2016 REGIONAL TRAVEL DEMAND MODEL AND MODEL VALIDATION

APRIL 2020

SCAG

2016 Regional Travel Demand Model and Model Validation

Funding: The preparation of this report was financed in part through grants from the United States Department of Transportation (DOT).

The preparation of this report was financed in part through grants from the Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation. The contents of this report do not necessarily reflect the official views or policy of the U.S. Department of Transportation.

Published April, 2020

SCAG

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PREFACE

The Southern California Association of Governments (SCAG) is a voluntary association of six counties—Los Angeles, Orange, Ventura, Riverside, San Bernardino, and Imperial—and 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 / Sustainable Communities Strategy (RTP/SCS), a Federal Transportation Improvement Program (FTIP), a State Transportation Improvement Program (STIP), and to identify and analyze Transportation Strategies for incorporation into the South Coast Air Quality Management Plan (AQMP).

This report describes how SCAG forecasts travel behavior using computer-based software programs 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 2016, including recent enhancements to the model to augment its capabilities for addressing policy directives and other transportation programs.

The Regional Transportation Model provides a common foundation for transportation planning and decision-making by SCAG and other agencies within the Region. Year 2016 is the base year for the transportation planning period and for the Regional Transportation Model. The Year 2016 base year travel data contained in this report will be referenced by, and is of interest to, the general public, as well as local, State, and federal agencies involved in transportation planning and traffic engineering. Various 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 07, 08, 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 County Transportation Authority (SBCTA), the Ventura County Transportation Commission (VCTC), the Imperial County Transportation Commission (ICTC), 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 2016 model validation.

This report summarizes the specification, calibration, and validation of the SCAG Regional Transportation Model to 2016 travel conditions. This model update was performed in preparation for the development and evaluation of the SCAG 2020 RTP/SCS. The new modeling capabilities introduced as part of this update address the need for 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. This updated model has enhanced sensitivities 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 2017 RTP Guidelines.

The 2020 RTP/SCS model is an Activity-Based Travel Demand Model (ABM). In an ABM, travel emerges from the desire to participate in activities. As such, activities are predicted first, and then travel is generated to link these activities in time and space.

The model system addresses the requirements of the metropolitan planning process and relevant State and federal requirements. It is equally suitable for conventional highway and transit projects, and for a wide variety of policy studies such as pricing, managed lanes, and travel demand management. The SCAG ABM is a comprehensive, robust, and forward-looking tool that addresses the following requirements:

- Produce 24 hours travel demand patterns with the necessary level of temporal resolution. The ABM structure essentially operates in continuous time and simulates a complete day for all individuals in the region. When the ABM is integrated with standard network procedures (highway and transit assignments) the corresponding trips are grouped by time-of-day periods (the implementation schema for all ABMs in practice so far). However, this ABM will also be ready for integration with more advanced Dynamic Traffic Assignment (DTA) operating in continuous time.
- Sensitive to the future land use, demographics and employment. The ABM structure takes advantage of the details of the synthetic population and addresses demographic changes including population age distribution and household composition, amongst other changes. The future labor force scenarios and job allocation scenarios are logically integrated starting from the population synthesis. In this regard, future structural shifts in the land-use and employment types will affect all sub-models including the synthetic population itself. All demographic, land-use, and employment inputs also affect tour and trip choices of destination, mode, and time of day.
- Sensitive to the implementation of various planning and transportation policies or visions. The ABM and supporting network procedures are designed to address a wide range of policies including different infrastructure capacity improvements and pricing schemes. Beyond the standard sensitivity of mode choice to travel time and cost, the ABM has a rich set of behavioral accessibility measures. Through these measures, the impacts of various policies on car ownership, commuting frequency, daily activity patterns, trip chaining, trip schedules, and joint travel arrangements can be captured.
- Sensitive to changes in transportation facilities and services. The ABM is supported by highway assignment and skimming procedures sensitive to the details of transportation facilities and services for highway, transit, and non-motorized modes.
- Produce quality information for project evaluation, including the assessment of economic benefits (e.g. variation in travel time and vehicle operation cost), environmental justice analysis (e.g. mobility and accessibility by income and race/ethnicity), and environmental impacts (e.g. energy consumption, pollutant emissions and greenhouse gases).

The Year 2016 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 the Highway Performance Monitoring System (HPMS), speed data from the Freeway Performance Measurement System (PeMS), and other travel survey data. The Regional Transportation Model sufficiently replicates the observed validation data as described herein.

The SCAG Activity-Based Travel Demand Model meets all the requirements of the Transportation Conformity Rule. SCAG held a Model Peer Review Meeting on May 31, 2019. Per the Model Review Committee assessment, the SCAG ABM "meets current state of the practice compared to peer MPOs (i.e., large metro areas in U.S.), given the complexity of region, and has some special features that go beyond standard practice." As such, the model is validated for use in preparing travel forecasts for the analysis of SCAG's RTP/SCS.

Chapter 1 Overview

Introduction

SCAG has evolved over the past five decades into the largest of nearly 700 councils of government in the United States. SCAG functions as the Metropolitan Planning Organization for six counties: Imperial, Los Angeles, Orange, San Bernardino, Riverside, and Ventura. The region encompasses a population exceeding 19 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, the STIP, 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 and the latest generation of the Coordinated Travel – Regional Activity Modeling Platform (CT-RAMP3).

This report combines information from several documents and other sources related to the enhancement and validation of the 2016 Regional Travel Demand Model (Regional Model) for Southern California. The Regional Model is managed and operated by SCAG with development assistance from private consulting firms. The model is one of several tools used by SCAG to forecast land use and travel demand. Peer Review panels have reviewed the specification and validation of the SCAG Regional Model.

Transportation Model Overview

SCAG develops and maintains state-of-the-art transportation models to support SCAG's planning program, shown to the right. These models are applied by SCAG to forecast transportation conditions and resulting air quality.

Activity Based Model	• 2020 RTP/SCS - Connect SoCal
Trip Based Model	• Support Local Analysis
Sub-regional Model Tool	• Modeling Tools for Local Agencies
Heavy-Duty Truck Model	• Truck and Goods Movements
Air Quality Models	• Conformity/GHG Determination

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. The ABM is the primary transportation model used in the development of the 2020 RTP/SCS.

Trip-Based Model

The Trip-Based Model (TBM) has historically been the main demand forecasting tool used by SCAG. The TBM was validated in 2015. SCAG maintains the TBM to support transportation analysis of local projects.

Subregional Model Tool

The Subregional Model 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 TBM. Application of the SMDT 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

SCAG developed the Heavy-Duty Truck (HDT) model to evaluate policy choices and investment decisions related to freight movements by truck. 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 California Air Resources Board (CARB) 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 air quality conformity purposes in California.

CALIFORNIA SB 375

California Senate Bill 375 requires metropolitan areas, such as the SCAG region, to meet regional GHG emission reduction targets for 2020 and 2035. SCAG's ABM has the capability to analyze the strategies comprising a SCS.

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 following strategies:

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

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 2016; the long-term forecast year is 2045.

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, 2008 and 2012. The base year of 2016 in the current model replaces the previous base year of 2012.

Overview of Model Enhancements

The main enhancement introduced for the 2020 RTP/SCS modeling platform is the adoption of an activity-based travel demand micro-simulation tool. Known as the SCAG ABM, this model exhibits the following characteristics:

- Based on *advanced principles of modeling* individual travel choices with high behavioral realism. The model addresses both household-level and person-level travel choices including intra-household interactions between household members across a wide range of activity and travel dimensions. It predicts travel as emerging from activity participation, using various innovative sub-models, such as a combinatorial mode choice model that predicts tour mode and trip mode simultaneously.
- Proven design concept, based on the second generation of the Coordinated Travel – Regional Activity Modeling Platform (CT-RAMP3) framework. The CT-RAMP framework has been evolving since 2005, and it has been *tested in practice* in several regions, including New York, Chicago, the San Francisco Bay Area, Atlanta, Miami, Columbus and Phoenix.
- Operates at a *fine level of temporal resolution*, with respect to modeling trip and activity timing and duration. Tour start and end times are modeled in discrete space with 15 min intervals. Subsequently, trip departure times and activity durations are modeled in continuous time. This ensures consistency of the generated activity and travel patterns and schedules at the individual level that are important for modeling congestion, road pricing and peak spreading. This level of temporal resolution also opens the door for integrating the ABM with an advanced network simulation model, such as Dynamic Traffic Assignment (DTA).
- Reflects and responds to *detailed demographic and socio-economic information*, including household structure, aging, changes in wealth, and other key attributes observed or expected in the dynamic Southern California region. The SCAG ABM incorporates different household, family, and housing types including a detailed analysis of different household compositions in their relation to activity-travel patterns.
- Extensive use of *daily and time-varying accessibility measures*. Accessibility measures are important behavioral components of an ABM that express closeness of the modeled individual to potential locations where the activity "supply" (employment of the corresponding type) is present. Accessibility has a strong impact on individual activity patterns and travel behavior. The SCAG ABM extends commonly-used accessibility measures by properly differentiating them by hour of day so that they can be linked to the corresponding time-of-day specific choices.
- Accounts for the *full set of existing and planned travel modes*. The SCAG ABM allows for addressing details of different auto modes (distinguished by occupancy), transit modes, taxi, ride-hailing modes, and non-motorized modes.

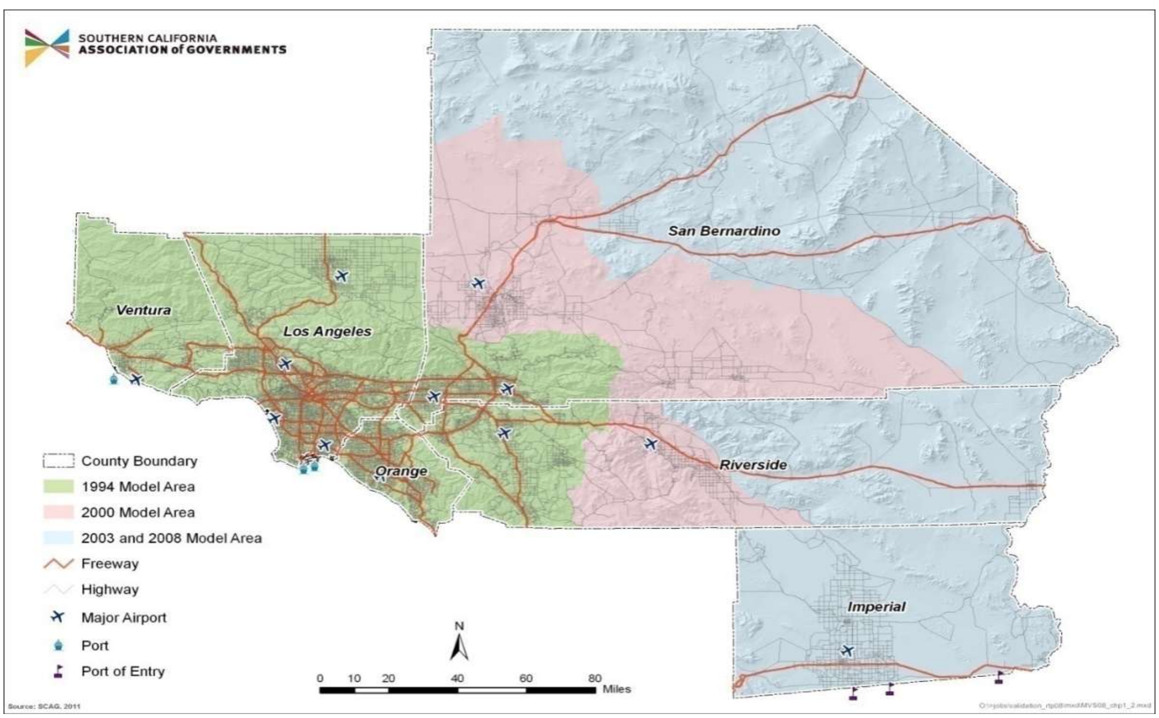
- The core demand model can be *easily integrated with other components* such as the existing truck model, the model of external travel to and from the region, and eventually, models of non-resident visitor travel, airport travel, and/or special event travel.
- Flexibility with respect to the network simulation platform available. This version of the SCAG ABM is implemented in combination with a conventional static assignment, since this is the only network simulation procedure feasible for Southern California region. However, the SCAG ABM structure can provide the *detailed inputs needed by traffic micro-simulation software* for engineering-level analysis of corridor and intersection design. Moreover, when coupled with DTA software, it will be possible to fully integrate transport demand and supply models in one coherent framework based on individual microsimulation. The proposed design of SCAG ABM fully accounts for this future possibility.

MODELING AREA

The modeling area of the SCAG 2016 Regional Travel Demand Model covers the following six counties in their entirety: Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura.

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

Figure 1-1: 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) 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 1-2 that allows for micro (i.e., neighborhood) and macro-scale (i.e., regional) analysis and reporting. The TAZ structure was last modified in 2012 to enhance the precision of micro-level land use and smart growth analysis for the RTP/SCS. 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.

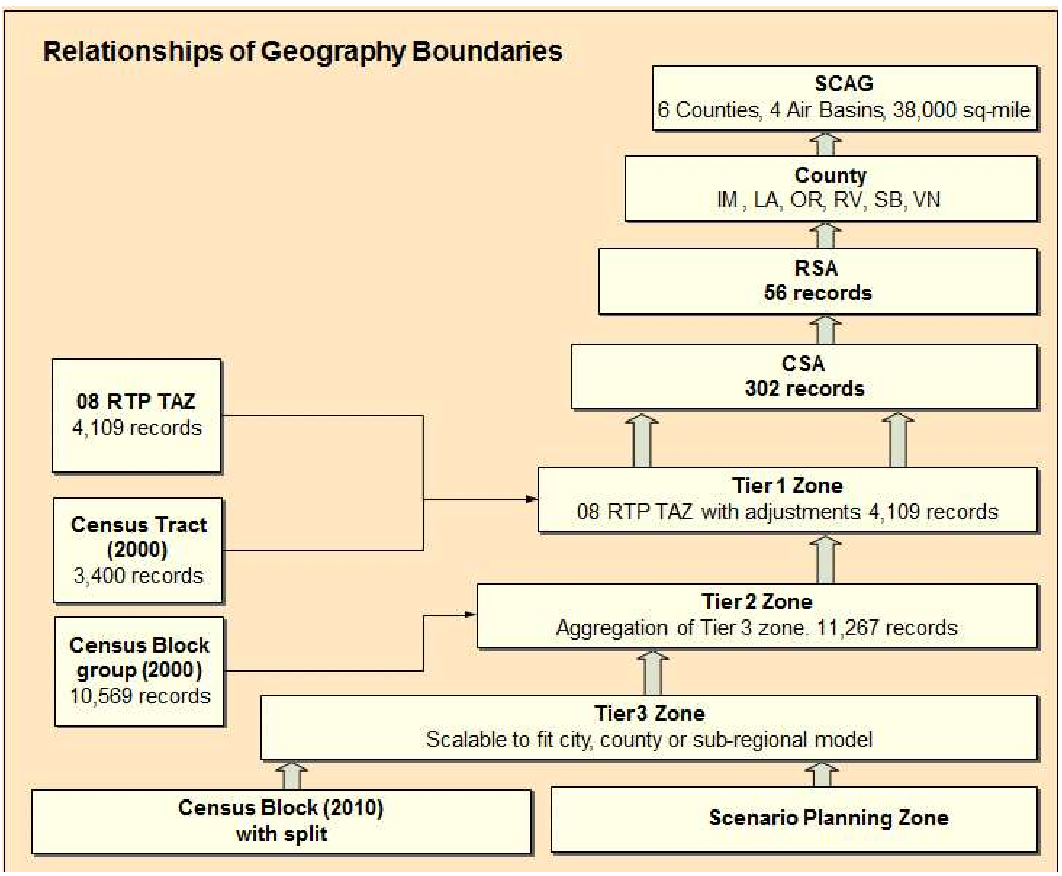


Figure 1-2: Structure of the Tiered Zone System in the SCAG Model

Table 1-1 and Figure 1-2 provide statistical information and a graphical display of the zone structure. In addition, the Regional Model contains 40 external stations to facilitate modeling of trips to, from, and through the region.

Table 1-1: Geographic Zone Summary

Modeling Area	2010 Census Tract	2010 Census Block Group	Regional Statistical Area (RSA)	Community Statistical Area (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**

Methodology

A tiered TAZ system was jointly developed by SCAG and its member agencies, based on sub-regional TAZs and SCAG Minimum Planning Units (MPU). 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, and it 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 current 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 where local inputs provide better boundaries.

- ***Consistency with 2009 TIGER/Line Block Group or Sub-regional TAZ Boundaries*** – for backwards consistency, the current Tier 1 TAZ boundaries are identical to the SCAG 2008 Model TAZs.

- ***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 assignment, existing and future freeways and principal arterials are generally represented as regional TAZ boundaries, consistent with other zonal creation criteria.

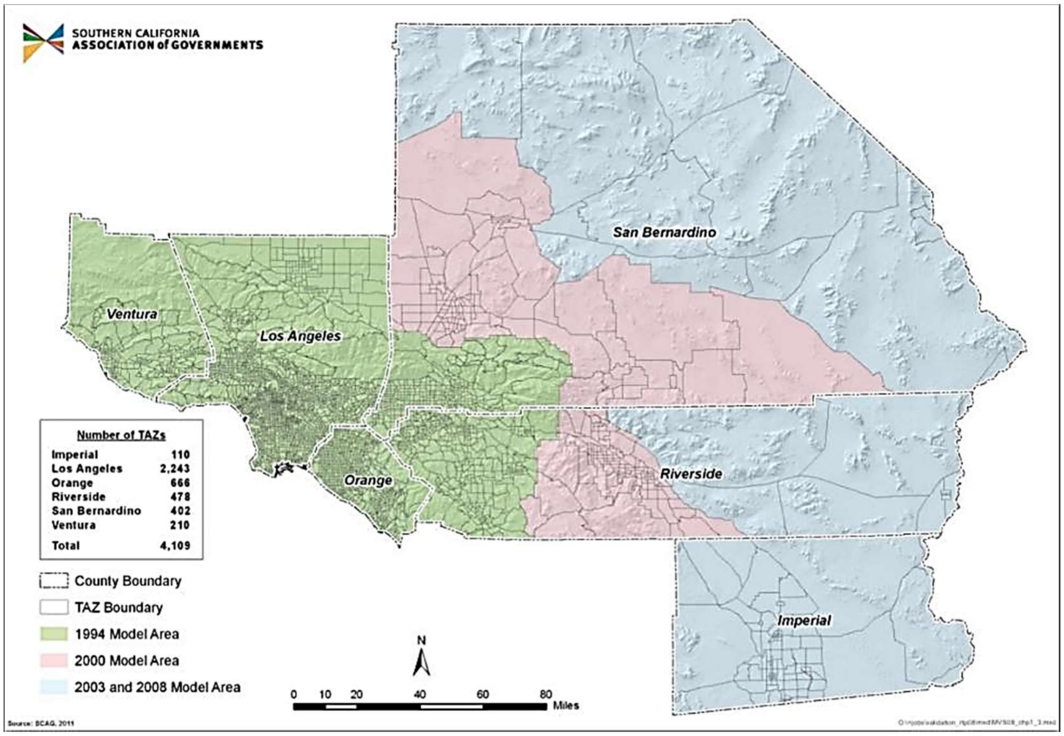
- ***Homogeneous Land Use*** – Land use maps and general plan maps were used to identify existing and future land use. Ideally, it is best to limit the number of different land uses contained within a zone. However, given the geographic size of the regional TAZs and the mixed-use development patterns 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 (for 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 with data processing and quality control. TAZ boundaries were adjusted so they are consistent with the 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 1-3 shows the Tier 1 TAZs.

