Shared HOV Ramps to MF
89 – Truck only

9 – Trucks

90 – Truck only

100 – Centroid Connector - Tier 1

200 – Centroid Connector - Tier 2

Flag Fields

Main Lane – Through Freeway Lanes
Aux_Lane – Auxiliary Lane of Capacity Significance
Accel_Decel Lane - Other Freeway Lane

Truck Climbing Lanes Flag

0 – None
1 – 1 Truck Climbing Lane
2 – 2 Truck Climbing Lane
3 – 3 + Truck Climbing Lane

Toll Flag

11 – Toll road with fixed tolls
12 – Toll road with per-mile tolls
21 – Express/HOT lane with fixed tolls
22 – Express/HOT lane with per-mile tolls

Signals Flag

0 – None
1 – Signal and progression optimized streets
2 – Divided and signal optimized
3 – Continuous left-turn Lanes

HOV Operation Flag

0 – Standard HOV
1 – HOV AM Peak Only
2 – HOV PM Peak Only
3 – HOV AM & PM Peak Only

Truck Prohibition Flag

0 - Truck Not Prohibited
1 - Trucks Prohibited

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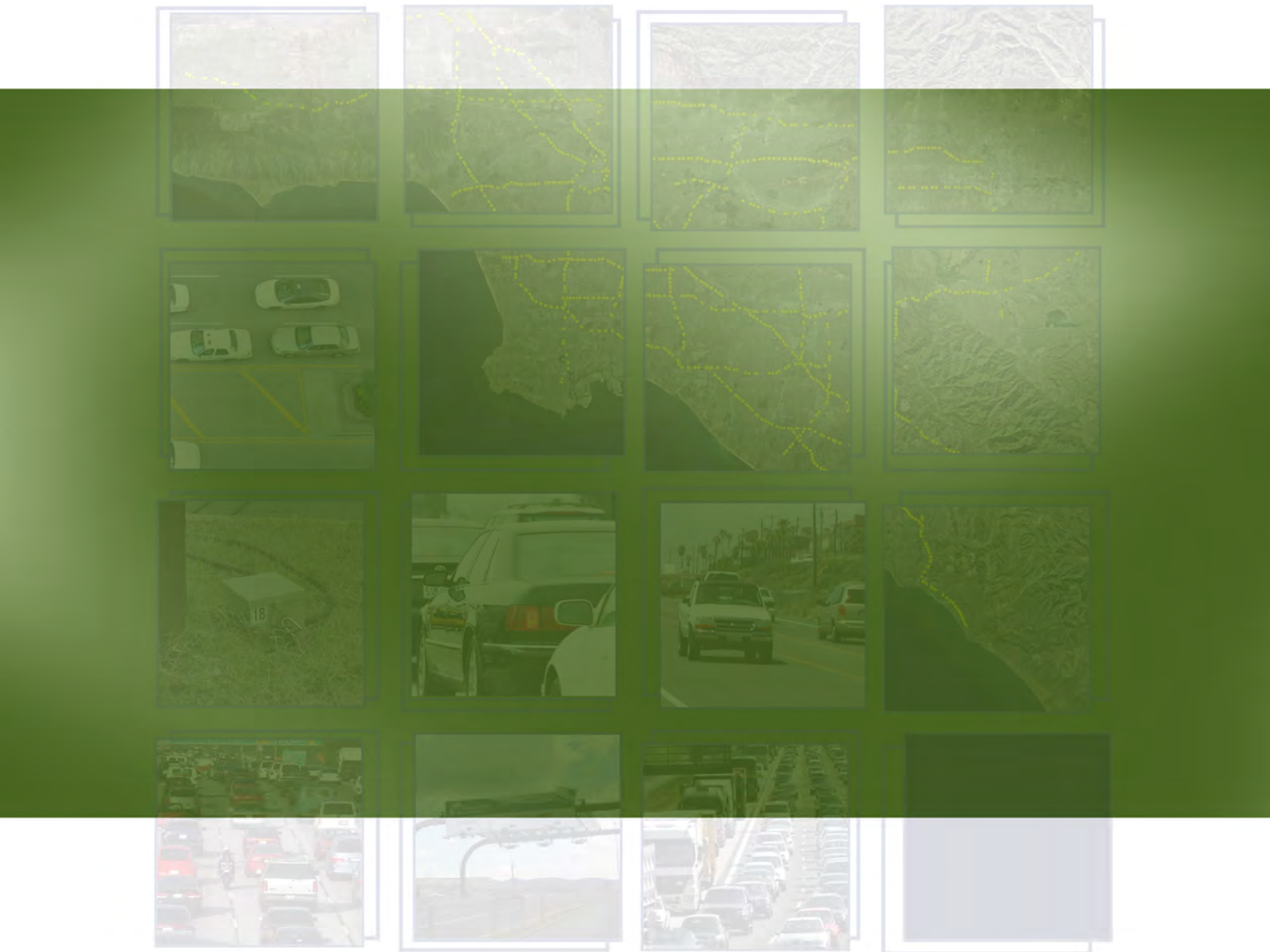
Appendix B: Auto Operating Costs



APPENDIX B: AUTO OPERATING COSTS

Auto operating cost (in cents/mile) is a key parameter in the calculation of the marginal utility cost functions used in mode choice. In the current mode split model, auto operating cost is defined as an out-of-pocket expense consisting of fuel (primarily gasoline) cost and "other" costs. Other costs include repairs, maintenance, tires, and accessories.

The table below summarizes the Year 2012 auto operation cost calculation and gives the values of the intermediate parameters. The calculation of the fuel cost per mile requires the composite fuel economy for the fleet and an average motor fuel price. Historical U.S. fuel efficiency data from 1980 to 2012 collected and compiled by the U.S. DOT National Highway Safety Administration was used by SCAG staff to calculate the average miles per gallon. The average price of a gallon of motor vehicle fuel was calculated as the sum of the prices of each grade sold, weighted by its fractional share of the market. The average fuel cost, including all taxes, for 2011 was 408.2 cents per gallon, which equates to 400.06cents per gallon in 2011 constant dollars. Thus the fuel costs for 2012 in terms of cents/mile can be derived from dividing fuel costs (400.06 cents/gallon) by average fuel efficiency (19.70 miles/gallon). As a result, the 20.31cents-per-mile fuel costs (in 2011 cents) was estimated and used for the 2012 model validation.

AUTO OPERATING COST CALCULATION

Description	Value	Based on
2012 On-road miles/gallon	19.70	MPG for SCAG Region (SCAG Model)
Avg. Year 2012 cents/gallon	408.20	Price & volume sold by fuel grade
Converted to 2011 cents*/gallon	400.06	
Fuel Cost (2011nts/mile)	20.31	Gallon/mile * cents/gallon
Other Costs (2011cents/mile)	6.47	Repairs, maint., tires, accessories
Total Cost/Mile (2011cents)	26.78	
Total Cost/Mile (2011 cents)	**26.78**	

Note: * CPI to 2011 = 1.02035

The Year 2012 Model Validation uses the value of 6.47 cents per mile (in 2011 dollars) for "other costs" as calculated by SCAG's Economic Analysis/Forecasting Section using data compiled by the General Services Administration and the National/Southern California AAA. Adding 6.47 cents per mile for "other" costs to the fuel costs per mile (20.31 cents/mile), yields a total auto operating cost of 26.78 cents per mile for 2012 in 2011 dollars.