Figure 1-3: Transportation Analysis Zone System (Tier 1)



Overview of Report

The input data, model enhancements, calibration, validation, and results of each of the modeling components of the SCAG 2016 Regional Model are summarized in the respective chapters:

Chapter 1 Overview

Chapter 2 General Design of the SCAG ABM

Chapter 3 Model Inputs

Chapter 4 Transportation Networks

Chapter 5 Long Term Choice

Chapter 6 Mobility Choice

Chapter 7 Mandatory Activity Generation and Tour Formation

Chapter 8 Coordinated Daily Activity Pattern (CDAP)

Chapter 9 School Escorting and Schedule Consolidation

Chapter 10 Fully Joint Tour Activity Generation and Scheduling

Chapter 11 Individual Non-mandatory Activity Generation

Chapter 12 Tour Formation

Chapter 13 Final Time of Day

Chapter 14 Mode Choice

Chapter 15 Heavy Duty Truck Model

Chapter 16 Trip Assignment

Supplemental information is contained in the following appendices:

Appendix A1: Highway Network Coding Conventions

Appendix A2: Auto Operating Costs

Acronyms

Chapter 2 GENERAL DESIGN OF THE SCAG ABM

GENERAL MODEL DESIGN

The general design of the SCAG ABM is shown in Figure 2-1 below. It consists of the following basic sequence of sub-models and associated travel choices:

1. Population synthesis – creates the list of households and persons that represent the model area population.
2. Long term choice – predicts choices of usual location for each mandatory activity for each household worker and student (workplace, university, school) including work or school from home (home-schooled) as one of the alternatives
3. Mobility choice – predicts decisions of holding driver license and number of cars owned by each household
4. Day-level models for activity generation

   4.1. Coordinated daily activity travel pattern - Daily activity-travel pattern type for each household member, with a linkage of choices across household members; this model includes a binary indicator of fully joint maintenance or discretionary tours Individual mandatory activities/tours for each household member

   4.2. Mandatory activity generation and tour formation

   - Frequency of mandatory activity generation and tour skeleton
   - Mandatory activity preliminary time of day (start-end time combination)
   - Escorting children to school by school half-tours

   4.3. Non-Mandatory activity generation

   - Maintenance activities that are generated by the household and allocated as tasks to an individual for implementation
   - Household frequency of maintenance tasks by purpose
   - Maintenance task allocation to one person in household

   4.4. Individual discretionary activities (conditional upon the available time window left for each person after the scheduling of mandatory)

5. Fully joint activity scheduling - Joint travel tours for shared non-mandatory activities (conditional upon the available time window left for each person after the scheduling of mandatory activities)

   5.1. Household joint tour frequency and person participation

   5.2. Tour formation that includes primary destination, stop frequency, and location for each joint tour

   5.3. Time-of-day choice for joint tour

6. Tour/Trip Scheduling

   6.1. Individual tour formation

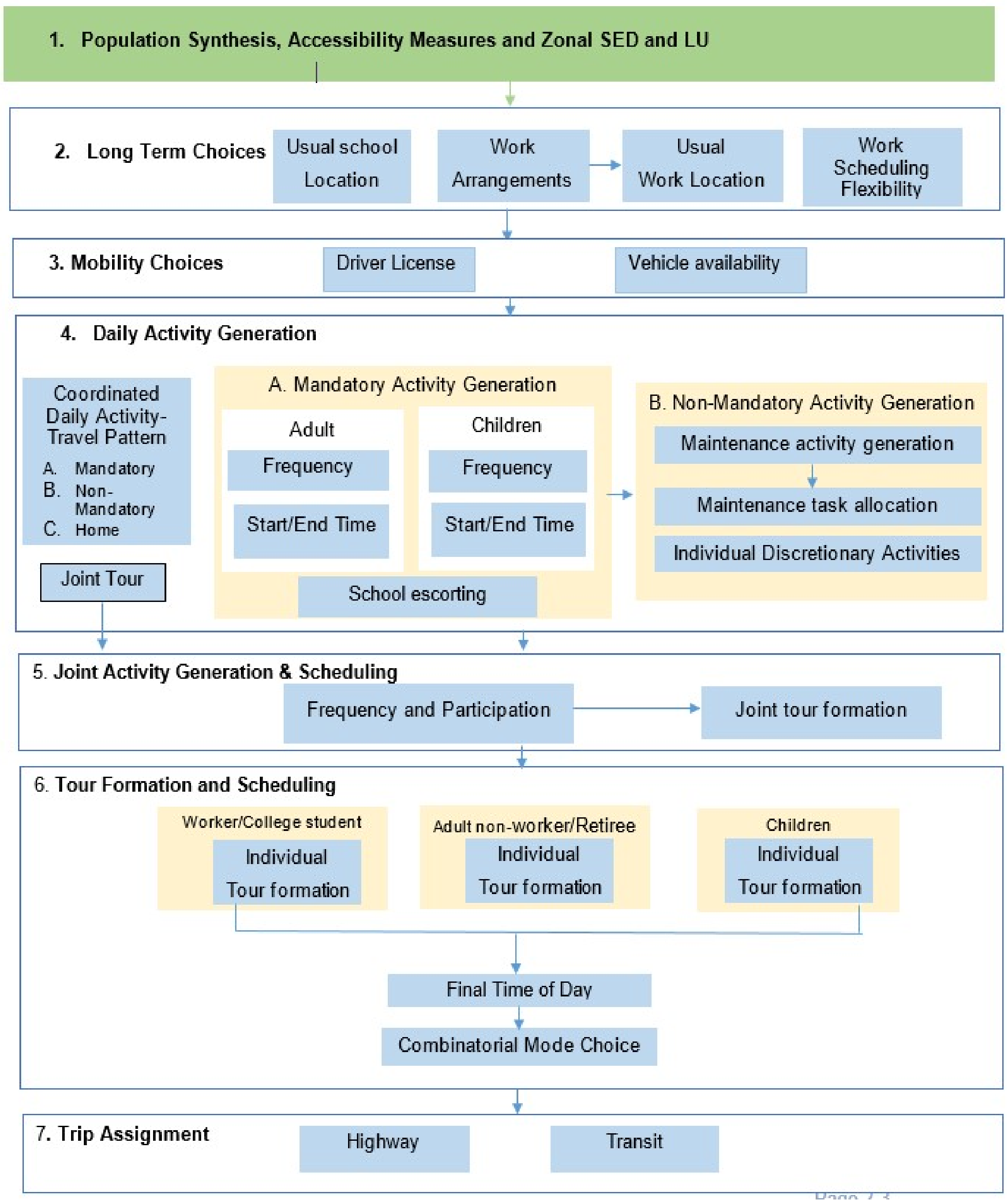
   - Allocation of individual non-mandatory activities to day segments for each person
   - Tour frequency and "breaks" (i.e. stops at home) for each person and person day segment
   - Activity sequence for each tour and sub-tour

   6.2. Tour and sub-tour time-of-day choice (from departure from home or work to arrival back home or to work)

6.3. Mode choice: In SCAG ABM, the tour-level and trip-level mode choices are integrated in a network combinatorial representation. The model considers all feasible trip mode combinations on the tour

6.4. Trip departure time and activity duration for each stop within the tour window

Figure 2-1: SCAG ABM System Design



Market Segmentation

Decision-Making Units

Decision-makers in the model system include both individual persons and households. These decision-makers are created (synthesized) for each simulation year based on tables of households and persons from the Census data persons by key socio-economic categories. These decision-makers select a single alternative from a list of available alternatives, following a probability distribution at each step of the entire-day decision-making process. These probability distributions are generated by discrete-choice models which account for the attributes of the decision-maker and the attributes of the various alternatives.

The decision-making unit is an important element of model estimation and implementation, and it is explicitly identified for each model specified in the following sections. In the SCAG ABM, there are five basic decision-making units that are used in most of the choice models:

- *Household*. Examples of choice dimensions pertinent to this unit include car ownership and frequency of joint travel tours.
- *Person*. Examples of choice dimensions pertinent to this unit include usual workplace and/or school location, frequency of individual discretionary activities and their allocation to person day segments. While these decisions are related to person attributes, the household which the person belongs in also plays an important role and provides additional variables and constraints explaining the person choices.
- *Person day segment*. Examples of choice dimensions pertinent to this unit include tour formation frequency and destination (activity location) choice. The key attribute of a person day segment is a time window defined by the prioritized activities that constraint the segment start and end.
- *Tour*. Examples of choice dimensions pertinent to this unit include time-of-day and tour mode choice that defines the sequence of trip modes on the tour. The person (or group of persons for joint tours) that implement the tour and their household provide additional important variables and constraints explaining the choice.
- *Trip*. Examples of choice dimensions pertinent to this unit include trip departure time and parking location (currently applied to park-and-ride trips only). The tour that includes the given trip, person implementing it, and household provide additional important variables and constrains explaining the choice.
- *Activity*. Examples of choice dimensions pertinent to this unit include the person to whom this activity is allocated (for household maintenance activities) and time allocation to the activity within the tour where this activity is included either as a primary destination or intermediate stop. Depending on the choice context all relevant tour, person, and household attributes are used as explanatory variables and/or constraints.

Person-Type Segmentation

Person types are assigned to the synthetic persons based on key socio-economic attributes: age, student status and employment status. A total of eight (8) person type segments are used in the SCAG ABM, as shown in Table 2-1. Person types are exhaustive and mutually exclusive, that is, every person in the synthetic population is assigned one, and only one, person type. Person types are used as explanatory variables and as model segmentation variables.

Table 2-1: SCAG ABM Person Type Definitions

Person Type	Name	Definition
1	Full-time worker	Age >=16, employed, work duration >= 35 hours, non- student Age >=16, employed, work duration >= 35 hours, attending 2-year college, 4-year college or graduate school
2	Part-time worker	Age >=16, employed, work duration < 35 hours, non- student Age >=16, employed, work duration >= 20 hours & work duration < 35 hours, attending 2-year college, 4-year college or graduate school
3	College student	Age >=16, employed, work duration < 20 hours, attending 2-year college, 4-year college or graduate school Age >=16, unemployed, attending 2-year college, 4-year college or graduate school
4	Non-worker	Age >= 16 & age < 65, unemployed, non-student
5	Retired	Age >= 65, unemployed, non-student
6	Driving age child	Age > 15 & age =< 18, attending high school
7	Pre-driving age child	Age > 5 & age =< 15, attending school
8	Pre-school children	Age <= 5

Activity-Type Segmentation

The 2011-12 California Household Travel Survey (CHTS) provided respondents with approximately 40 options to record the purpose of each trip. The model however understands a more concise set of activity purposes, which nonetheless capture the variety of activities reported. The extended set of options is useful to aid respondents in remembering everything they did during the survey day, and to maintain consistency across different respondents. For modeling, a more parsimonious classification is desirable to keep the number of sub-models manageable and avoid a proliferation of infrequent activity types.

Table 2-2 shows the classification of survey trip purposes into the model activity purposes. All in-home activities, which comprise survey purposes 1-8, are modeled as the same type of activity in the SCAG ABM. Out of home activities are further grouped into two main categories, mandatory activities and non-mandatory activities, as follows:

Mandatory Activities	Non-Mandatory Activities	
• Work	• Escort	• Eating out
• University	• Shopping	• Visiting
• School	• Maintenance	• Discretionary

Table 2-2: Activity Purpose Classification

Survey Activity/Trip Purpose		SCAG ABM Activity Purpose	
#	**Description**	**#**	**Description**
1	Personal Activities (Sleeping, Personal Care, Leisure, Chores)	0	
2	Preparing Meals/Eating	0	
3	Hosting Visitors/Entertaining Guests	0	
4	Exercise (With or Without Equipment)/Playing Sports	0	
5	Study / Schoolwork	0	
6	Work for Pay at Home Using Telecommunications Equipment	0	
7	Using Computer/Telephone/Cell or Smart Phone or Other Communications Device for Personal Activities	0	
8	All Other Activities at my Home	0	
9	Work/Job Duties	1	Work
10	Training	12	Work/Business
11	Meals at Work	1	Work
12	Work-Sponsored Social Activities (Holiday or Birthday Celebrations, etc.)	12	Work/Business
13	Non-Work-Related Activities (Social Clubs, etc.)	7	Discretionary
14	Exercise/Sports	10	Discretionary
15	Volunteer Work/Activities	7	Discretionary
16	All Other Work-Related Activities at My Work	1	Work
17	In School/Classroom/Laboratory	2	School / University
18	Meals at School/College	2	School / University
19	After School or Non-Class-Related Sports/Physical Activity	10	Discretionary
20	All Other After School or Non-Class Related Activities (Library, Band Rehearsal, Clubs, etc.)	7	Discretionary
21	Change Type of Transportation/Transfer (Walk to Bus, Walk To/From Parked Car)	0	
22	Pickup/Drop Off Passenger(S)	4	Escorting
23	Drive Through Meals (Snacks, Coffee, etc.)	6	Maintenance
24	Drive Through Other (ATM, Bank)	6	Maintenance
25	Work-Related (Meeting, Sales Call, Delivery)	12	Work-related
26	Service Private Vehicle (Gas, Oil, Lube, Repairs)	6	Maintenance
27	Routine Shopping (Groceries, Clothing, Convenience Store, Household Maintenance)	5	Shopping
28	Shopping for Major Purchases or Specialty Items (Appliance, Electronics, New Vehicle, Major Household Repairs)	5	Shopping
29	Household Errands (Bank, Dry Cleaning, etc.)	6	Maintenance
30	Personal Business (Visit Government Office, Attorney, Accountant)	6	Maintenance
31	Eat Meal at Restaurant/Diner	11	Eat-out
32	Health Care (Doctor, Dentist, Eye Care, Chiropractor, Veterinarian)	6	Maintenance
33	Civic/Religious Activities	7	Discretionary
34	Outdoor Exercise (Playing Sports/Jogging, Bicycling, Walking, Walking the Dog, etc.)	10	Discretionary
35	Indoor Exercise (Gym, Yoga, etc.)	10	Discretionary
36	Entertainment (Movies, Watch Sports, etc.)	8	Discretionary
37	Social/Visit Friends/Relatives	9	Visiting Friends/Family
38	Other (Specify)	13	Discretionary

Survey Activity/Trip Purpose		SCAG ABM Activity Purpose	
#	Description	#	Description
39	Loop Trip (For Interviewer Only-Not Listed on Diary)	0	
97	No Additional Activities	0	
99	Don't Know/Refused	0	

Employment Classification

The SCAG ABM uses employment to represent the economic activity at each TAZ. The nine employment categories recognized by the model are shown in Table 2-3. Employment is used to specify trip attraction measures in the location choice models and in the accessibility measures.

Table 2-3: Employment Classification

#	NAICS Codes	Industry Type
1	11, 21	Agriculture, Mining
2	48, 22, 23	Construction, Utility
3	31, 42	Manufacturing, Wholesale
4	44, 81	Retail, Other Service
5	51, 54, 55, 56	Information, Business Service
6	61, 62	Education & Health/Social Service
7	52, 53	Finance, Investment, Real Estate Services
8	71, 72	Arts, Entertainment, and Hospitality, Food Service
9	92	Public Administration

Temporal Resolution

The SCAG ABM functions at a *temporal resolution of fifteen minutes* for all sub-models that generate activities and tours; that is, up to sub-model 6.3. The Trip Departure Time sub-model (6.4) operates with *continuous time*. The fifteen-minute increments begin with 3:00 A.M and end with 2:59 A.M the next day. Temporal integrity is ensured so that no activities are scheduled with conflicting time windows (overlapping in time for the same individual), except short activities/tours that are completed within a fifteen-minute increment. For example, a person may have a very short tour that begins and ends within the 8:30 A.M-8:44 A.M period, as well as a second longer tour that begins within this time interval and ends later in the day.

Trip Mode Classification

The trip mode classification is shown in Table 2-4. The auto modes are defined by driver vs passenger, and in the case of drivers by car occupancy (single, 2-person carpool, 3+ person carpool). The transit modes are defined by access mode at the home end of the tour (walk, park and ride, kiss and ride), and primary mode combination (conventional transit, which includes local bus, rapid bus, and streetcars; and premium transit, which includes premium bus, BRT, urban rail, commuter rail or high-speed rail as the main line-haul option). Non-motorized travel is captured by the walk and bike modes. In addition, school bus is a choice for trips to/from school.

Table 2-4: Trip Modes

Number	Mode
1	Auto driver, 1-person occupancy
2	Auto driver, 2-person occupancy
3	Auto driver, 3+ person occupancy
4	Auto passenger
5	Walk to conventional transit
6	Park and ride to conventional transit
7	Kiss and ride to conventional transit
8	Walk to premium transit
9	Park and ride to premium transit
10	Kiss and ride to premium transit
11	Walk
12	Bike
13	Taxi
14	School bus

Each trip mode is associated with its own travel time and cost, also known as level of service (LOS). For the auto driver modes, LOS depends on the facilities which are available to each mode, as shown in Table 2-5. The LOS for the auto passenger mode is the same as for 2-person carpools. For the transit modes, LOS includes in-vehicle time, out-of-vehicle time, transfer penalty, and fare. The path-building modes available to each skim set, corresponding to the trip modes, are shown in Table 2-6.

Table 2-5: Highway Availability Settings for LOS Skimming

LOS Skim Set	Auto Driver 1P	Auto Driver 2P	Auto Driver 3P+	Auto Passenger
GP Lanes	✓a	✓	✓	✓
HOV Lanes (2p+)		✓	✓	✓
HOV Lanes (3p+)			✓	✓
Toll Roads	✓	✓	✓	✓
Express Lanes (2P+)[1]	✓(pay)	✓(free)	✓(free)	✓(free)
Express Lanes (3P+)[2]	✓(pay)	✓(pay)	✓(free)	✓(pay)

1 Express lanes 2p+ are toll facilities where carpools with 2 or more occupants travel for free
2 Express lanes 3p+ are toll facilities where carpools with 3 or more occupants travel for free

Table 2-6: Transit Availability Settings for LOS Skimming

LOS Skim Set	Mode →	CT1 Walk	CT PNR	CT KNR	PT2 Walk	PT PNR	PT KNR
Walk Access	1	✓			✓		
Drive Access	2		✓	✓		✓	✓
Walk Transfer and Egress	4	✓	✓	✓	✓	✓	✓
Local Bus	30,31, 32	✓	✓	✓	✓	✓	✓
Rapid Bus	33	✓	✓	✓			
Express Bus	20, 21, 22, 23	✓	✓	✓			
BRT	19				✓	✓	✓
Urban Rail	11				✓	✓	✓
Comm. Rail	10				✓	✓	✓
HSR	12				✓	✓	✓

CT: Conventional transit 2 PT: Premium transit

Chapter 3 MODEL INPUTS

Socio-Economic Data

Socioeconomic data, which describes both demographic and economic characteristics of the region by TAZ, is a major input to SCAG's travel demand model. Travel demand analysis is based on the concept that travel is derived from the demand for activity participation. The attributes of the zonal population, such as income, auto ownership and household composition, explain the demand for activity participation, while economic characteristics, such as the number and types of jobs, and housing units, are indicative of where activities take place, and the level of activities.

The socioeconomic inputs for year 2016 consist of zone-level data, household-level data, and person-level data. Zonal level data include population, households, school enrollments, household income, workers, and employment, summarized to the 4,109 Tier 1 and 11,267 Tier 2 TAZs. Individual household and person data summarized at the TAZ level are also prepared as inputs to the population synthesis step.

The base year socioeconomic variables were developed using diverse public and private sources of data and advanced estimation methods. The major data sources include 2010 Census, American Community Survey (ACS), California Department of Finance (DOF), California Employment Development Department (EDD), firm-based InfoGroup data, 2016 Land Use data and County Assessor's Parcel Database.

Population, households, and employment are the three major variables anchoring other input variable development. The major variables were developed by incorporating the latest survey data and in collaboration with local jurisdictions. The secondary variables, including workers, household size, household income, and employment sectors, were further developed as input for the TBM and ABM (see Table 3-1).

Table 3-1: Primary and Secondary Socioeconomic Variables

Population and Household Variables	Employment Sector Variables
Population	Agriculture and mining
Residential population	Construction
Group quarters population	Manufacturing
Occupied housing units	Wholesale trade
Median household income ($2011)	Retail trade
Student enrollment by place of school (public and private)	Transportation and warehousing
Kindergarten to 8th grade	Information
9th grade to 12th grade	Finance, insurance and real estate
College and university	Professional and business service
	Education and health service
	Leisure and hospitality service
	Other service
	Public administration

These secondary variables at the TAZ level were estimated using the Small Area Secondary Variables Allocation Model (SASVAM). SASVAM is based on a probabilistic choice model that segments the population, household or employment control totals into subgroups (e.g., household size groups). The model was estimated with historical data. In application, the disaggregation reflects the change over time of the control total, as well as the change in the individual attribute (for example, reflecting a trend in average household size). More detailed population and employment attributes, shown in Table 3-2, are also maintained for use in the population synthesis.