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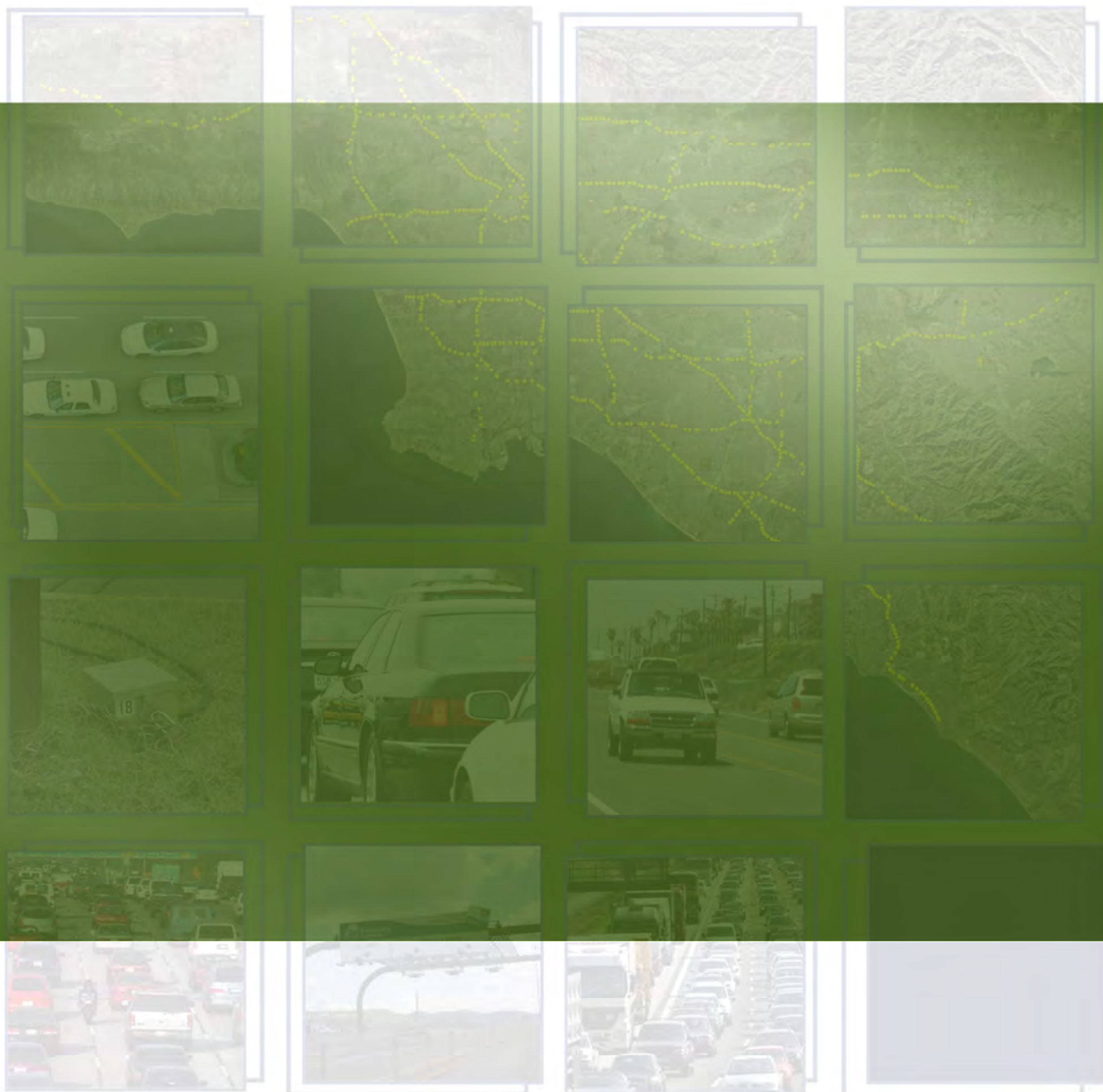
Appendix C: SCAG Model Peer Review #4



APPENDIX C: SCAG MODEL PEER REVIEW #4

Background

The primary objective of the Peer Review Panel was to review SCAG's model development program, validation tests and results, expert panel discussions, and overall model enhancement effort for validity with regard to state of the practice so that the Model can be applied with sufficient reliability in the RTP, FTIP, and AQMP planning processes. The Panel was also asked to provide recommendations for future short-term and long-term model enhancements. Their major conclusions and recommendations are described in this Appendix.