Table 3-2: Population Synthesis Household and Person Variables

1. Household	2. Residential Population
1.1 Household type 1) Residential 2) Institutional group quarter 3) Non-institutional group quarter	2.1 Age
1.2 Number of people in a household	
1.3 Annual household income	2.3 Gender
1.4 Housing type 1) Single detached 2) Single attached 3) Multiple 4) Other	2.4 Ethnicity
1.5 Housing tenure 1) Owned with mortgage or loan 2) Owned free and clear 3) Rented 4) Occupied without payment of rent.	2.5 Employment status
	2.6 Worker by industry
	2.7 Worker by occupation
	2.8 Person by type
	2.9 Person by education attainment
	2.10 Student by grade

Socioeconomic Input Data Summary

Selected socioeconomic data input totals are presented in the following tables and figures. Table 3-3 presents a summary of 2016 socioeconomic data totals by county and for the SCAG Region.

Table 3-3: Year 2016 Socioeconomic Input Data

County	Persons			Households	Employment	School enrollment	
	Total	Residential	Workers			K-12	College
Imperial	187,000	178,000	64,000	50,000	67,000	38,500	10,000
Los Angeles	10,110,000	9,929,000	4,533,000	3,319,000	4,743,000	1,653,700	771,800
Orange	3,180,000	3,136,000	1,636,000	1,025,000	1,710,000	528,800	271,500
Riverside	2,364,000	2,330,000	711,000	716,000	743,000	444,700	115,300
San Bernardino	2,141,000	2,103,000	757,000	630,000	791,000	417,900	96,900
Ventura	850,000	839,000	320,000	271,000	335,000	155,700	50,600
Total	**18,833,000**	**18,516,000**	**8,022,000**	**6,011,000**	**8,389,000**	**3,239,300**	**1,316,100**

Figure 3-1 to Figure 3-3 show 2016 population density, household income distributions, and employment density for the Tier 2 TAZs.

Figure 3-1: Year 2016 Population Density

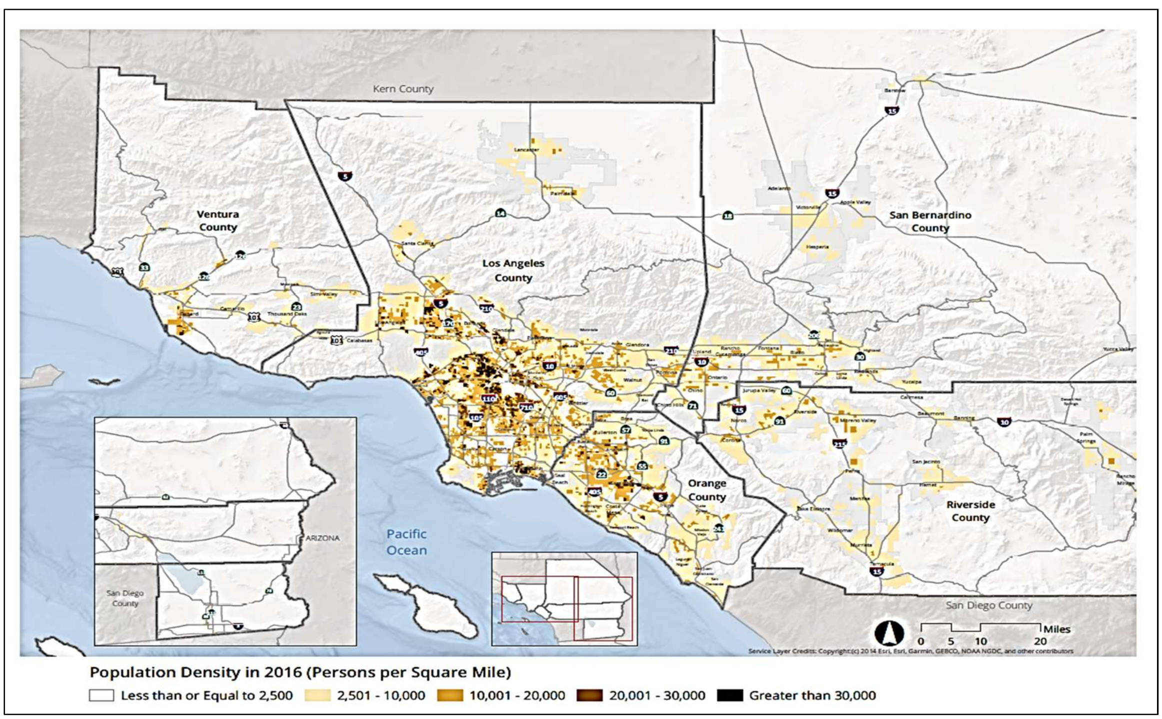
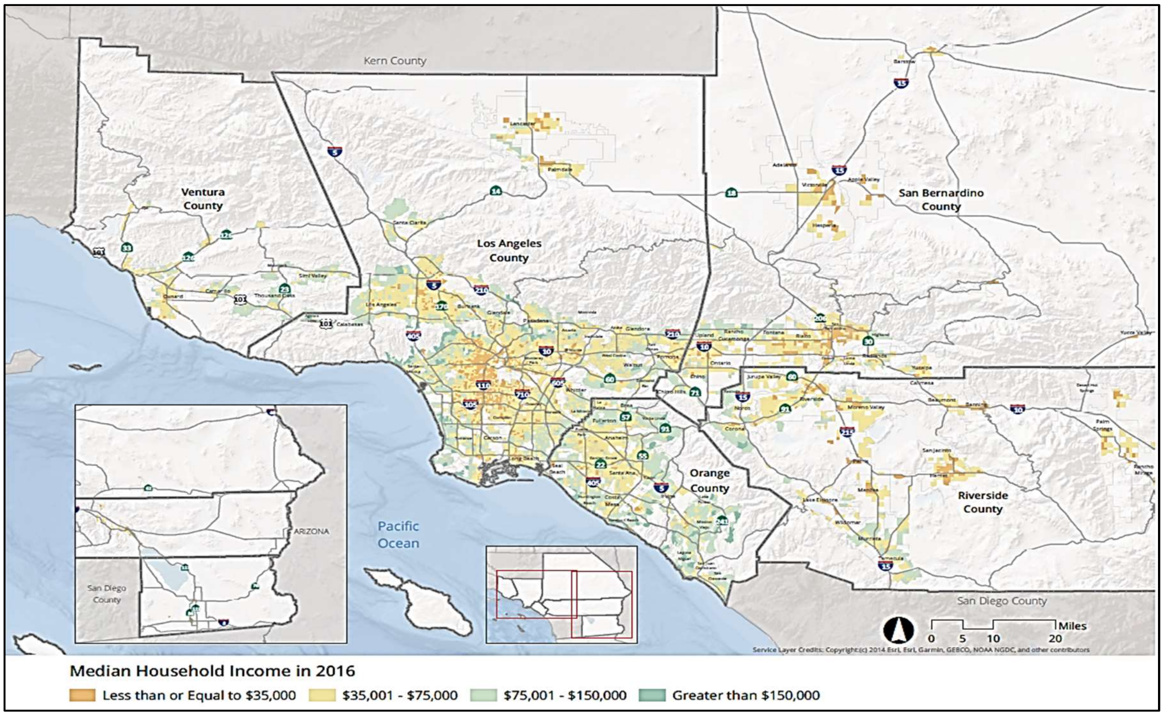
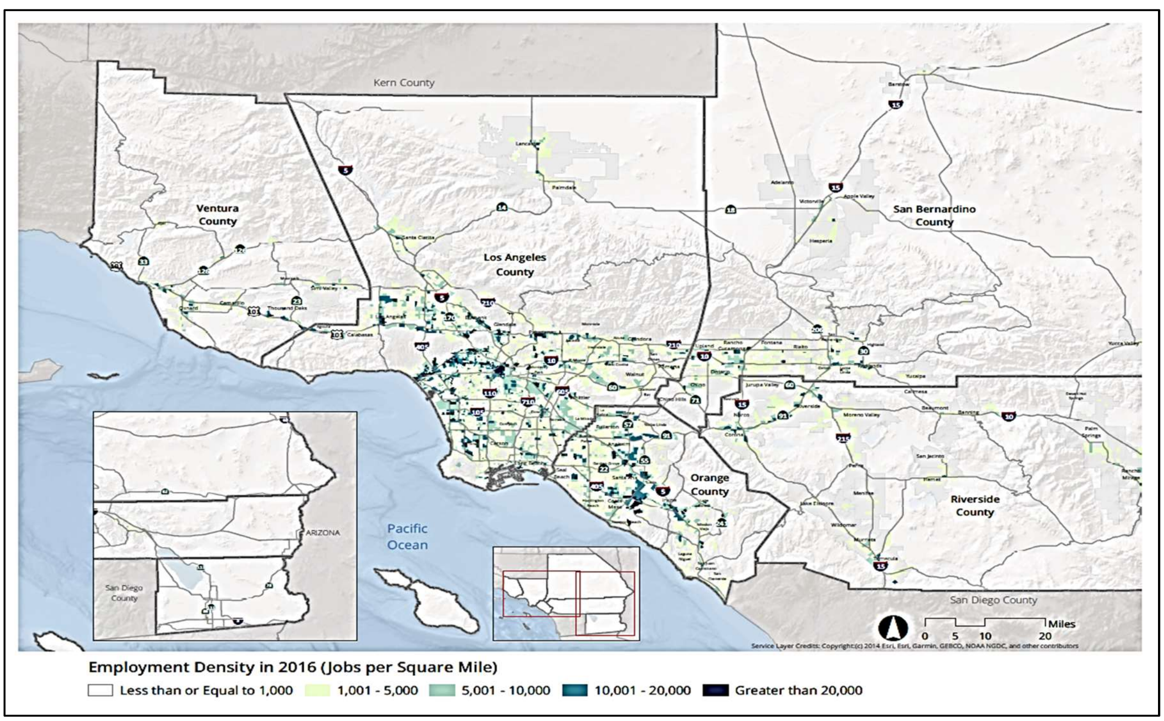


Figure 3-2: Year 2016 Household Income Distribution



Note: TAZs with population density at or below 2,500 persons per square mile not included

Figure 3-3: Year 2016 Employment Density



SYNTHETIC POPULATION

The population synthesis sub-module creates a list of households and persons for the entire model area that represents the region population for each horizon year. Two types of persons are generated independently of each other – household residents and group quarter residents. In the ABM, group quarter residents are treated as one-person households. Table 3-4 shows the control variables for generating the synthetic population, while Table 3-5 compares the control totals (input) to the synthesized totals for various demographic categories (output).

Table 3-4: PyPopSyn Control Variables

Table Name	Columns
Rescontrol	• **household**: total number of households in the Tier2 TAZ • **res**: residential population • **res by age category**: 0-4, 5-17, 18-24, 25-64, 65+ • **res_race**: Hispanic, Non-Hispanic While, Non-Hispanic Black, Non-Hispanic Indian, Non-Hispanic Asian, Non-Hispanic Other • **household by size**: 1, 2, 3, 4, 5+ • **household by housing type**: SFD, SFA, MF, Other • **household by income category**: 0 – 25K – 50K – 100K – 150K (2011 dollars)
county_control	• **halfHH**: half of total county households (to match the number of households of which income is lower than the median income)
region_control	• **total**: total worker • **workers**: by 20 Sectors (n11=Ag, n21=extract/Mine, n22=Utility, n23=Construct, n31=Manufacture, n42=wholesale, n44=Retail, n48=Transport, n51=Information, n52=Finance, n53=Real Estate, n54=Prof Service1, n55=Management, n56=Prof Service2, n61=Education, n62=Personal Care, n71=Entertainment, n72=Accommodation, n81=Service, Admin, n99=Military Other
Gqcontrol	• **gq, gi, gn**: total, institutional and non-institutional population • **res by age category**: 0-4, 5-17, 18-24, 25-64, 65+ • **res_race**: (see the rescontrol categories)

Table 3-5: Validation of the 2016 Base Year Synthetic Population

Variable	Output	Control	% Diff
Households	6,011,531	6,011,531	0.00%
One-person households	1,399,741	1,401,422	-0.12%
Two-person households	1,706,601	1,706,642	-0.00%
Three-person households	1,014,520	1,014,183	0.03%
Four-person households	942,257	941,587	0.07%
Five or more person households	948,412	947,697	0.08%
Single family detached dwelling units	3,286,648	3,286,644	0.00%
Single family attached dwelling units	431,272	431,260	0.00%
Multi-family dwelling units	2,091,706	2,091,938	-0.01%
Other dwelling units	201905	201,689	0.11%
Persons	18,831,752	18,831,769	0.00%
Age 0-4 years old	1,207,943	1,215,852	-0.65%
Age 5-17 years old	3,264,710	3,267,438	-0.08%
Age 18-24 years old	1,963,953	1,956,231	0.39%
Age 25-64 years old	9,929,850	9,929,239	0.09%
Age 65 or older	2,465,296	2,463,009	0.09%
Ethnicity			
Hispanic	8,700,163	8,700,275	0.00%
Non-Hispanic White	5,976,287	5,976,950	0.00%
Non-Hispanic Black	1,185,558	1,184,329	0.10%
Non-Hispanic Indian	46,395	46,792	-0.85%
Non-Hispanic Asian	2,448,226	2,448,052	0.01%
Non-Hispanic Other	474,583	475,371	-0.17%
Workers	8,020,845	8,027,568	-0.08%

LAND USE AND BUILT ENVIRONMENT (LUBE)

The measures used to characterize land use and the built environment are shown in Table 3-6.

Table 3-6: Land Use and Built Environment Measures

Measure*	Description and Formulas
Household Density	L_HHden = Ln (HH/Acre + 0.001)
Population Density	L_RPden = Ln (Res/Acre + 0.001)
Total Employment Density	L_Eden = Ln (Tot_emp/Acre + 0.001)
Jobs to Households Ratio	L_EHratio = Ln (Tot_emp/HH + 0.001) if HH>0 L_EHratio = -7 if HH=0
Total transit stop density	TTstop/Acre; (#stops / acre)
Percent of Households in Multi-family Dwelling Units (DU)	Mlt_pct = MFDU/HH if HH>0; =0 if HH=0
High Quality Transit Percentage	HQstop/Acre; (#stops / acre): High-quality transit includes 1) all rail modes, and 2) any other transit service with peak headway less or equal to 15 minutes (greater than 0 minute).
Bike Lane Density Indicator	Total Weighted Bike Lane length by Classes per acre

* LUBE variables are calculated by SCAG Tier-2 TAZ

ACCESSIBILITY MEASURES

Accessibility measures are important behavioral components of the ABM that express proximity of the modeled individual to potential locations where the activity "supply" (employment of the corresponding type) is present. Accessibility has a strong impact on individual activity patterns and travel behavior. Multiple sets of accessibility measures are used across different parts of the SCAG ABM. Each set corresponds to a given activity purpose and are sometimes further segmented by travel arrangement type, user class, and/or mode. Special effort was made to make these accessibility measures properly differentiated by hour of day so that they can be linked to the corresponding time-of-day specific choices.

Table 3-7: Travel Impedance Measures

#	Description	Type of Travel	User Class	Applicable Mode Set
1	School accessibility	School		SOV-HOV-WT-NM
2	University accessibility	School		SOV-HOV-WT-NM
3	Non-mandatory accessibility			SOV-HOV
4				WT
5				NM
6	Non-mandatory accessibility	Individual	Zero cars	HOV-WT-NM
7			Car insufficient	SOV-WT-NM
8			Car sufficient	SOV-WT-NM
9	Non-mandatory accessibility	Joint	Zero cars	HOV-WT-NM
10			Car insufficient	SOV-WT-NM
11			Car sufficient	SOV-WT-NM
12	Work accessibility	Work		SOV-HOV-WT-DT-NM

Origin-based accessibility measures are defined as the logsum for the destination choice that is calculated over all attractions in the region discounted by the travel impedance. The size and impedance terms both should correspond to the same period for which the accessibility measure is desired.

Figure 3-4: Representative Accessibilities by Mode

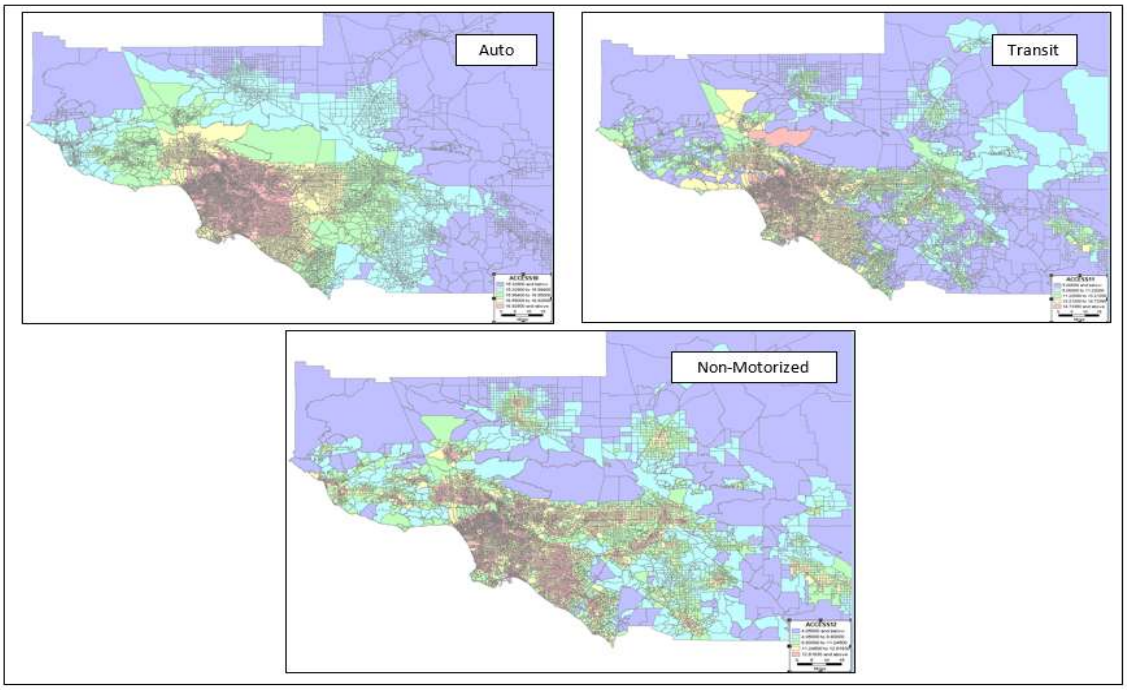


Table 3-8: Non-Mandatory Accessibility Size Variable Coefficients

	Escort	Shop	Main	Visit	Eat	Disc	At work	Non Mandatory
Population	0.129							
Households		0.161	0.207	0.155	0.069	0.216		0.808
Agriculture, mining		0				0.144		0.144
Transportation, construction		0	0.06				0.021	0.081
Manufacturing, wholesale		0	0					
Retail, other services		1.327	0.552	0.068	0.38	0.187	0.09	2.604
Information, professional			0.085			0.061	0.07	0.216
Education, health	0.101	0.037	0.206	0.04	0.033	0.069	0.02	0.506
Finance, insurance, real estate					0.283		0.114	0.397
Food and hospitality	0.196	0.176	0.171	0.042	0.181	0.366	0.042	1.174
Public administration			0.087		0.097	0.027	0.018	0.229

Chapter 4 TRANSPORTATION NETWORKS

INTRODUCTION

The Year 2016 highway network went through an extensive review to examine network coding accuracy and to ensure proper network connectivity. The transit network was built directly off the highway network ensuring an integrated network approach.

Attributes for the Year 2016 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 2016 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 with these agencies were conducted to discuss coding conventions and to accept comments and revisions.

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.

HIGHWAY NETWORKS

In 2007-2008, SCAG conducted an extensive Highway Network Inventory Program to gather information on the regional highway network and to transfer attributes to SCAG 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. Subsequently, periodic detailed reviews and updates of the highway network have been completed using aerial photography to ensure the base year network accurately represents 2016 conditions. As part of the network inventory, primary and secondary attributes were geo-coded. Primary attributes are those identified as critical to the performance of the travel demand model.

Primary Attributes:

- Speed limits
- Number of lanes (by time period)
- Intersection control (at model nodes)
- Median type
- Directionality (one-way versus two-way streets)

Secondary Attributes:

- Linear reference system
- Shoulder type
- Other controlled Intersections
- Parking
- School zones
- Advisory speeds
- HOV access
- Ramp gore points
- Bike lanes

The highway network was prepared 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. The Year 2016 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 8:59 AM)
- Midday period (9:00 AM to 2:59 PM)
- PM peak period (3:00 PM to 6:59 PM)
- Evening period (7:00 PM to 8:59 PM)
- Night period (9:00 PM to 5:59 AM)

Facility Types

The facility type (FT) definitions used in SCAG's Year 2016 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 (Tier 1)
- FT 200 – Centroid connector (Tier 2)

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 (AT) of each link. Free flow speeds and capacities are presented in Table 4-1 through Table 4-6.

Table 4-1: Year 2016 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
Freeway 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
AT2: Central Business District
AT3: Urban Business District
AT4: Urban
AT5: Suburban
AT6: Rural
AT7: Mountain
PS = Posted Speed

Table 4-2: Year 2016 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 AT2: Central Business District AT3: Urban Business District

AT4: Urban AT5: Suburban AT6: Rural AT7: Mountain

Table 4-3: Year 2016 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 --			
		525	475	475
		675	550	550
6-Lane		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 2016 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 2016 Freeway Capacity

Type	Posted Speed (miles 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- 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 2016 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 2016 highway network incorporates all toll facilities, including the Metro Express Lanes on I-110 and I-10 in Los Angeles County, the SR-91 Express Lanes in Orange County, and the SR-73, SR-133, SR-241 and SR-261 toll roads in Orange County.

Heavy Duty Truck Designation

The Year 2016 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

The Year 2016 highway network includes 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 2016 Highway Network Summary

Table 4-7 summarizes the Year 2016 Highway Network by tallying the number of highway centerline and lane-miles represented in the network for each county and facility type. The centerline mile summary includes both directions of travel, even if the roadway is represented by two separate one-way links in the coded network. Figure 4-1 through Figure 4-3 depict the Year 2016 highway network by facility type and area type. Figure 4-4 shows the location of the external cordon sites at the modeling area's boundary.

Table 4-7: Year 2016 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	629	4,601	4,601	4,601	4,601	4,601
Orange	167	1,325	1,325	1,325	1,325	1,325
Riverside	308	1,765	1,765	1,765	1,765	1,765
San Bernardino	471	2,542	2,542	2,542	2,542	2,542
Ventura	94	534	534	534	534	534
Subtotal	**1,764**	**11,148**	**11,148**	**11,148**	**11,148**	**11,148**

Toll Facilities (including HOT)						
Imperial	0	0	0	0	0	0
Los Angeles	27	83	83	83	83	83
Orange	61	331	331	331	331	331
Riverside	0	1	1	1	1	1
San Bernardino	0	0	0	0	0	0
Ventura	0	0	0	0	0	0
Subtotal	**87**	**414**	**414**	**414**	**414**	**414**

County	Centerline Miles	Lane Miles				
		AM Peak	Midday	PM Peak	Evening	Night
Freeway (HOV)						
Imperial	0	0	0	0	0	0
Los Angeles	235	472	472	472	472	472
Orange	117	243	243	243	243	243
Riverside	49	99	99	99	99	99
San Bernardino	57	115	115	115	115	115
Ventura	4	8	8	8	8	8
Subtotal	**462**	**936**	**936**	**936**	**936**	**936**
Major Arterial						
Imperial	183	611	611	611	611	611
Los Angeles	1,944	8,367	8,376	8,367	8,374	8,376
Orange	694	3,551	3,551	3,551	3,551	3,551
Riverside	309	1,260	1,260	1,260	1,260	1,260
San Bernardino	532	1,804	1,804	1,804	1,804	1,804
Ventura	216	805	806	806	806	806
Subtotal	**3,877**	**16,398**	**16,409**	**16,399**	**16,406**	**16,408**
Minor Arterial						
Imperial	266	546	546	546	546	546
Los Angeles	2,873	8,970	8,968	8,970	8,965	8,964
Orange	784	2,769	2,769	2,769	2,769	2,769
Riverside	1,006	2,944	2,944	2,944	2,944	2,944
San Bernardino	1,442	3,864	3,864	3,864	3,864	3,864
Ventura	357	996	996	996	996	996
Subtotal	**6,728**	**20,090**	**20,087**	**20,089**	**20,083**	**20,083**
Collector						
Imperial	1,219	2,470	2,470	2,470	2,470	2,470
Los Angeles	3,229	6,906	6,905	6,905	6,904	6,906
Orange	408	1,003	1,003	1,003	1,003	1,003
Riverside	2,077	4,892	4,892	4,892	4,892	4,892
San Bernardino	2,894	6,155	6,154	6,154	6,154	6,154
Ventura	495	1,054	1,054	1,054	1,054	1,054
Subtotal	**10,322**	**22,479**	**22,478**	**22,478**	**22,477**	**22,479**

County	Centerline Miles	Lane Miles				
		AM Peak	Midday	PM Peak	Evening	Night
Total All Facilities (excluding truck, ramps, centroid connectors)						
Imperial	1,763	4,006	4,006	4,006	4,006	4,006
Los Angeles	8,937	29,399	29,406	29,399	29,399	29,403
Orange	2,229	9,222	9,222	9,222	9,222	9,222
Riverside	3,748	10,961	10,961	10,961	10,961	10,961
San Bernardino	5,396	14,479	14,478	14,478	14,478	14,479
Ventura	1,166	3,397	3,397	3,397	3,397	3,397
Total	**23,239**	**71,464**	**71,471**	**71,464**	**71,464**	**71,467**

Figure 4-1: Year 2016 Network by Facility Type

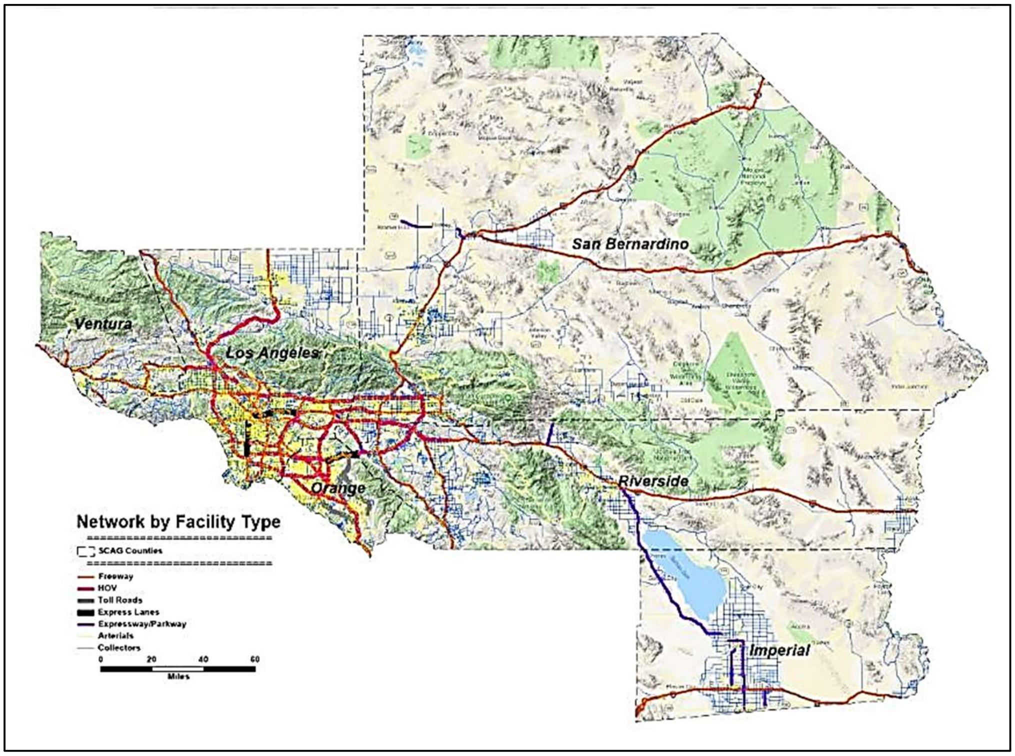


Figure 4-2: Year 2016 Modeling Area by Area Type

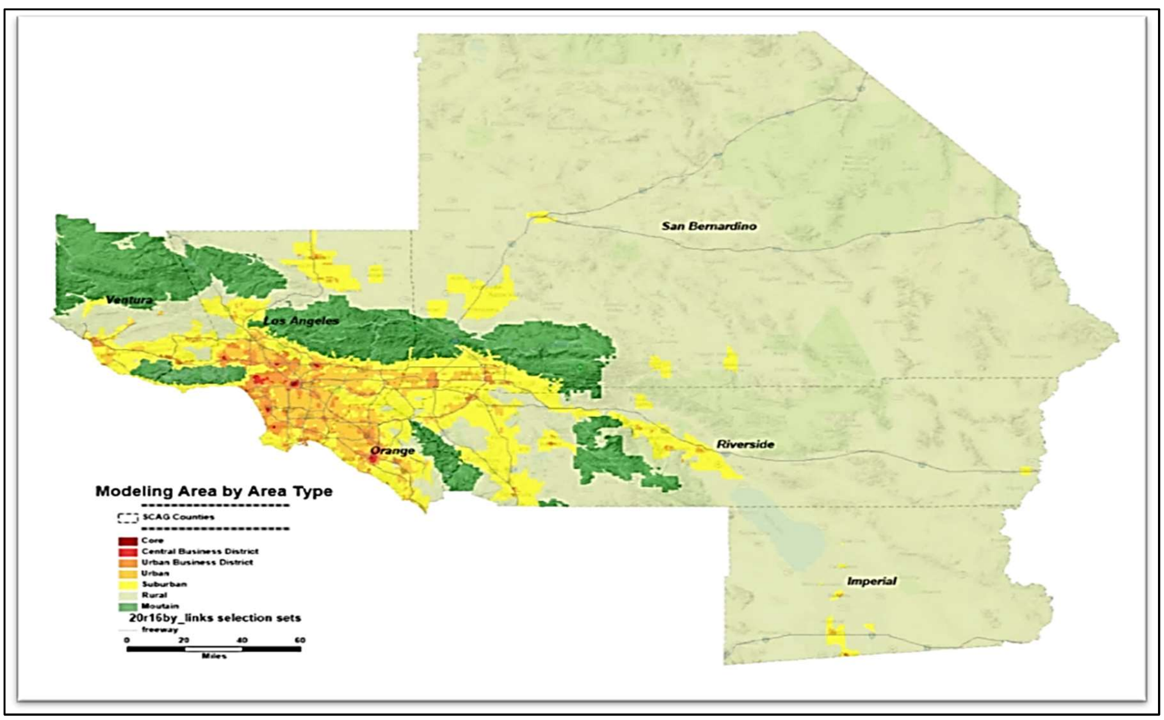


Figure 4-3: Year 2016 Network by Area Type

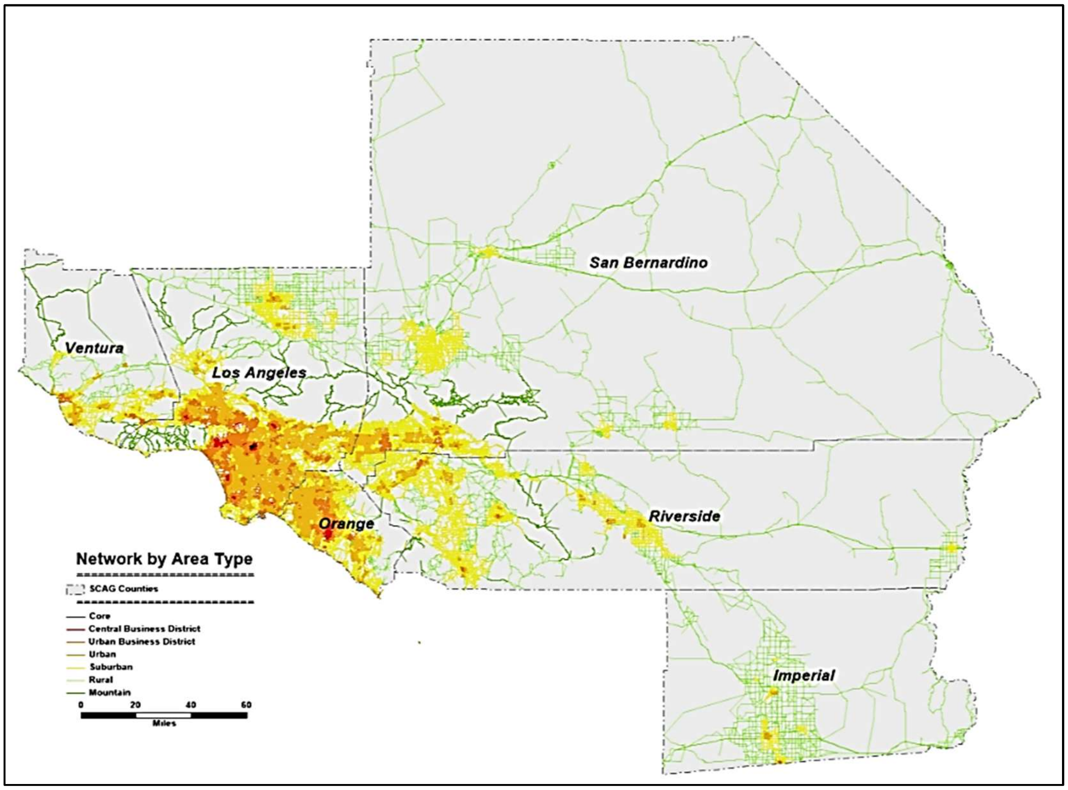
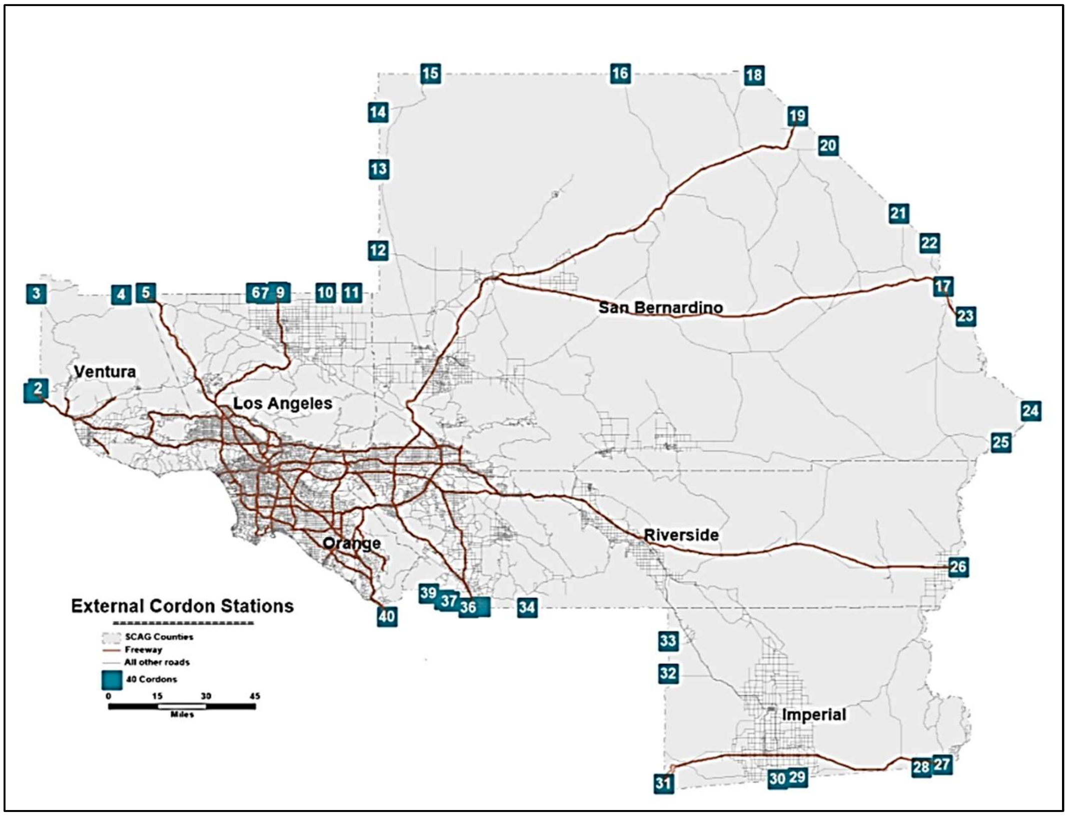


Figure 4-4: Modeling Area External Cordon Locations



TRANSIT NETWORKS

The Year 2016 transit network covers the entire SCAG region, with nearly 3,000 transit route patterns operated by more than 70 transit carriers in the six-county model area. The year 2016 transit network includes the following key features:

- For each transit carrier, GTFS (General Transit Feed Specification) data were converted to the TransCAD transit route systems.
- Route patterns that have different pairs of start and end stops were separated for more accurate calculation of average headways.
- Fares were coded at the route level, and fare factors were estimated at the carrier level to calculate average fares.
- Reflects transit operations by five times of day (AM, MD, PM, EVE, NT), rather than peak and off-peak.
- A U.S. street network is used 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.

Transit services in the SCAG region are grouped into six transit modes, based on their service characteristics and fare structures. An additional mode, High Speed Rail, has been added to future year networks. Four non-transit modes are used to represent walk and drive access and egress to the transit stops and stations. The Year 2016 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 average headway and frequency 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.

The following six transit modes are included in the Year 2016 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. As of 2016 Metro runs two subway lines (Red and Purple) and four light rail lines (Blue, Gold, Green and Expo).
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. Some express buses operate on a semi-dedicated right of way (busway, HOV lanes) with limited stops at freeway stations. These services are also referred to as Transitway buses. An example is the Metro Silver line.
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. Bus Rapid Transit (BRT) has limited stops, a dedicated guideway, distinctive branding and vehicles. In Year 2016, only the Metro Orange line is considered BRT.

Two types of transit access/egress links are coded in the Year 2016 transit network:

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

The Year 2016 transit network includes three types of transit fares: average initial boarding fares, average transfer fares, and average zonal fares:

- Published full cash fares at the route level are used as a base for initial boarding fares. To take complex fare structures into account, such as one-way walkup fares, daily/weekly/monthly passes, senior/student/disabled fares, and other special fares, fare factors at the carrier level were estimated from boarding and revenue data that SCAG collected through the Year 2008

Transit Level of Service Data Collection Program. By applying the fare factors to the published full cash fares, the resulting fares represent initial boarding fares paid by an average passenger.

- Average transfer fares are defined at the transit mode level through a mode-to-mode transfer table. For example, the transfer fares from Metrolink to Urban Rail are specified as free in the transfer table.
- The commuter rail service, Metrolink, has a distance-based zonal fare structure. To specify the station-to-station fares, a fare matrix was developed with fares paid by an average rider reflecting all discount types.

All fare types (average initial boarding fares, average transfer fares, and average zonal fares) 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.

Year 2016 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 4-5 shows the geographic distribution of the existing rail transit network (Metrolink and Local Rail). Figure 4-6 shows the entire Year 2016 transit network.