SCAG's 2008 Regional Travel Model Peer Review Panel was comprised of nationally-recognized experts in the fields of travel demand modeling and data collection and analysis. The panel members are listed below:

Peer Review Panel Members

Name	Organization
Guy Rousseau (Chair)	Atlanta Regional Commission
Chaushie Chu, Ph.D.	Los Angeles County Metropolitan Transportation Authority (Metro)
Chris Forinash	Environmental Protection Agency (EPA)
David Levinson, Ph.D.	University of Minnesota
David Ory, Ph.D.	Metropolitan Transportation Commission (MTC)
Eric Pihl	Federal Highway Administration (FHWA)
Kara M. Kockelman, P.E., Ph.D.	University of Texas, Austin; Expert Panel – Congestion Pricing
Ken Cervenka	Federal Transit Administration (FTA)
Mark Bradley	Mark Bradley Research and Consulting

Recommendations and Findings

Overall Findings of the Peer Review Panel

The current SCAG travel demand model is an advanced 4-step model that meets and in many cases exceeds the state of the practice – with the exception of the lack of zero-vehicle ownership sensitivity in the destination and mode choice models. With this one change properly addressed, the model is suitable for use in preparing 2016 RTP, conformity analysis, and SCS.

Model Strengths

The Panel feels that the level of effort for the SCAG model is impressive and ambitious. SCAG should continue to manage and coordinate the overall model enhancement program and individual consultant work efforts. The Panel encourages SCAG to continue to explore and implement as practical activity-based modeling and land use forecasting models.

There are a number of new features in the model that in all cases meet and in many instances are an improvement over the typical state of the practice, including:

- the multi-level geographic zone structure, particularly the "Tier 2" zone system with over 11,000 zones,
- a truck model that includes all classes of commercial vehicles, as well as a special generator model for the Ports of L.A and Long Beach (San Pedro Bay ports),
- grade-based PCE adjustments for heavy-duty trucks,
- the modeling of secondary truck trips associated with transload facilities,
- an auto ownership model that includes a number of different land use and accessibility variables,
- origin zone income model,
- the use of destination choice models with logsums from mode choice, instead of gravity models,
- the use of a time-of-day choice model, instead of fixed factors,
- the congestion pricing model's ability to analyze user benefits with regard to delay and mobility performance perspectives,
- the use of a nested mode choice model with a large number of competing modes, and
  the use of advanced models for congestion pricing.

Recommendations for Model Validation and 2012 RTP Process(Short-Term)

The major conclusions and recommendations of the Peer Review Panel for short-term consideration by SCAG are listed in this section. The recommendations described herein are intended for short-term implementation in the model prior to using the model for developing the 2012 RTP. In some cases, the recommendations do not require additional efforts on the part of the model development team.

- **Auto Ownership Sensitivity** – The Peer Review Panel suggests adding auto ownership sensitivity in the destination choice and mode choice models. Along with travel time and cost, auto availability is one of the most significant explanatory variables. For example, there may be zero-car households in higher income categories that are not captured by household income groups. Furthermore, there are single people and couples in high accessibility areas that choose to own less than one vehicle per driver. The California Transportation Commission's 2010 RTP Guidelines specifically mention auto availability per household as an important quantifiable variable for describing travel behavior. This could potentially be a significant issue in forecast years; and there may be significant cultural/immigrant differences that should be considered. In updating the model, the calibrated constant for zero-car household transit riders should be closely reviewed.

  Note: The 2001 onboard transit survey data does not include auto ownership information. The upcoming 2011 onboard survey being conducted by Metro will include this information.

  - *Response / Follow-Up – SCAG retained a consultant to address the Peer Review Panel's recommendation regarding auto ownership sensitivity. The final 2012 RTP Model is now stratified by car sufficiency and household income through the entire set of core demand models.*

- **Sensitivity Testing** – The Panel suggests doing sensitivity testing on a single-county version of the model, or something similar, since model run times limit opportunities for extensive testing. The sensitivities to longer travel by medium and high density areas should be reviewed.