Table 4-8: Year 2016 Transit Network Route Patterns and Route Pattern Miles

Mode ID	Mode Number	Description	Route Patterns		Route Pattern Miles	
			Peak	Off Peak	Peak	Off Peak
10	1CR	Commuter Rail	28	27	1,769	1,868
11	2LR	Local Rail	15	16	265	286
20-22	3EX	Express Bus	126	68	3,771	1,943
33	4RB	Rapid Bus	78	68	1,196	1,034
30-32	5LB	Local Bus	1,659	1,411	22,334	19,352
23	6TW	Transitway	42	28	1,157	786
19	7BR	Bus Rapid Transit	6	6	75	75
Total			**1,954**	**1,624**	**30,568**	**25,345**

Figure 4-5: Year 2016 Metrolink and Local Rail Network

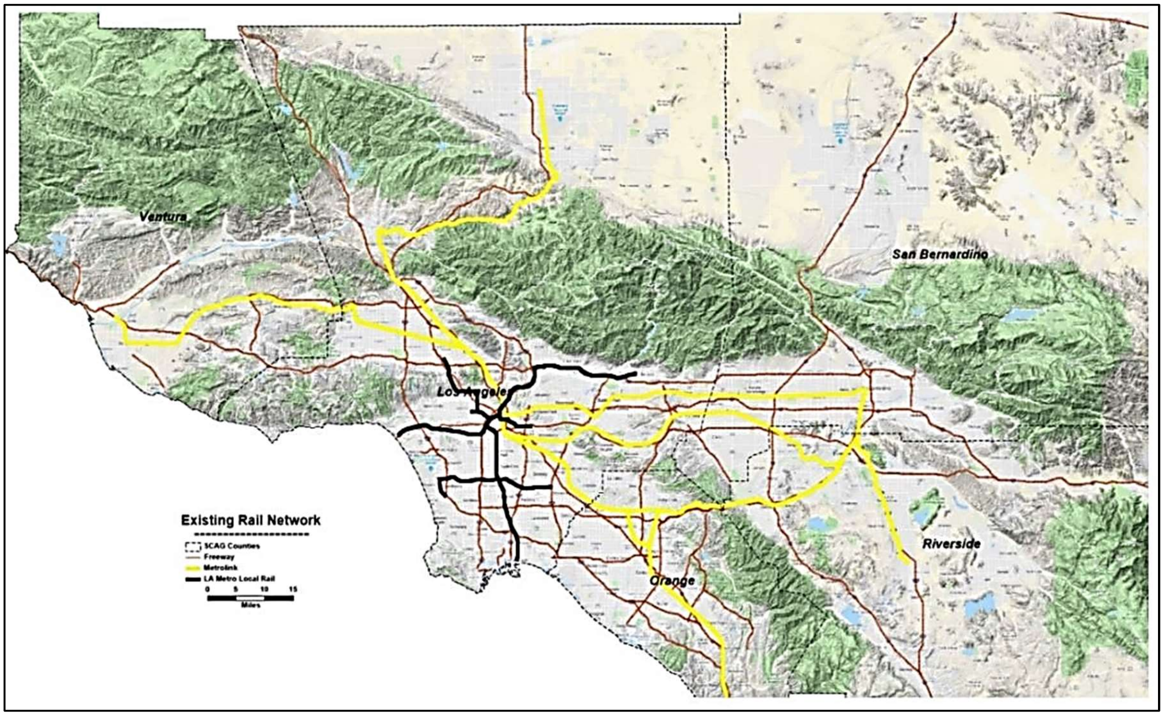
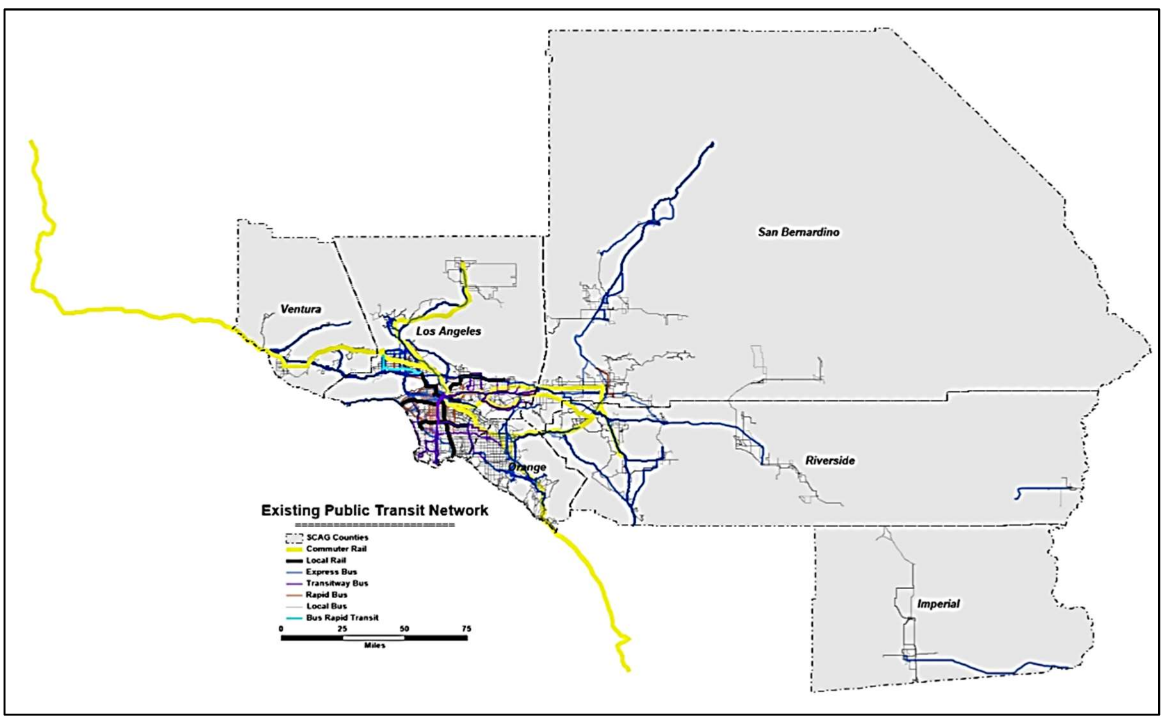


Figure 4-6: Year 2016 Rail and Bus Transit Network



Chapter 5 Long Term Choice

INTRODUCTION

The long-term choice module of the SCAG ABM includes the following sub-models: Usual Work Arrangements, Usual Workplace Location Choice, Usual School Location Choice, fully segmented by type of student—pre-school students, grade school students and college/university students, and Usual Work Schedule Flexibility.

USUAL WORK ARRANGEMENTS

The usual work arrangement model (model 2.2.1) simultaneously predicts three responses – (i) the weekly work hours for the primary job, (ii) the number of jobs, and (iii) the primary workplace location type. It applies to all workers in a household, including student workers. This model takes the form of a multinomial logit model, with choice alternatives defined by all possible combinations of the three main response variables. The categories defined for each response variable are defined below. The number of alternatives is the Cartesian product of these categories, for a total of 18 choices (3*2*3).

Weekly work duration on primary job	Primary workplace location type	Number of jobs
• Less than 20 hours • 21-34 hours • 35 or more hours	• Fixed work place • Home • Variable work place	• One job • Multiple jobs

The model was calibrated to the proportions of workers by type of workplace reported by the American Community Survey (ACS), 2011-2015 release. Table 5-1 shows the proportion of workers by workplace type for various household income levels, while Figure 5-1 and Figure 5-2 show the calibration results of the two other joint decisions, compared to data from the 2011 California Household Travel Survey (CHTS).

Table 5-1: Workers by Work Location Type

		Household Income (% of Households)				
		< $35k	$35k-$75k	$75k-$150k	>$150k	All
ACS 2011 -2015	Fixed	73.4	84.4	84.4	86.4	82.7
	Home	7.1	4.5	4.5	4.3	5.0
	Variable	19.5	11.0	11.0	9.3	12.3
Predicted	Fixed	82. 3	84.0	83.8	81.6	83.2
	Home	8.2	6.2	6.9	10.0	7.5
	Variable	9.6	9.8	9.3	8.4	9.3
Difference	Fixed	8.9	-0.5	-0.6	-4.8	0.5
	Home	1.0	1.7	2.3	5.7	2.5
	Variable	-9.9	-1.2	-1.7	-0.9	-3.0

Figure 5-1: Work Duration Calibration Results

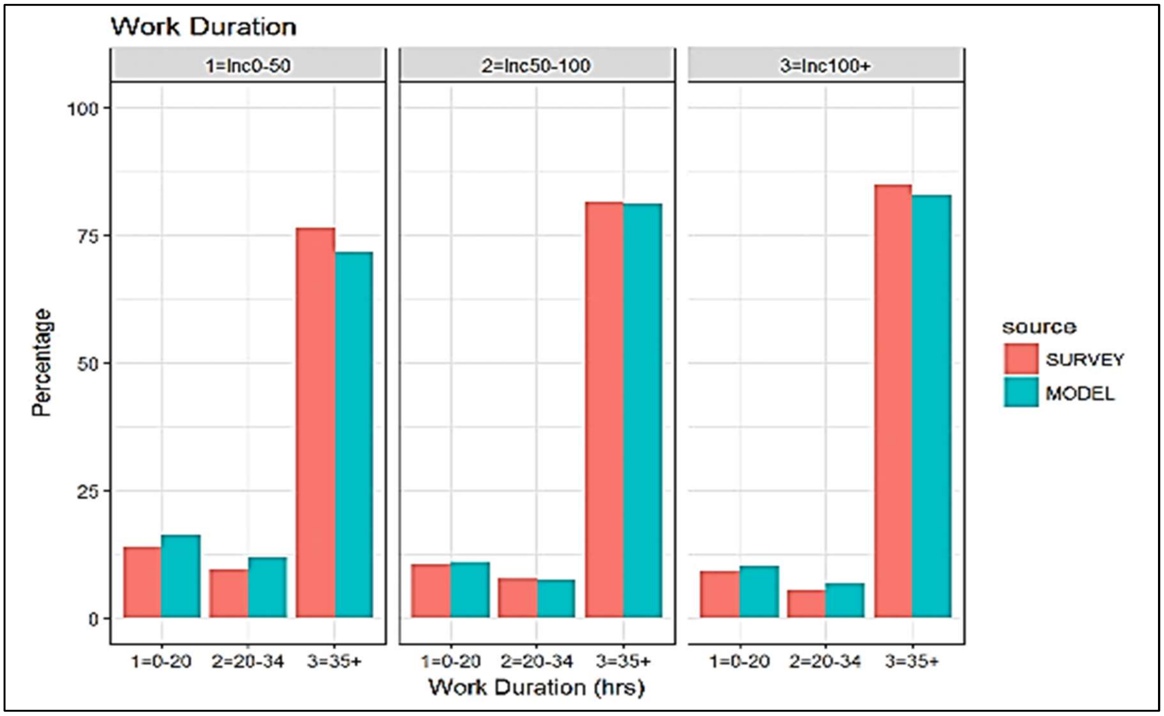
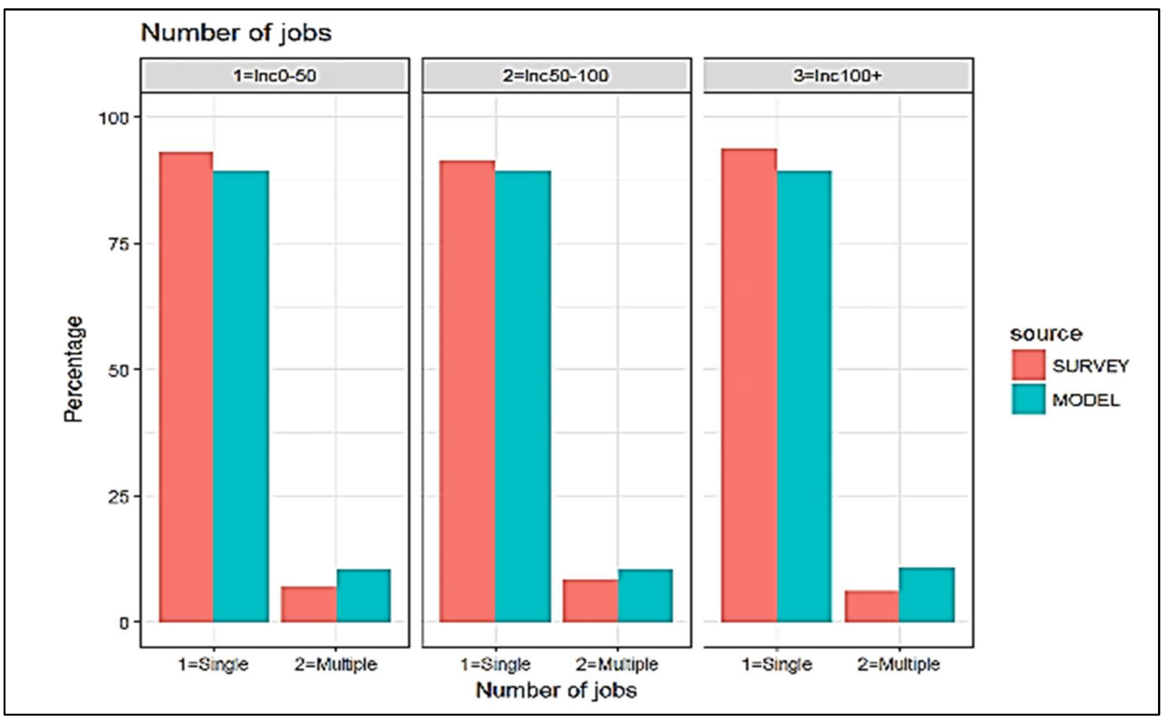


Figure 5-2: Number of Jobs Calibration Results



Usual Work Location Choice

The usual workplace location choice model assigns a workplace TAZ to every employed person in the synthetic population that does not work from home. That is, only workers with fixed or variable workplace type, as determined by the work arrangements model, are exposed to the usual work location model. The model takes the form of a multinomial logit destination choice model with size terms. Work location is segmented by nine industry categories. The size term or attraction variable is the number of jobs in each industry class in each TAZ. The total number of workers assigned to each TAZ is tracked for each industry, and it is constrained to not exceed the number of available jobs.

The workplace location model was compared to trip length frequency information obtained from the 2011 CHTS and the 2014 Longitudinal Employment – Household Dynamics (LEHD) dataset, and County-to-County flows obtained from the 2011 CHTS and 2011-2015 Census Transportation Planning Product (CTPP). The LEHD data was used to calibrate the tail of the trip length distribution, because there were few observations of these long commute patterns captured in the CHTS. These comparisons are shown below.

Table 5-2: Average Commute Distance

Distance Range (mi)	Commute Shares			Average Distance (mi)		
	CHTS	**LEHD**	**Model**	**CHTS**	**LEHD**	**Model**
0-30	81.2%	78.0%	83.9%	9.4	10.9	10.8
30-60	16.7%	14.9%	11.8%	40.4	42.1	40.8
60-90	1.4%	4.5%	1.2%	68.9	75.0	72.3
90+	0.7%	2.7%	3.1%	n/a	134.3	130.2
Region	**100%**	**100%**	**100%**	**12.5**	**20.6**	**17.1**

Figure 5-3: Home to Work Distance

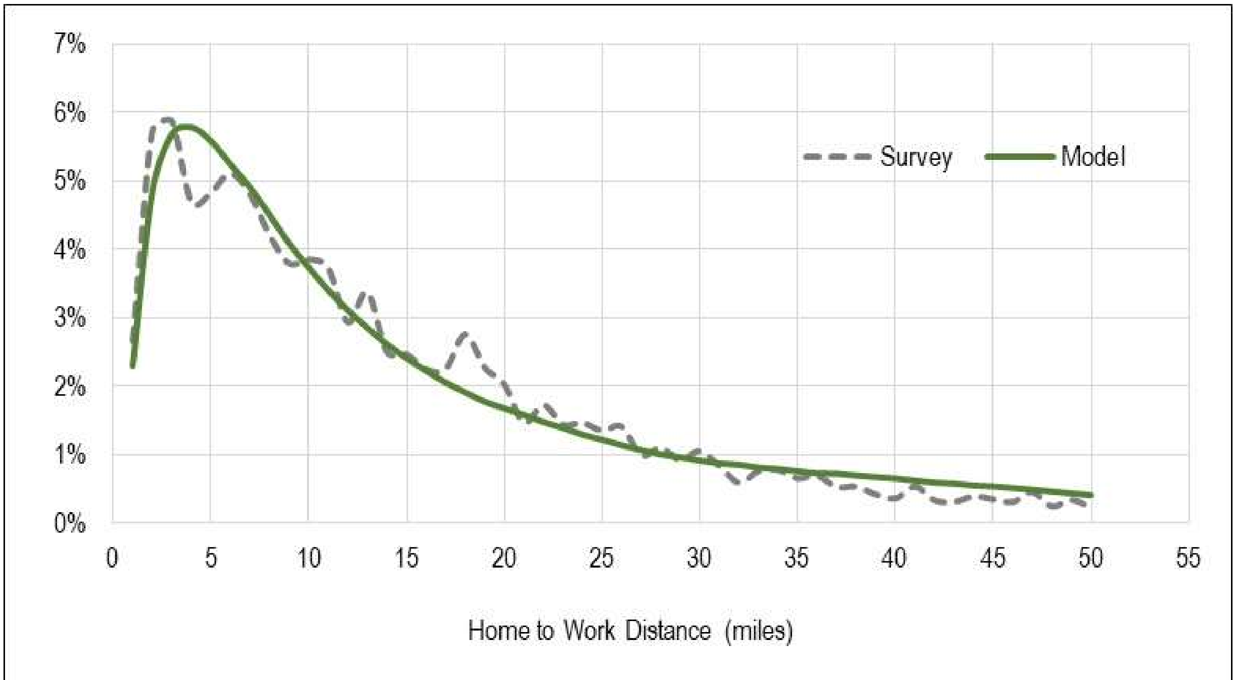


Table 5-3: County-to-County Workers Flows

Worker Flows, ACS 2008-2012								
	County	**IM**	**LA**	**OR**	**RIV**	**SB**	**VN**	**Sum**
25	Imperial	97.1%	0.2%	0.0%	2.5%	0.3%	0.0%	100%
37	Los Angeles	0.0%	93.1%	4.4%	0.3%	1.3%	0.9%	100%
59	Orange	0.0%	13.4%	84.5%	1.1%	1.0%	0.1%	100%
65	Riverside	0.1%	6.5%	9.4%	71.9%	12.1%	0.1%	100%
71	San Bernardino	0.0%	17.8%	4.6%	8.3%	69.2%	0.1%	100%
111	Ventura	0.0%	19.3%	0.3%	0.1%	0.1%	80.2%	100%
Worker Flows, LEHD 2015								
	County	**IM**	**LA**	**OR**	**RIV**	**SB**	**VN**	**Sum**
25	Imperial	80.2%	7.8%	3.1%	6.1%	2.1%	0.6%	100%
37	Los Angeles	0.0%	86.2%	8.2%	1.4%	2.7%	1.5%	100%
59	Orange	0.0%	23.7%	70.0%	2.9%	2.8%	0.6%	100%
65	Riverside	0.6%	14.8%	14.3%	54.3%	15.4%	0.7%	100%
71	San Bernardino	0.1%	26.3%	10.2%	11.6%	51.1%	0.7%	100%
111	Ventura	0.0%	34.8%	4.7%	1.1%	1.5%	57.8%	100%

Worker Flows, 2016 Model Estimate								
	County	IM	LA	OR	RIV	SB	VN	Sum
25	Imperial	97.8%	0.0%	0.0%	2.2%	0.0%	0.0%	100%
37	Los Angeles	0.0%	86.9%	4.8%	2.3%	3.6%	2.4%	100%
59	Orange	0.0%	16.6%	75.6%	4.5%	3.0%	0.2%	100%
65	Riverside	0.1%	10.3%	14.3%	63.1%	12.1%	0.1%	100%
71	San Bernardino	0.0%	17.2%	8.6%	12.7%	61.4%	0.2%	100%
111	Ventura	0.0%	28.8%	0.1%	0.4%	0.6%	70.0%	100%

Table 5-4: Sub Air Basin to County Work Trip Validation

Worker Flows, 2008-2012 ACS							
Sub Air Basin	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura	SCAG
SCCAB (VENTURA COUNTY)	84	87,868	196	1,208	1,518	201,331	292,205
SCAB (LOS ANGELES COUNTY)	388	3,449,520	246,525	92,754	161,283	102,313	4,052,783
MDAB (ANTELOPE VALLEY)	185	293,229	1,097,781	71,994	47,563	3408	1,514,160
SCAB (ORANGE COUNTY)	131	69,466	94,256	282,236	87,008	480	533,577
SCAB (RIVERSIDE COUNTY)	55	126,158	63,811	85,085	282,630	1090	558,829
MDAB (RIV DESERT)	13	130,971	33	400	5,108	482	137,007
MDAB (BLYTHE)	21	8,563	354	17,972	117,711	127	144,748
SSAB (COACHELLA VALLEY)	0	20	0	0	506	0	526
SCAB (SAN BERNARDINO CO)	1	30	0	386	4,192	0	4,609
MDAB (VICTOR VALLEY)	0	0	0	181	0	0	181
MDAB (SBD DESERT)	32	0	0	3,588	2	0	3,622
MDAB (SEALES VALLEY)	399	1	0	114,751	3,033	0	118,184
SSAB (IMPERIAL/WEST)	4,508	0	0	874	1	0	5,383
SSAB (IMPERIAL/EAST)	896	0	0	47	0	0	943
SSAB (IMPERIAL PM2.5 NON-ATT)	53,798	0	0	356	8	0	54,162
SCAG Region	**60,511**	**4,165,826**	**1,502,956**	**671,832**	**710,563**	**309,231**	**7,420,919**

Worker Flows, Model							
Sub Air Basin	**Imperial**	**Los Angeles**	**Orange**	**Riverside**	**San Bernardino**	**Ventura**	**SCAG**
SCCAB (VENTURA COUNTY)	79	84,279	425	1,266	1,768	204,613	292,430
SCAB (LOS ANGELES COUNTY)	465	3,513,152	202,455	96,519	141,591	98,465	4,052,647
MDAB (ANTELOPE VALLEY)	175	251,527	1,145,712	68,439	45,688	3,357	1,514,898
SCAB (ORANGE COUNTY)	118	67,735	93,655	295,079	76,285	547	533,419
SCAB (RIVERSIDE COUNTY)	75	113,440	60,084	72,374	311,675	1,144	558,792
MDAB (RIV DESERT)	9	127,762	121	599	7,629	1,022	137,142
MDAB (BLYTHE)	36	8,110	562	17,310	118,311	119	144,448
SSAB (COACHELLA VALLEY)	-	16	-	-	521	-	537
SCAB (SAN BERNARDINO CO)	-	34	-	399	4,192	-	4,625
MDAB (VICTOR VALLEY)	-	-	-	173	-	-	173
MDAB (SBD DESERT)	24	-	-	3,603	3	-	3,630
MDAB (SEALES VALLEY)	471	4	4	114,739	2,946	-	118,164
SSAB (IMPERIAL/WEST)	4,493	-	-	891	1	-	5,385
SSAB (IMPERIAL/EAST)	866	-	-	48	-	-	914
SSAB (IMPERIAL PM2.5 NON-ATT)	53,723	-	-	366	5	-	54,094
SCAG Region	**60,534**	**4,166,059**	**1,503,018**	**671,805**	**710,615**	**309,267**	**7,421,298**

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 (SAN BERNARDINO CO)	1.7%	1.3%	0.9%	6.8%	-10.8%	0.1%	0.0%
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%**

Usual School Location

The usual school location model is fully segmented by type of student, as follows: pre-school students, kindergarten to 8th grade school students, 9th grade to 12th grade students, and college/university students. All sub-models take the form of destination choice models. The size term for the grade school and college/university models is the number of enrolled students at the school location; for pre-school students, the model uses a composite term that considers education employment and households.

Table 5-5: Average Home to School Distance (miles)

School Segment	Observed	Estimated
Pre-School	3.3	4.1
Grade K to 8th	3.4	2.9
Grade 9th to 12th	4.1	4.0
College/University	11.5	13.8

Figure 5-4: Usual School Location Calibration, Preschool

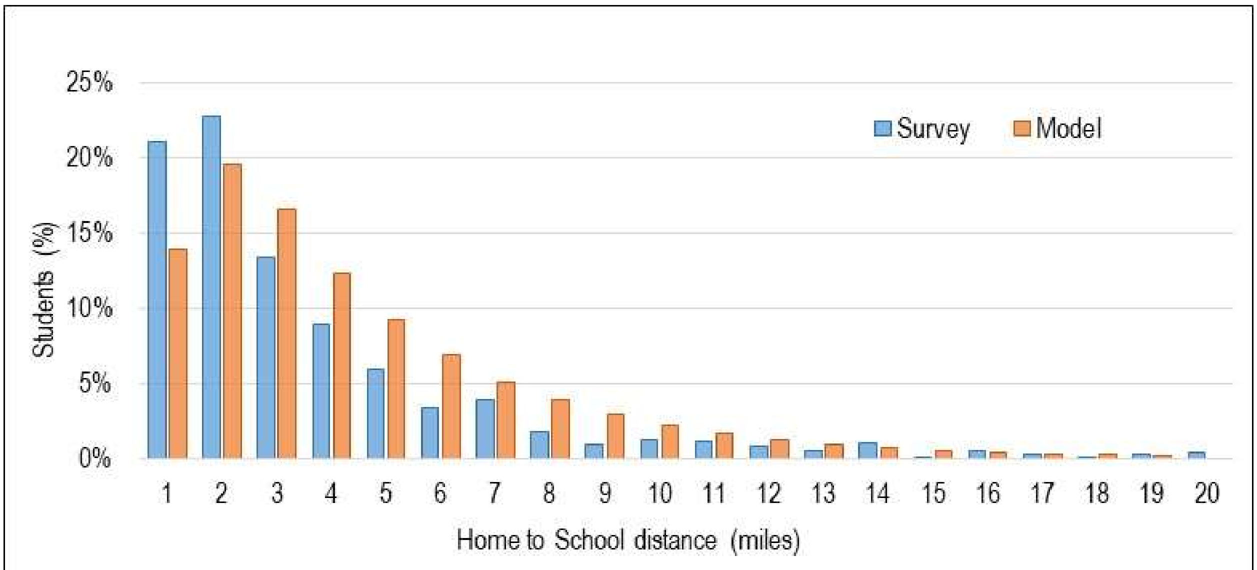


Figure 5-5: Usual School Location, Grade k-8 Students

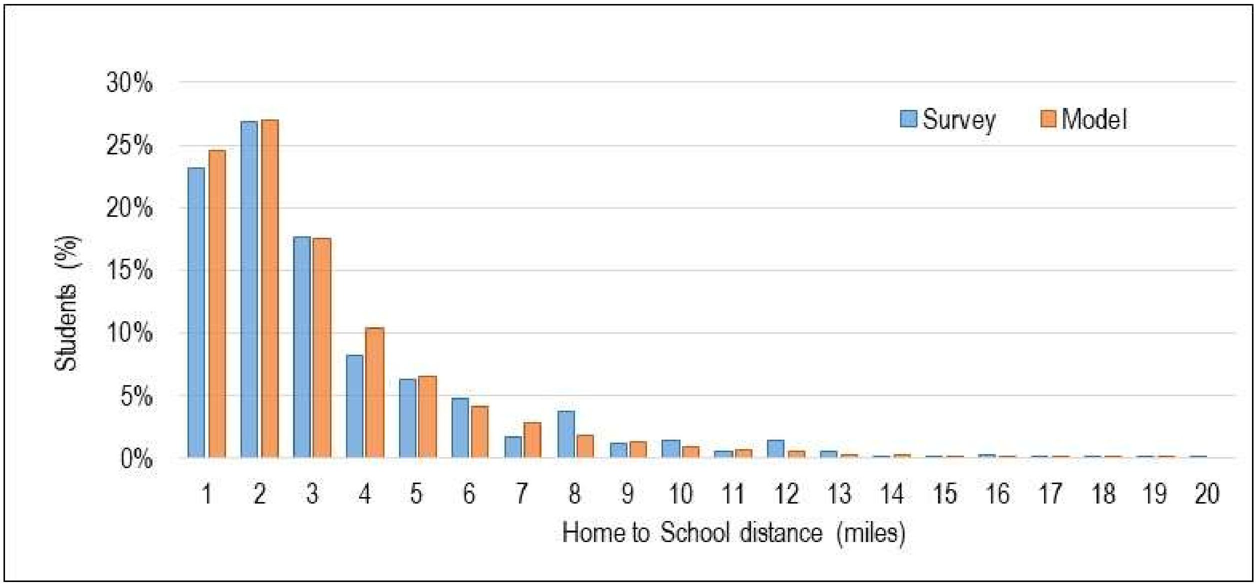


Figure 5-6: Usual School Location, Grade 9-12 Students

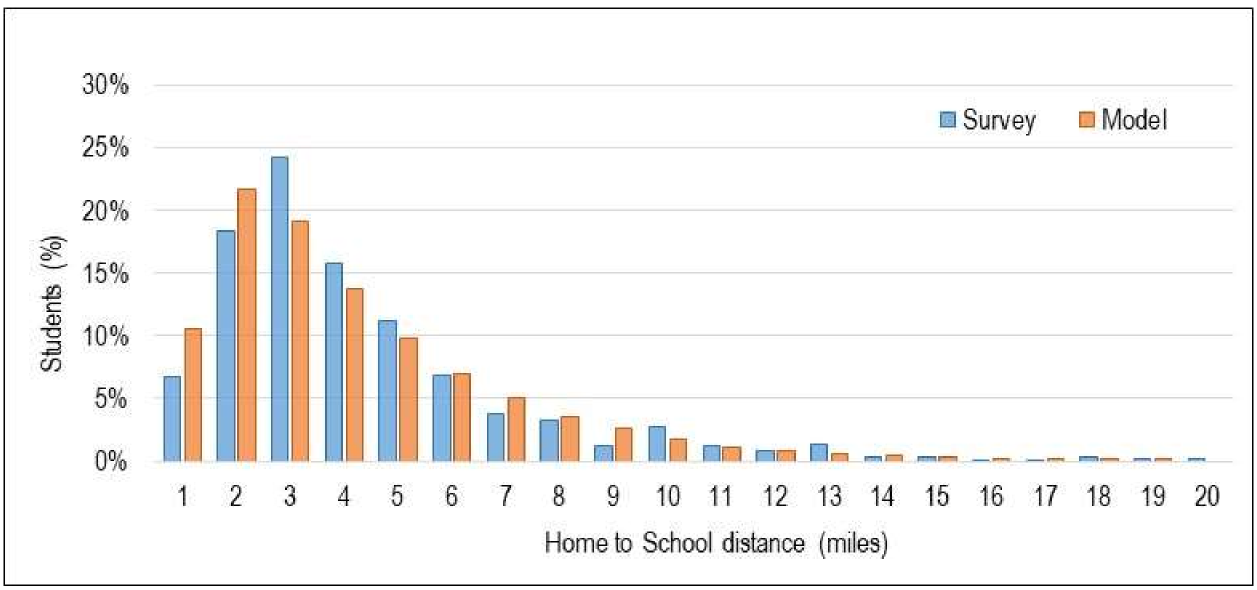
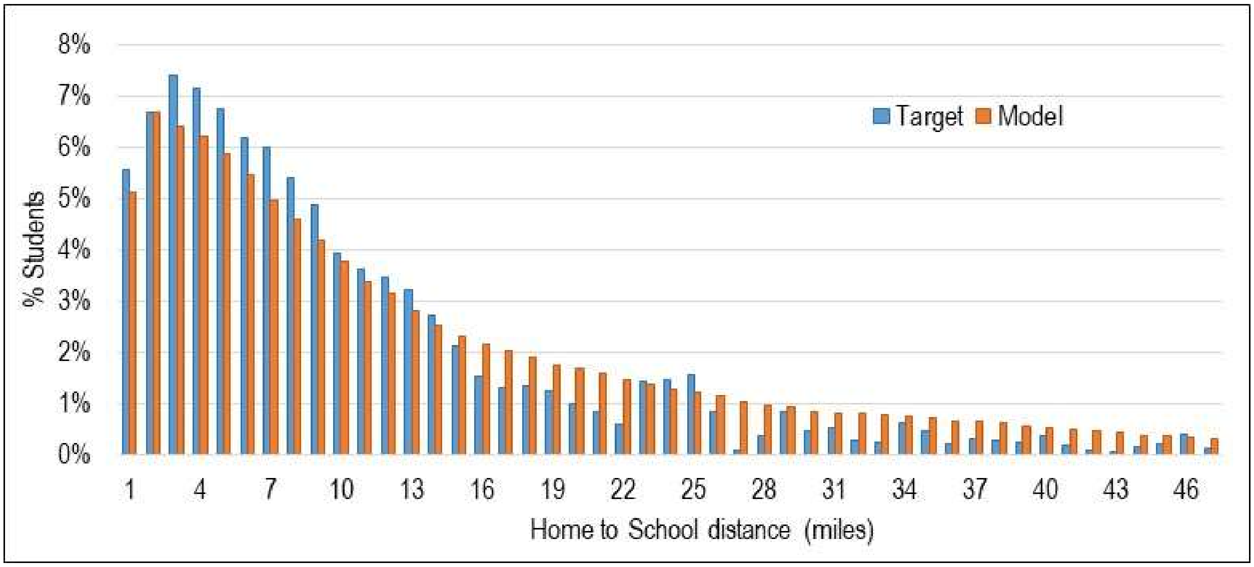


Figure 5-7: Usual School Location Calibration, College/University Students



Usual Work Schedule Flexibility

The usual work schedule flexibility model simultaneously predicts three responses – (i) number of days per week working at primary job, (ii) work flexibility at primary job, and (iii) the availability of compressed week option at primary job. It applies to all the workers in a household, including student workers. This model takes the form of a multinomial logit model, with choice alternatives defined by all possible combinations of the three main response variables. The categories defined for each response variable are shown below. The number of alternatives is the Cartesian product of these categories, for a total of 18 choices (3×3×2).

Number of days per week	Work scheduling flexibility	Compressed week option
• Five days per week • Less than five days per week • More than five days per week	• None • Moderate • High	• Available • Not available

The model was calibrated to the proportions exhibited by the 2011 CHTS, separately for full-time and part-time workers. The model calibration results are shown in Figure 5-8 to Figure 5-10.

Figure 5-8: Numbers of Days at Work, Observed and Predicted

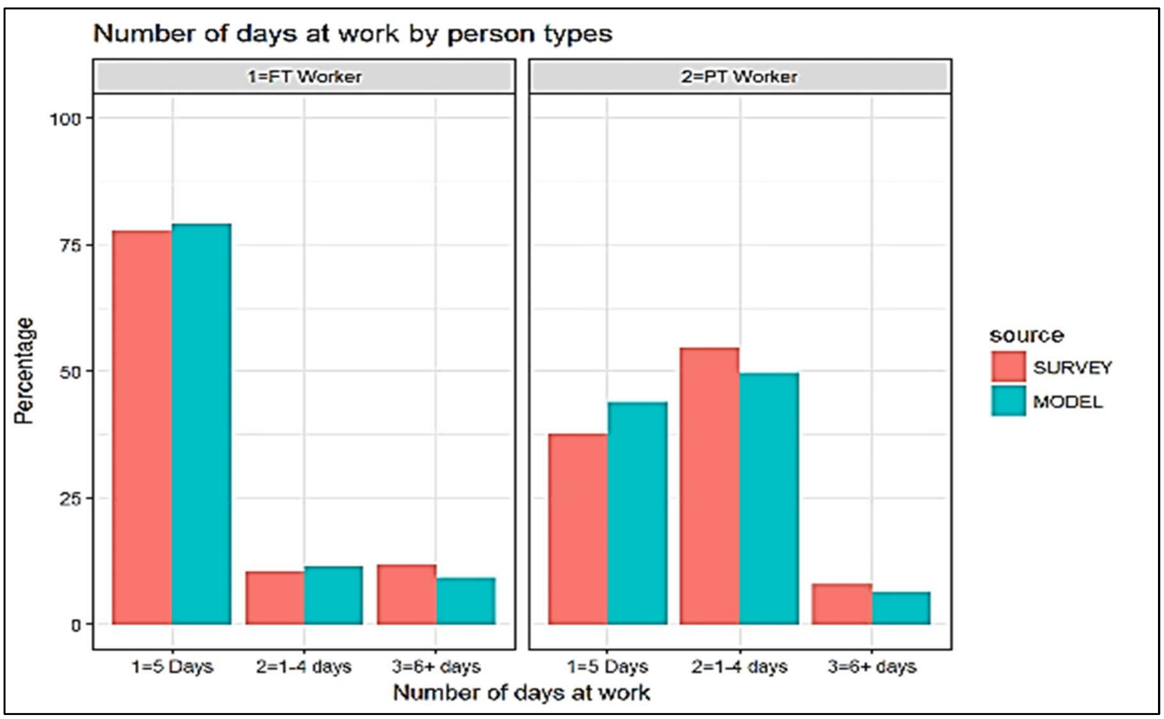


Figure 5-9: Work Schedule Flexibility, Observed and Predicted

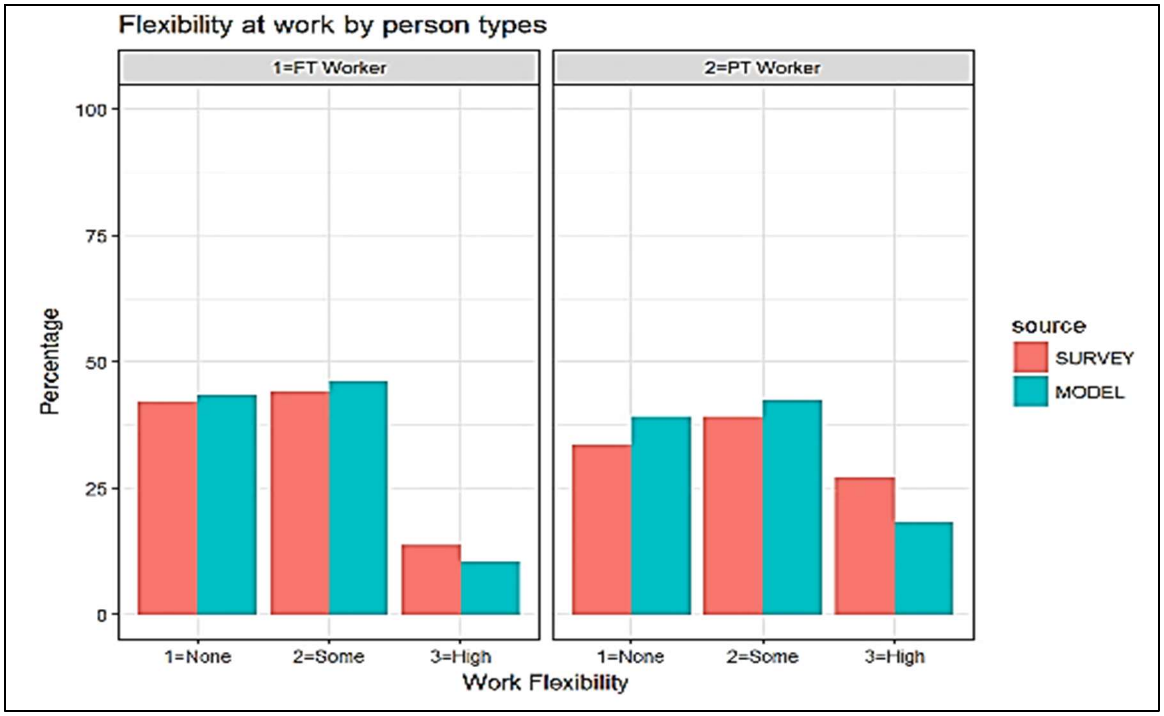
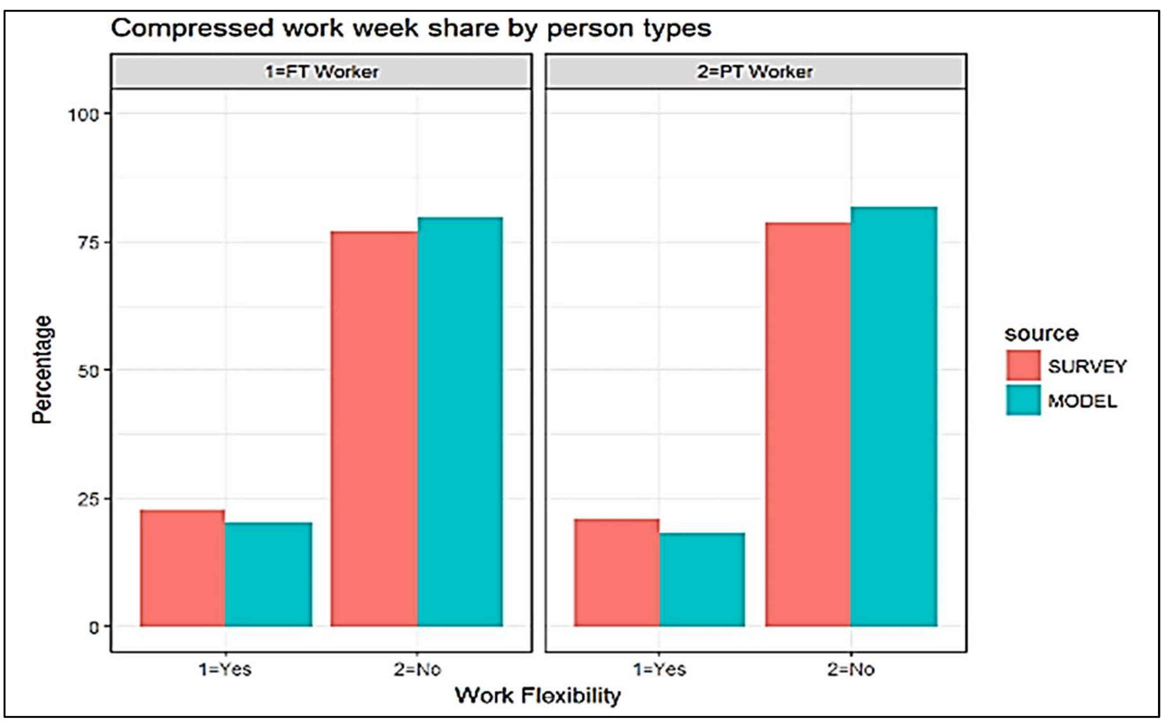


Figure 5-10: Availability of Compressed Work Schedules, Observed and Predicted



Chapter 6 Mobility Choice

Driver License

The driver license model (model 3.1) predicts whether an individual holds a valid driver's license or not. It applies to all persons 16 years old and older. The model takes the form of a binary logit model. The utility of the "no driver license" choice is assumed equal to zero. Variables that explain possession of a driver license include household and individual socio-demographics, land use and built environment characteristics of the home zone, and accessibility from the home zone to non-mandatory opportunities using different modes. A summary of the model results by person type is shown in Figure 6-1, and the validation to Department of Motor Vehicle registrations is shown in Table 6-1.