  - *Response / Follow-Up – Model sensitivity tests were performed as part of the validation process. The Model displayed reasonable responses to changes made to the following variables:*
    1. *Fuel Pricing*
    2. *Auto Operating Costs*
    3. *Transit Capacity – Bus Frequency*
    4. *Transit Capacity – Rail Frequency*
    5. *Transit Capacity (bus, rail, BRT, etc. combined)*
    6. *Telecommute*
    7. *Freeway Capacity*
    8. *Income Distribution*

- **Traffic Count Averaging** – SCAG might consider averaging traffic counts over 3 or so years instead of using single year counts.

  - *Response / Follow-Up - The traffic counts on screenlines were closely reviewed against historical and current data on the specific link or adjoining links. This was done in an attempt to verify the quality of each screenline traffic count as well as to replicate 2008 conditions as closely as possible. If the desire is to replicate conditions before 2008 (i.e., before the economic* *downturn), this could be accomplished with geo-spatial (e.g., district, county, etc.) adjustment factors.*

- **Heavy-Duty Truck Model Validation** – The Panel suggests comparing model results and observed data grouped by percent of trucks on roadway links to look at the model results in a different way.
  - *Response / Follow-Up - The Traffic Assignment Chapter provides tables showing heavy-duty trucks grouped and summarized by several different criteria.*

- **Validation of Speeds/Travel Times** - SCAG should try to match observed travel times (speeds) on links as part of validation.
  - *Response / Follow-Up - SCAG agrees with this comment and will attempt to implement this in future model validations. SCAG is currently investigating technology based methods for building an accurate region-wide speed database for this purpose.*

- **Reporting** - Add basic demographic profiles including maps of the SCAG region to the Validation Report.
  - *Response / Follow-Up – Maps displaying the geographic distribution of the basic demographic variables are included in this Report.*

Recommendations for Model Enhancement Program (Long-Term)

The major conclusions and recommendations of the Peer Review Panel for longer-term consideration by the SCAG and consultant modeling team are listed in this section. The recommendations described herein are intended for exploration or implementation in the model after the 2008 model validation is final. These longer-term recommendations would be anticipated prior to using the model for developing the 2016 RTP. In some cases, the recommendations do not require additional efforts on the part of the model development team.

- Model Inputs and Assumptions
    - Consider the use of actual speeds as free-flow speeds in the model rather than artificially capping them at the speed limit.
    - Review the potential for better enforcement of speeds through technology in the future and how this may impact assumptions in the model. Or, consider using the model to test the impacts of policy scenarios such as more comprehensive speed enforcement.
    - Incorporate the most recent Census data (e.g., SF-1) into the model assumptions, recognizing that it will not be available for the 2012 RTP analysis.
    - SCAG may wish to explore the use of the US Census LEHD (Longitudinal Employer - Household Dynamics) data for validation. There are some concerns that the LEHD data does not contain realistic home to work data.

      Note #1: Longitudinal Employer-Household Dynamics (LEHD) is an innovative program within the U.S. Census Bureau. Modern statistical and computing techniques are used to combine federal and state administrative data on employers and employees with core Census Bureau censuses and surveys while protecting the confidentiality of people and firms that provide the data (Source: US Census LEHD website).

      Note #2: The Atlanta Regional Commission has worked with LEHD data and is available for consultation.
    - Area types and densities may not be the best variables for determining roadway attributes (e.g., capacities, speeds, etc.). SCAG may wish to explore the use of roadway widths and intersections per mile surrogate variables to augment this approach.
    - The model should include attributes that allow for the specific quantification of benefits from ramp metering.
    - Toll-choice models in both mode choice and assignment may increase model run times unnecessarily. SCAG may wish to consider turning off one of these processes to reduce run times.

- Trip-Based Model Enhancements

    - Consider reversing the order of destination / mode choice nesting when the 2011 onboard transit survey data is available so that the mode choice logsum coefficient in the destination / mode choice model does not need to be constrained, or allow the inclusive value coefficient to be the estimated value even if it is greater than 1 (one).