Figure 6-1: Driver License Holding by Person-Type, Observed and Predicted

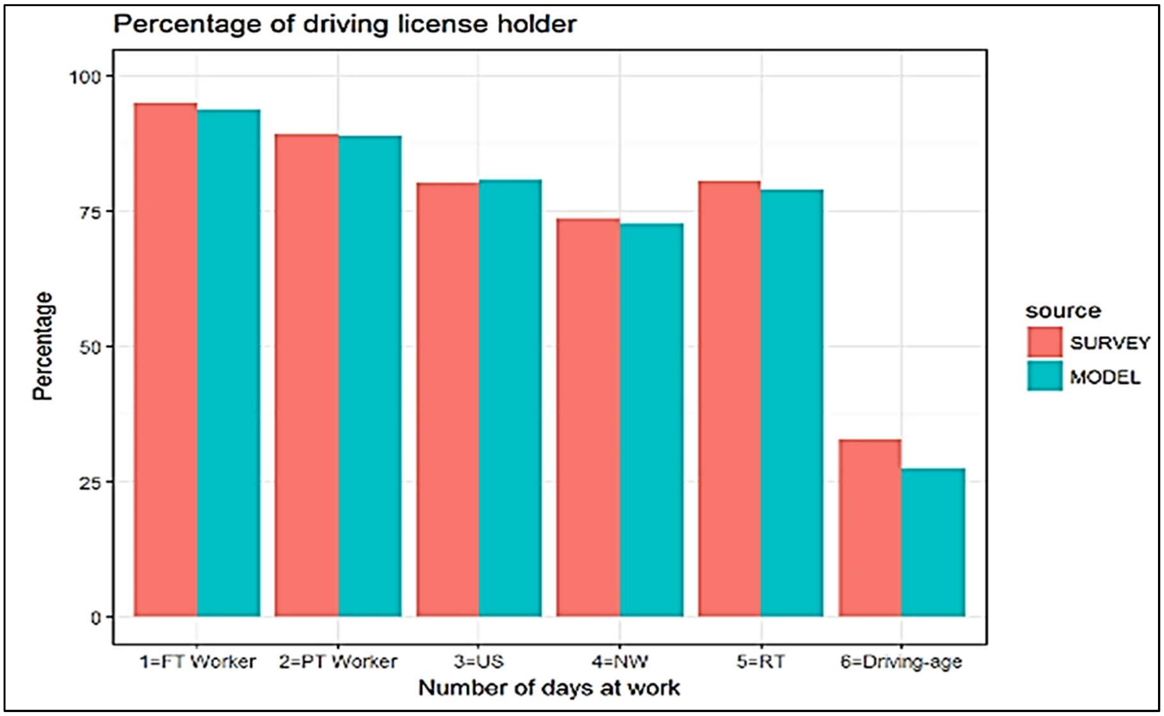


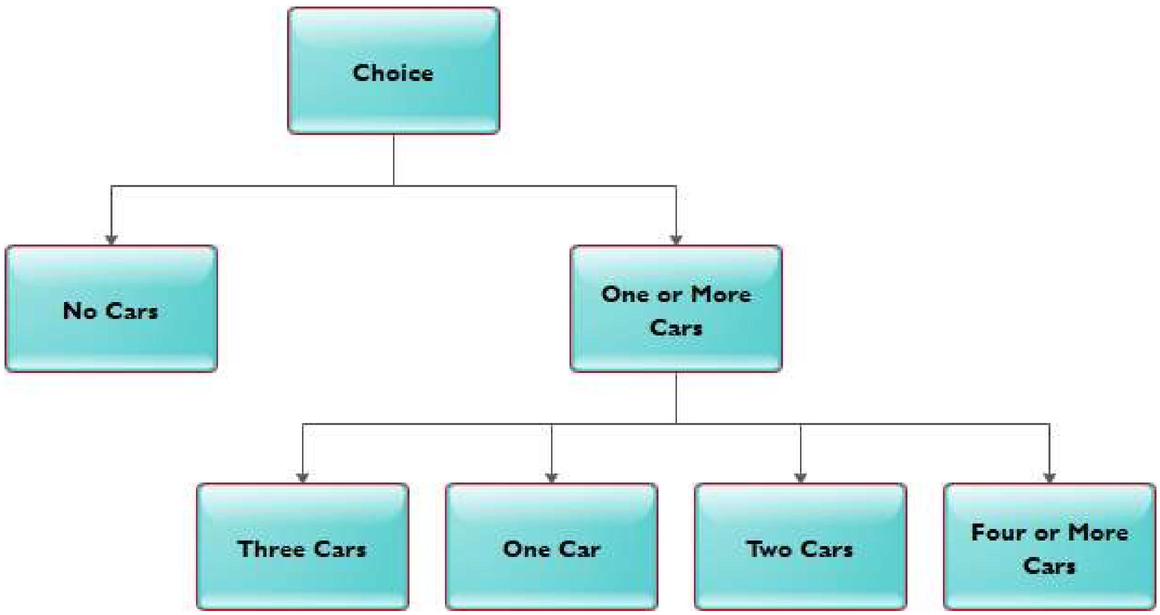
Table 6-1: Validation of Licensed Drivers Prediction, Year 2016

Residence County	Registered Drivers CA Department of Motor Vehicles	Predicted Driver Licensed Persons	Difference
Imperial	116,404	104,767	90%
Los Angeles	6,591,324	6,498,534	99%
Orange	2,274,825	2,208,883	97%
Riverside	1,519,434	1,513,043	100%
San Bernardino	1,370,722	1,336,859	98%
Ventura	608,734	581,158	95%
Total	**12,481,443**	**12,243,244**	**98%**

AUTO OWNERSHIP

The auto ownership model (model 3.2) predicts the number of cars, light-duty trucks and motorcycles owned by each household. It applies to all households in the synthetic population. The model was estimated with approximately 20,000 observations (household records) from the 2011 CHTS. The model takes the form of a nested logit model, with nesting structure shown in Figure 6-2.

Figure 6-2: Auto Ownership Model Nesting Structure



Auto ownership is explained as a function of household socio-demographics, work and school location of constituent household members, land use and built environment characteristics of home zone, and accessibility using different modes to non-mandatory activities from home zone.

Some of the household composition variables are stratified using car sufficiency. Car sufficiency is calculated as the difference between the number of cars owned by the household and the number of people with valid driving license in a household.

MODEL CALIBRATION AND VALIDATION

Table 6-2 shows a comparison of the model predicted car ownership to household auto ownership by county of residence from the 2011-2015 ACS. As shown, the model reproduces well the observed car ownership pattern in each county. The validation of household auto ownership segmented by number of licensed drivers is shown in Figure 6-3. This comparison also shows a good correspondence between the observed proportions, which were obtained from the 2011 CHTS, and the model predictions.

The model predictions were also compared to vehicle registrations obtained from the Department of Motor Vehicles (DMV). The total predicted number of vehicles owned by households in the region, including motorcycles, is approximately 92% of the vehicles registered at the DMV in 2016. Rental cars and institutional fleets such as police cars are not included in the DMV estimate.

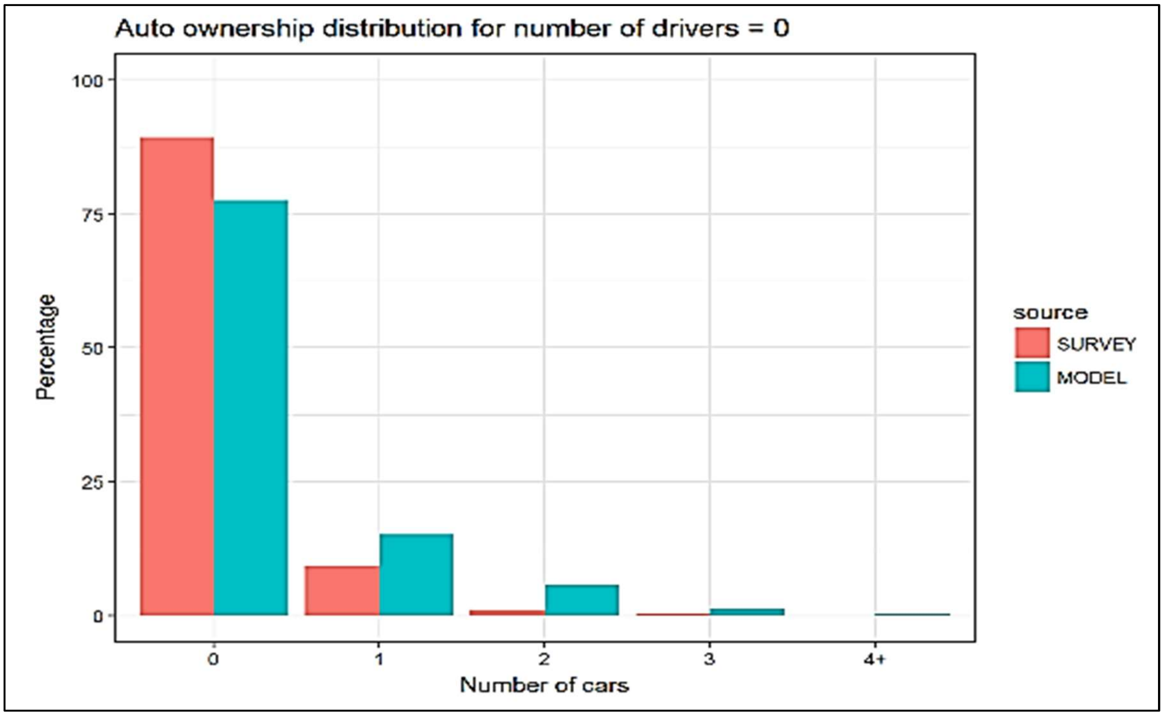
Table 6-2: Year 2016 Auto Availability Forecast – County of Residence Validation

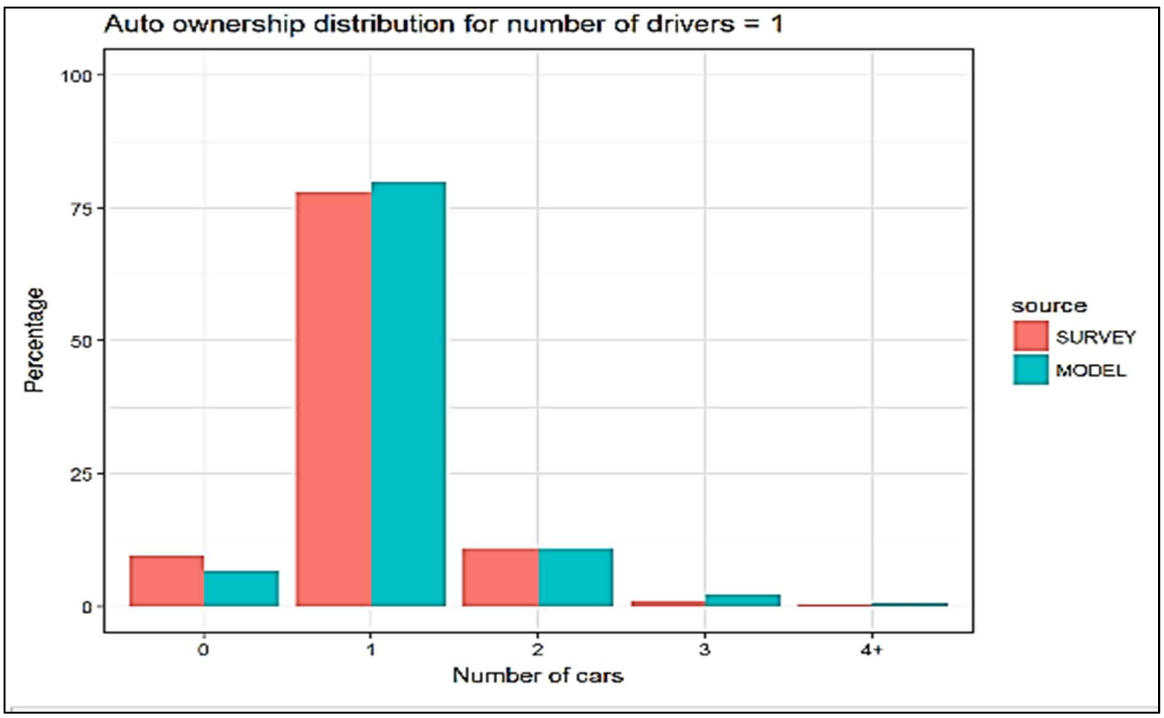
ACS 2011-2015 Auto Availability						
Residence County	**0 Cars**	**1 Car**	**2 Cars**	**3 Cars**	**4+ Cars**	**Total**
Imperial	4.6%	25.9%	42.5%	14.1%	12.9%	100.0%
Los Angeles	8.7%	32.1%	37.8%	14.2%	7.1%	100.0%
Orange	3.2%	27.8%	41.0%	17.5%	10.4%	100.0%
Riverside	3.8%	27.8%	40.0%	18.0%	10.4%	100.0%
San Bernardino	3.4%	28.6%	36.3%	22.3%	9.4%	100.0%
Ventura	6.4%	30.0%	38.8%	16.3%	8.6%	100.0%
Total	**6.5%**	**30.4%**	**38.5%**	**16.2%**	**8.4%**	**100.0%**

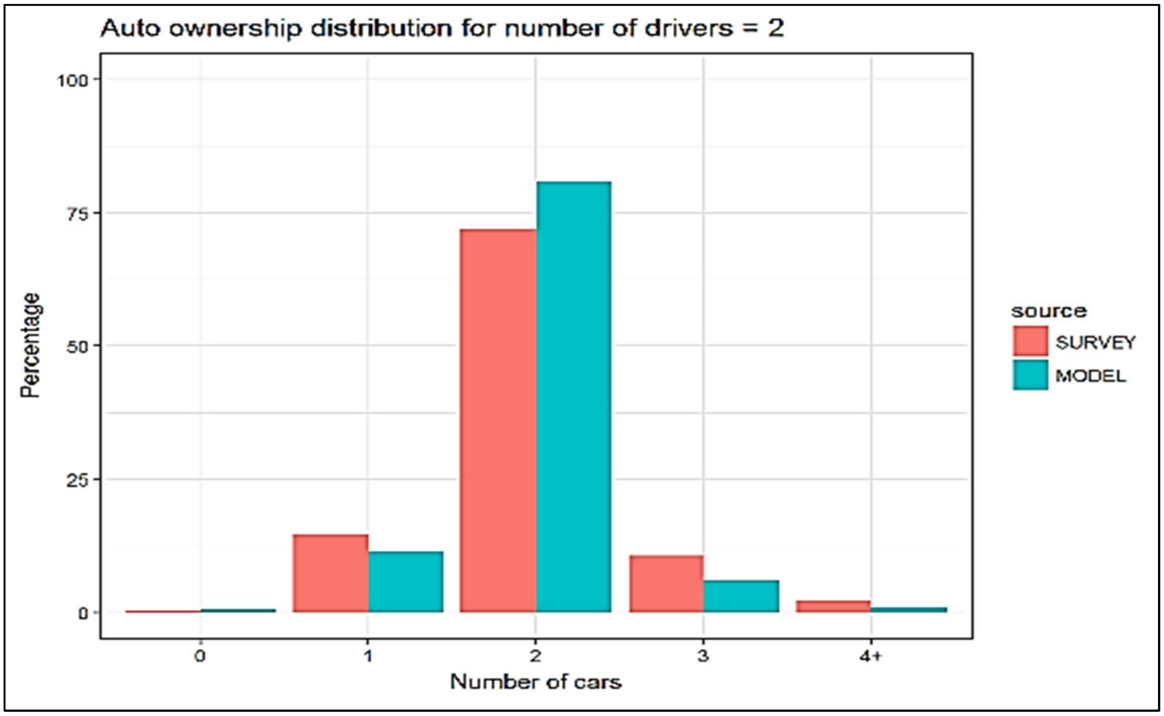
2016 Model Forecast						
Residence County	**0 Cars**	**1 Car**	**2 Cars**	**3 Cars**	**4+ Cars**	**Total**
Imperial	4.4%	26.7%	42.7%	16.8%	9.3%	100.0%
Los Angeles	8.1%	34.0%	36.5%	14.6%	6.8%	100.0%
Orange	3.3%	28.8%	42.9%	16.7%	8.4%	100.0%
Riverside	3.1%	29.0%	40.6%	18.3%	9.0%	100.0%
San Bernardino	3.6%	30.2%	39.4%	18.1%	8.8%	100.0%
Ventura	6.3%	30.0%	37.7%	17.4%	8.4%	100.0%
Total	**4.4%**	**26.7%**	**42.7%**	**16.8%**	**9.3%**	**100.0%**

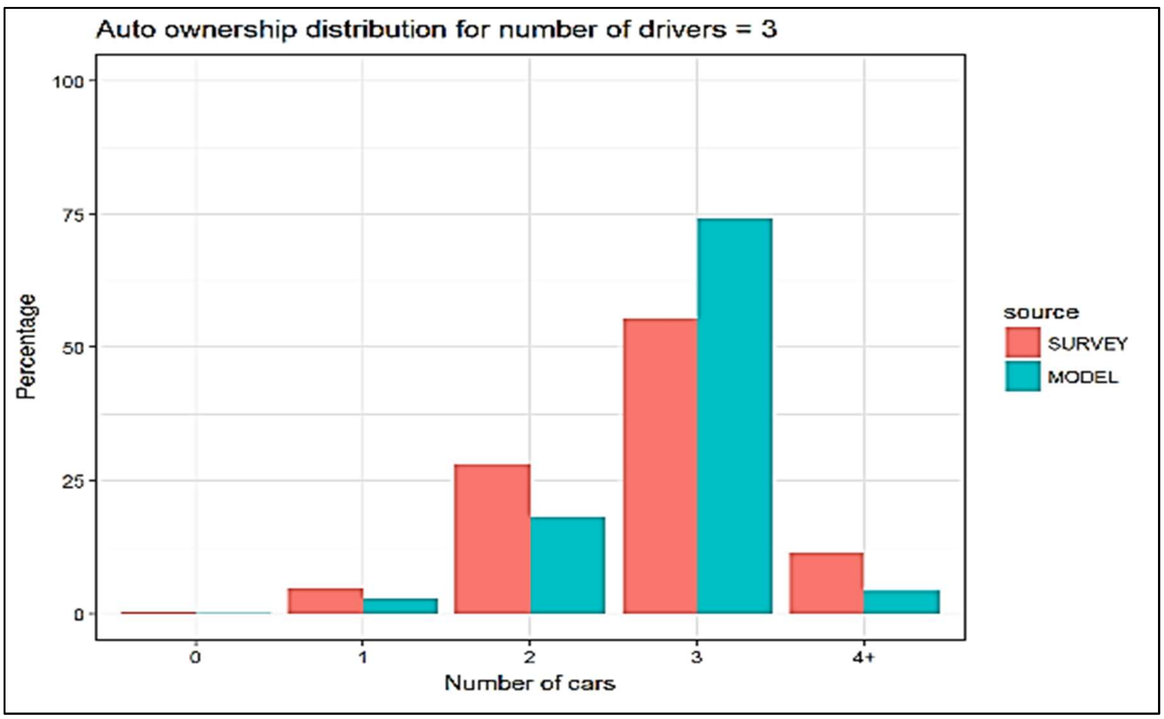
Forecast Difference (%), County Normalized						
Residence County	**0 Cars**	**1 Car**	**2 Cars**	**3 Cars**	**4+ Cars**	**Total**
Imperial	-0.2%	0.9%	0.3%	2.7%	-3.6%	0%
Los Angeles	-0.6%	1.9%	-1.4%	0.3%	-0.3%	0%
Orange	0.0%	0.9%	1.9%	-0.8%	-2.1%	0%
Riverside	-0.7%	1.2%	0.6%	0.3%	-1.5%	0%
San Bernardino	0.1%	1.6%	3.1%	-4.2%	-0.6%	0%
Ventura	0.0%	0.1%	-1.1%	1.2%	-0.2%	0%
Total	**-0.2%**	**0.9%**	**0.3%**	**2.7%**	**-3.6%**	**0%**

Figure 6-3: Auto Ownership by Number of Drivers in the Household, Observed and Predicted






Auto ownership distribution for number of drivers = 2
Percentage
100
75
50
25
0
0
1
2
3
4+
Number of cars
source
SURVEY
MODEL