    - Conduct rigorous performance checks of model results once the 2011 onboard transit survey data is available. These may include trip-based and activity-based district-to-district transit rider flows by mode, market segment, and mode of access, etc.

    - Run the model with observed travel times and review results.

    - The SCAG model uses a 5-option multi-nomial logit choice model used for auto ownership. Some have argued that this is an ordered choice. SCAG may wish to explore the use of negative binomial or ordered probit models for auto ownership.

    - The workplace allocation component of the destination choice model has room for improvement according to some panel members based on calibration/validation results. SCAG should review its methodology and ensure that the upcoming activity-based modeling will address these issues.

    - Consider the use of stochastic user equilibrium in traffic assignment to reduce the effects of all travelers taking the shortest path. This may however increase model run times.

    - The SCAG model currently runs the time-of-day choice model runs after mode choice. Some panel members suggested that SCAG consider reviewing the processing order.

    - SCAG should consider improving the integration between the time-of-day model and the congestion pricing model components.

- Model Integration and Software Implementation

    - SCAG should invest in the appropriate computer technology (e.g., servers with sufficient storage and processing power and/or multiple computers to run separate model components) to meet the demands of their ambitious modeling needs in the future.

    - Identify which modeling steps are scalable and where additional computers could reduce model run times through parallel processing.

- Congestion Pricing

    - Stated Preference survey results should be studied and validated to the extent possible before using them in the model for future applications such as the 2016 RTP.

    - The trip suppression model component appears ad hoc and should be better integrated with the model.

- Societal equity is often a political concern for any type of road pricing. A process (similar to the FTA SUMMIT program) to identify benefits/dis-benefits for users as well as non-users resultant from road pricing alternatives would be a helpful tool to address the equity concerns that may be raised by elected officials and interest groups.

- Heavy-Duty Truck Model
  - Review the assumption that the trucks per employee stay constant over time. Possibly use historical trends and commodity flow information to augment this part of the truck forecast assumptions.
  - Review and possibly update the assumptions for forecasting transload facilities.
  - Compare model results using the grade-adjusted PCE factors against model results without the PCE adjustment.

- Activity-Based Modeling
  - Model results should be compared at the 2035 future scenario level and fully understood before using ABM for the 2016 RTP.
  - SCAG should investigate how well the ABM results are matching journey to work data.
  - Next steps in developing the ABM modeling should be considered in the context of the weaknesses of the trip based model. For example, the workplace location choice, mode/destination choice order, capacity representation, etc. should be revisited.
  - The Activity Based Model should be used where possible to conduct sensitivity tests to the SB 375 / SCS policies that aren't well-represented in the trip-based model.

- Land Use Forecasting
  - Consider utilizing the PECAS / Land Use model to inform the heavy duty truck model. It is well-suited for this task.

ACRONYMS

Acronym	Definition
ABM	Activity-Based Modeling
ACS	American Community Survey
ADT	Average Daily Traffic
AOC	Auto Operating Cost
AQMP	Air Quality Management Plan
ARB	California's Air Resources Board
ASC	Alternative-Specific Constants
AT	Area Type
BPR	Bureau of Public Roads
BRT	Bus Rapid Transit
CBD	Central Business District
CEMDAP	Comprehensive Econometric Micro-simulator of Daily Activity-travel Patterns
CIP	Capital Improvement Program
CMAQ	Congestion Mitigation and Air Quality Improvement Program
CMP	Congestion Management Program
CPI	Consumer Price Index
CTPP	Census Transportation Planning Package
DOF	California Department of Finance
DOT	Department of Transportation
EDD	California Employment Development Department
EE	External-External
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FIRES	Finance/Insurance/Real Estate/Services
FT	Facility Type
FTA	Federal Transit Administration

Acronym	Definition
FTIP	Federal Transportation Improvement Program
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HBCU	Home-Based College and University
HBNW	Home-Based Non-Work
HBO	Home-Based Other Trips
HBSC	Home-Based School
HBSH	Home-Based Shopping Trips
HBSP	Home-Based Serving-Passenger
HBSR	Home-Based Social-Recreational Trips
HBW	Home-Based Work
HBWD	Home-Based Work Direct
HBWS	Home-Based Work Strategic Trips
HCM	Highway Capacity Manual
HDT	Heavy Duty Truck
HH	Household
HHDT	Heavy-Heavy Duty Trucks
HIS	Household Interview Survey
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HPMS	Highway Performance Monitoring System
ICTC	Imperial County Transportation Commission
HU	Housing Unit
IE/EI	Internal-External and External-Internal
IMX	Intermodal
ITMS	Intermodal Transportation Management System

Acronym	Definition
IVT	In-Vehicle Time
KNR	Kiss-and-Ride
KSF	Thousand Square Feet
LACMTA	Los Angeles County Metropolitan Transportation Authority
LADOT	Los Angeles Department of Transportation
LHDT	Light-Heavy Duty Trucks
LOS	Levels of Service
LS	Logsum
LTL	Less-Than-Truckload
LU	Land Use
MDAB	Mojave Desert Air Basin
MHDT	Medium-Heavy Duty Trucks
MPO	Metropolitan Planning Organization
MPU	Minimum Planning Unit
MTC	Metropolitan Transportation Commission
NAICS	North American Industrial Classification Standard
NHB	Non-Home Based
NHTS	National Household Travel Survey
NRE	Non-Retail Employment
NTD	National Transit Database
OBO	Other-Based Other Trips
OCTA	Orange County Transportation Authority
OD	Origin-Destination
PA	Production-Attraction
PCEs	Passenger Car Equivalents
PCPLPH	Passenger Car Per Lane Per Hour
PeMS	Performance Measurement System
PNR	Park-and-Ride

Acronym	Definition
PS	Posted Speed
PUMS	Public Use Microsample
QA/QC	Quality Assurance/Quality Control
RCTC	Riverside County Transportation Commission
RE	Retail Employment
RMSE	Root Mean Squared Error
RSA	Regional Statistical Area
RSE	Retail/Service Employment
RTP	Regional Transportation Plan
SACOG	Sacramento Area Council of Governments
SANBAG	San Bernardino Association of Governments
SASVAM	Small Area Secondary Variables Allocation Model
SB 375	California's Senate Bill 375
SCAB	South Coast Air Basin
SCAG	Southern California Association of Governments
SCCAB	South Central Coast Air Basin
SCS	Sustainable Communities Strategy
SMT	Subregional Modeling Tool
SP	Stated Preference
SSAB	Salton Sea Air Basin
SSCAB	South Central Coast Air Basin
STCC	Standard Transportation Commodity Classification
TAZ	Transportation Analysis Zone
TCA	Transportation Corridor Agency
TDM	Transportation Demand Management
TIGER	Topographically Integrated Geographic Encoding and Referencing
TL	Truckload
TOD	Time-of-Day

Acronym	Definition
TRB	Transportation Research Board
TSM	Transportation System Management
VCTC	Ventura County Transportation Commission
VDF	Volume-Delay Function
VHT	Vehicle-Hours Traveled
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle Miles of Travel
VOT	Value of Time
VTRIS	Vehicle Travel Information System
WBO	Work-Based Other Trips
WIM	Weigh In Motion

ACKNOWLEDGMENTS

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- SCAG Subregional Agencies
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- South Coast Air Quality Management District
- Ventura Air Pollution Control District
- Mojave Desert Air Quality Management District
- Imperial County Air Pollution Control District
- Antelope Valley Air Pollution Control District
- Los Angeles County Metropolitan Transportation Authority
- Orange County Transportation Commission
- Riverside County Transportation Commission
- Riverside County
- San Bernardino Associated Governments
- Ventura County Transportation Commission
- Imperial County Transportation Commission
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- Federal Transit Administration
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