Auto ownership distribution for number of drivers = 3
Percentage
100
75
50
25
0
0
1
2
3
4+
Number of cars
source
SURVEY
MODEL

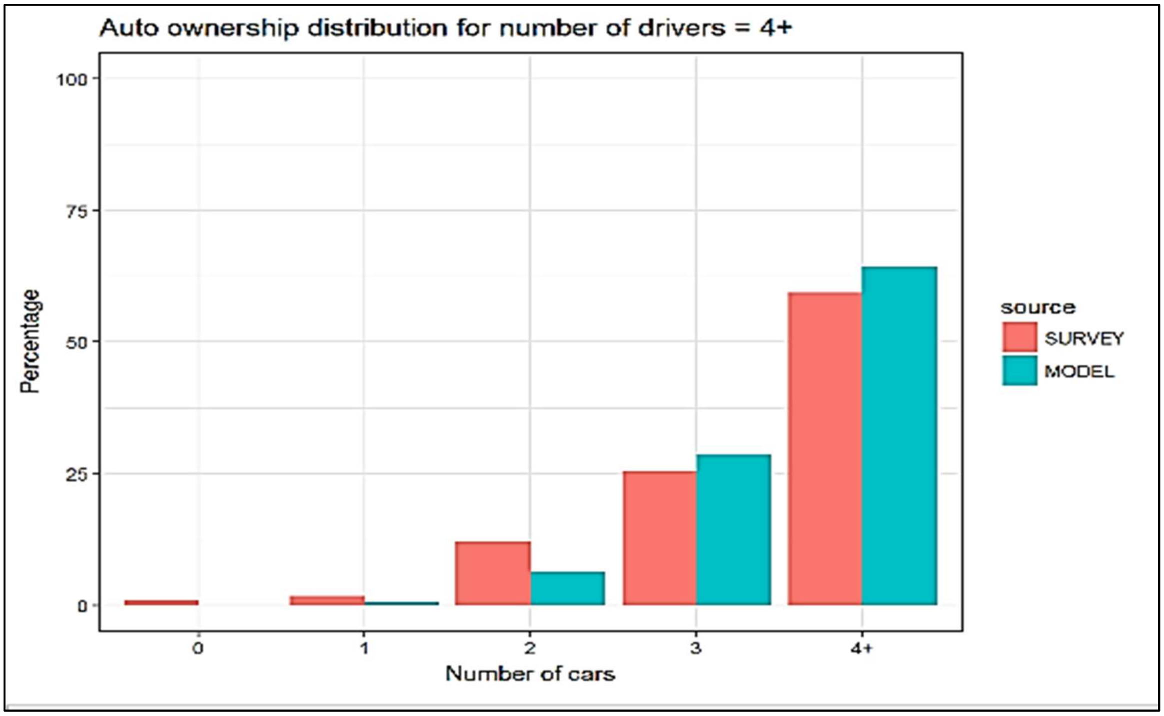


Table 6-3: Household Car Holdings Validation, Year 2016

Residence County	Registered Vehicles CA Department of Motor Vehicles	Predicted Household Vehicles	Difference
Imperial	124,640	102,994	-17%
Los Angeles	6,646,626	6,186,616	-7%
Orange	2,368,773	2,120,209	-11%
Riverside	1,442,061	1,493,790	3%
San Bernardino	1,313,136	1,308,065	0%
Ventura	615,871	542,479	-12%
Total	**12,511,107**	**11,754,441**	**-6%**

Chapter 7 MANDATORY ACTIVITY GENERATION AND TOUR FORMATION

Overview of Tour Formation Approach

In the activity-based travel demand modeling approach, travel is derived from activities; that is, the central unit of modeling is the activity in which an individual intends to participate during the day. However, most ABMs, in practice and research, do not entirely incorporate this central idea. The most frequently used ABMs generate travel tours up-front and subsequently add details on intermediate stops in each tour. Other ABMs generate the activities that a traveler intends to participate in, but they still involve a series of tour frequency and stop-insertion models to model daily travel. This framework is largely borrowed from tour-based travel demand models, where the basic unit for travel analysis is the tour.

It can be reasonably hypothesized that an individual makes a preliminary decision to participate in a certain set of activities. His or her scheduling decisions are then driven by the associated temporal and spatial constraints and activity priorities. For example, a worker who goes to work on the modeled day will generally have a higher priority associated with work activities relative to an individual shopping or discretionary activity. However, these priorities can change if, for example, the shopping activity is undertaken jointly (assuming a major shopping trip such as buying a car or furniture) or when the discretionary activity is a special “ticketed” event such as a football game.

The modeling approach applied in the SCAG ABM builds on the idea that certain activities are inflexible or less flexible (referred to as *prioritized activities*) relative to other activities. The traveler plans the schedule of these prioritized activities first and then schedules other activities around them. The four main steps that predict activity generation and form tours from the activity participation decisions are the following:

Model for mandatory activity tour skeletons

- Chapter 8 Mandatory Activity Frequency and Time of Day
- Chapter 9 School Escorting and Scheduling Consolidation

Model for fully-joint tours for intra-household shared non-mandatory activities – Chapter 10

Individual Tour Formation

- Chapter 11 Individual Non-mandatory Activity Frequency and Time of Day
- Chapter 12 Model for activity sequencing and within-segment tour formation

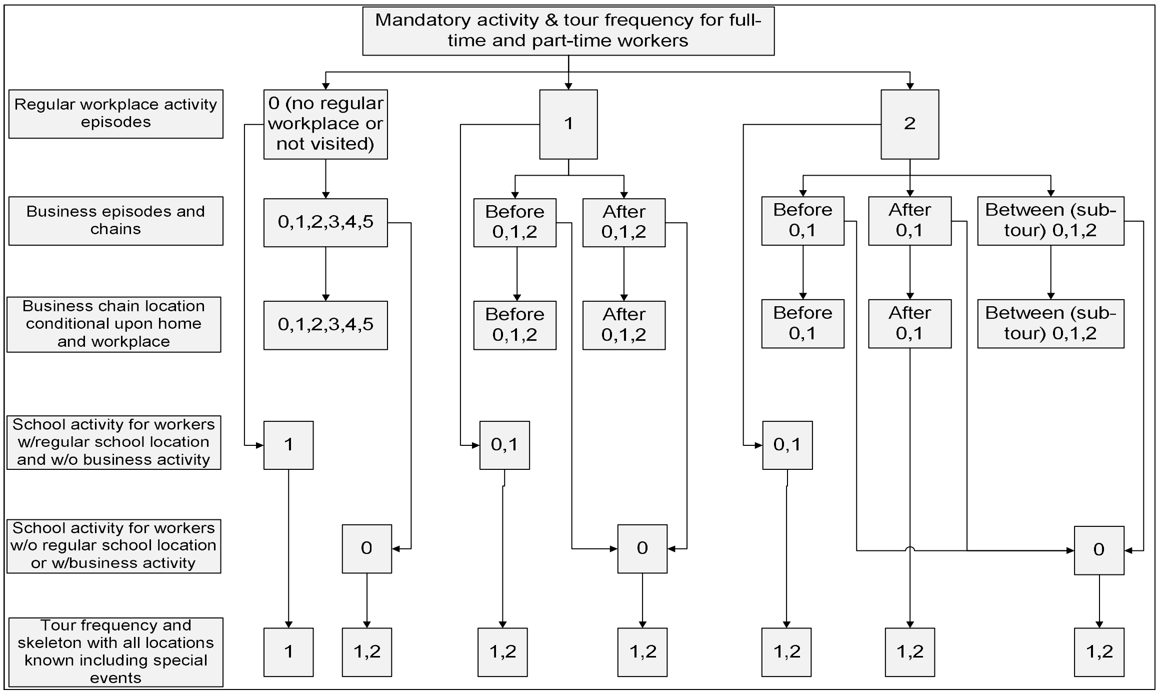
For a more detailed description of these sub-models, please refer to the Model Specification Report.

Mandatory Activity Tour Skeleton

Mandatory Activity Frequency and Order for Worker

The first sub-model predicts mandatory activity frequency and order. The alternatives are defined by the number of workplace episodes, the number of business activities, and the relative ordering of business activities with respect to workplace episodes. Business activities scheduled to occur one after another are considered a “business chain”. These chains could be placed before, after or between workplace episodes depending on the number of workplace episodes in the alternative. Based on the observed frequency distribution, this model has a total of 43 alternatives.

Figure 7-1: Mandatory Activity and Tour Frequency Modeling Framework



Business Chain Location

Once the mandatory activity chain (including workplace and other business stops) for a worker has been predicted, the next step is to assign a location to each of the non-workplace (business) stops. A business stops chain can start and end at home or at the usual workplace. The number of business stops in each chain ranges from one to five.

Business stops share the same size variable. This attraction variable is specific to the worker industry and occupation and is computed as the sum of total employment for the worker's industry and total number of households. Since a sequential choice does not guarantee a logical non-zigzag spatial pattern, business stop locations are chosen simultaneously as an entire chain out of the generated sample of chains.

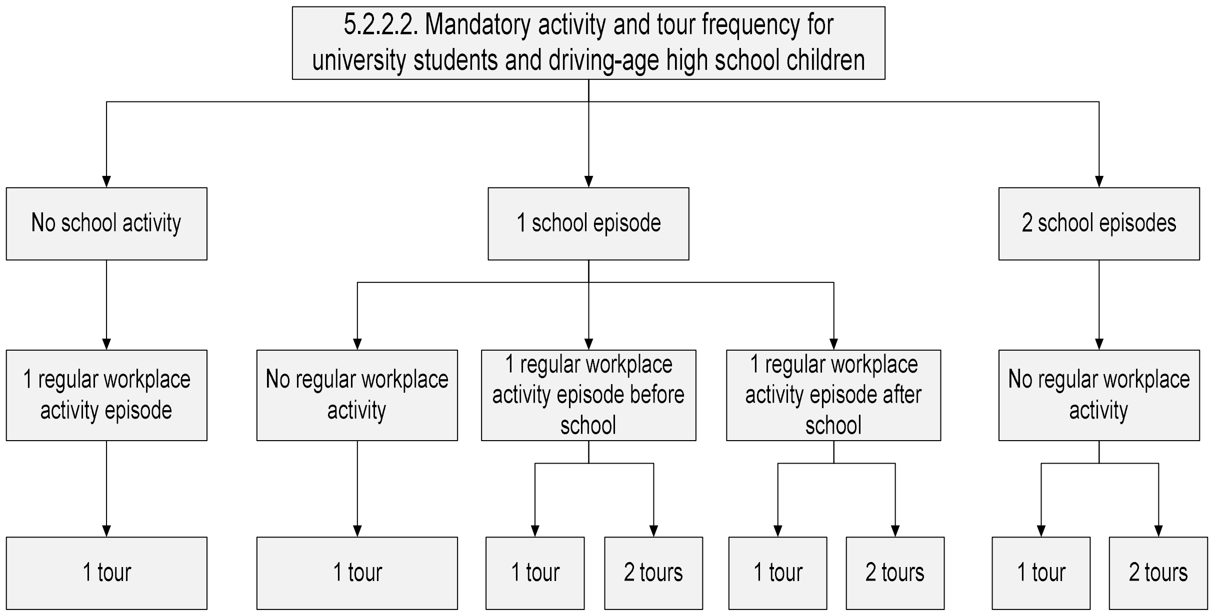
Mandatory Tour Skeleton Choice

After the mandatory activity pattern and locations have been decided, a worker has a choice to pursue these activities as part of a single tour or in multiple tours. A worker has an option to break the tour and return home after each mandatory activity, except for the last one. For example, in the case of six mandatory activities, there are five positions at which the tour could be broken, resulting in five alternatives. The base alternative is always not to break the chain and pursue all mandatory activities as part of a single tour, resulting in a total of six alternatives. Availability of the other five alternatives is identified based on the number of activities being implemented by the worker.

Mandatory Activity and Tour Frequency Choice for Students

University students and driving-age children can participate in school and work activities. The number of school and work episodes, and their chronological order, is predicted simultaneously. The alternatives are defined by the number of school episodes, number of work episodes, and the relative ordering of work and school activities (see Figure 7-2). This model has a total of 10 alternatives. The model predicts one school episode and one mandatory tour for pre-driving age students and pre-school age children when their DAP is mandatory, and no school episodes otherwise.

Figure 7-2: Mandatory Activity and Tour Frequency Modeling Framework for Students



Preliminary Mandatory Activity Schedule

After the mandatory tour skeletons are generated, the arrival time to and departure time from the primary mandatory activity are chosen simultaneously. The tour time of day choice model is a discrete-choice construct that operates with arrival time and departure time combinations as alternatives. The utility structure is based on "continuous shift" variables. It represents an analytical hybrid that combines the advantages of a discrete-choice structure (flexible in specification and easy to estimate and apply) with the advantages of a duration model (a simple structure with few parameters, and which supports continuous time). The model has a temporal resolution of 15-minute arrival/departure time alternatives.

Model Application and Calibration

The mandatory activity frequency sub-model was calibrated by adjusting the frequency choice-specific constants, which are stratified by person type. These models are applied to workers and students with a mandatory DAP only. The work and business episode frequency for the worker person-types is shown in Table 7-1 and depicted in Figure 8-3. The school episode activity frequency is shown in Table 7-2.

Table 7-1: Work Activity Episode Frequency, Workers

Episode Frequency	Full-Time Workers		Part-Time Workers	
	Observed	Estimated	Observed	Estimated
Work Activities				
0	9.6%	7.3%	6.1%	12.7%
1	86.1%	88.9%	90.4%	80.8%
2	3.7%	3.8%	3.6%	6.4%
Business Activities				
0	85.6%	86.8%	85.6%	80.3%
1	7.8%	7.1%	7.8%	15.5%
2	3.8%	3.5%	3.8%	3.3%
3	1.1%	1.0%	1.1%	0.1%
4	1.4%	1.3%	1.4%	0.8%
5	0.3%	0.3%	0.3%	0.1

Table 7-2: School Activity Episode Frequency, Students

Episode Frequency	College		Driving-Age Children		Pre-Driving Age Children		Pre-School Children	
	Obs	Est	Obs	Est	Obs	Est	Obs	Est
0	<0.1%	0.2%	<0.1%	0.0%	n/a	n/a	n/a	n/a
1	97.0%	99.3%	99.1%	99.0%	98.5%	100.0%	93.0%	100.0%
2	3.0%	0.5%	0.9%	1.0%	1.5%	0.0%	7.0%	0.0%

Figure 7-3: CDAP Calibration Results

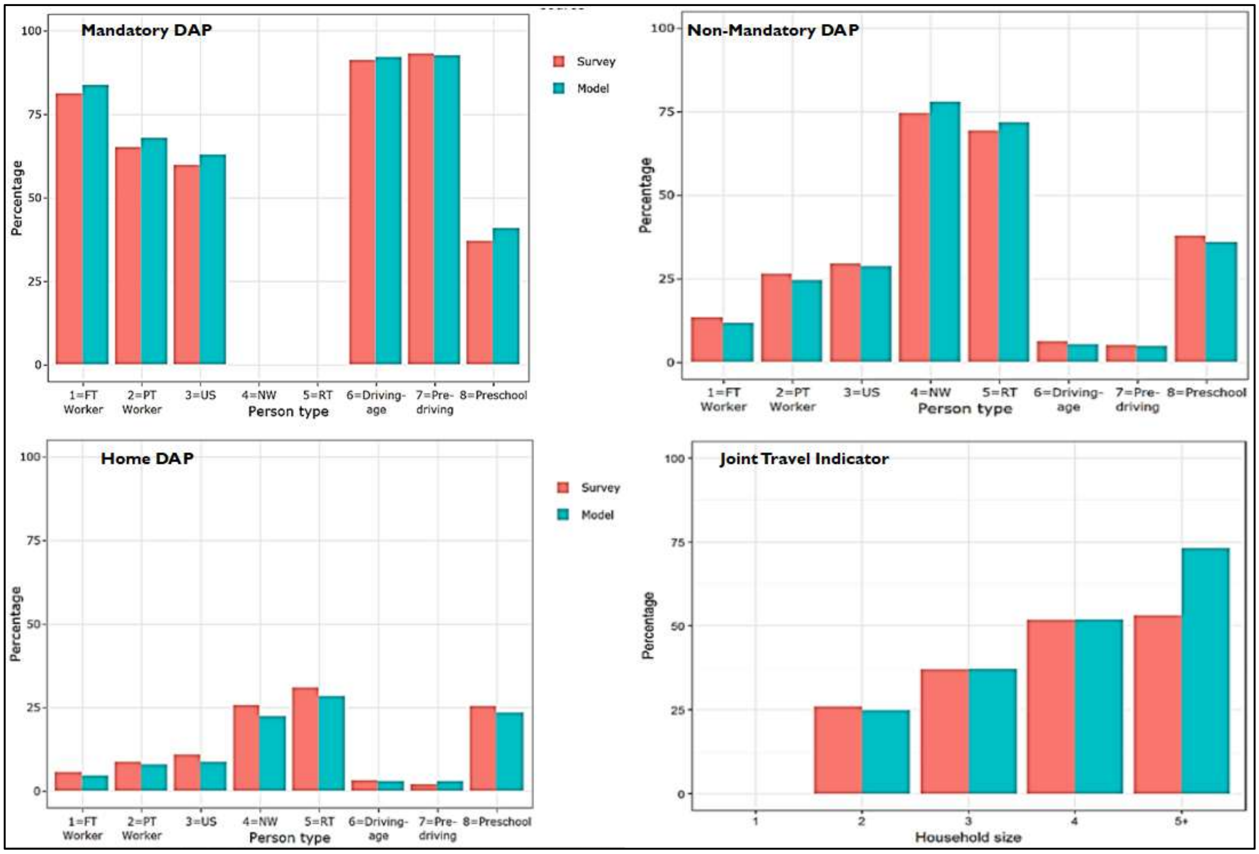
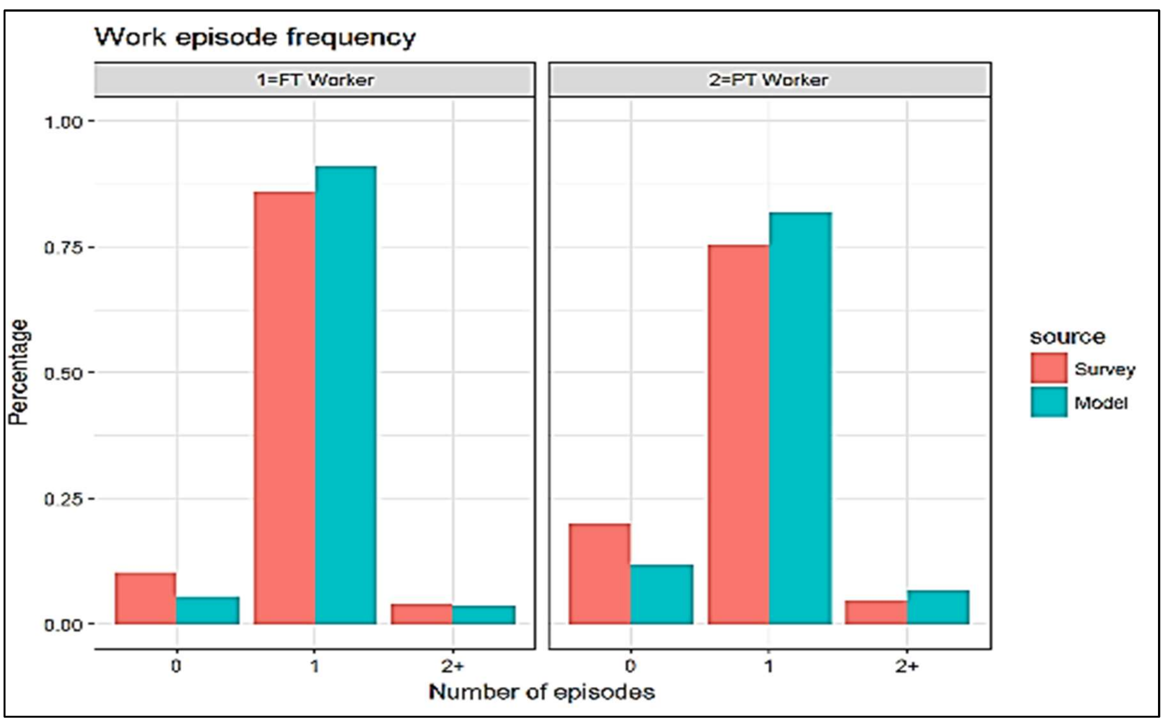
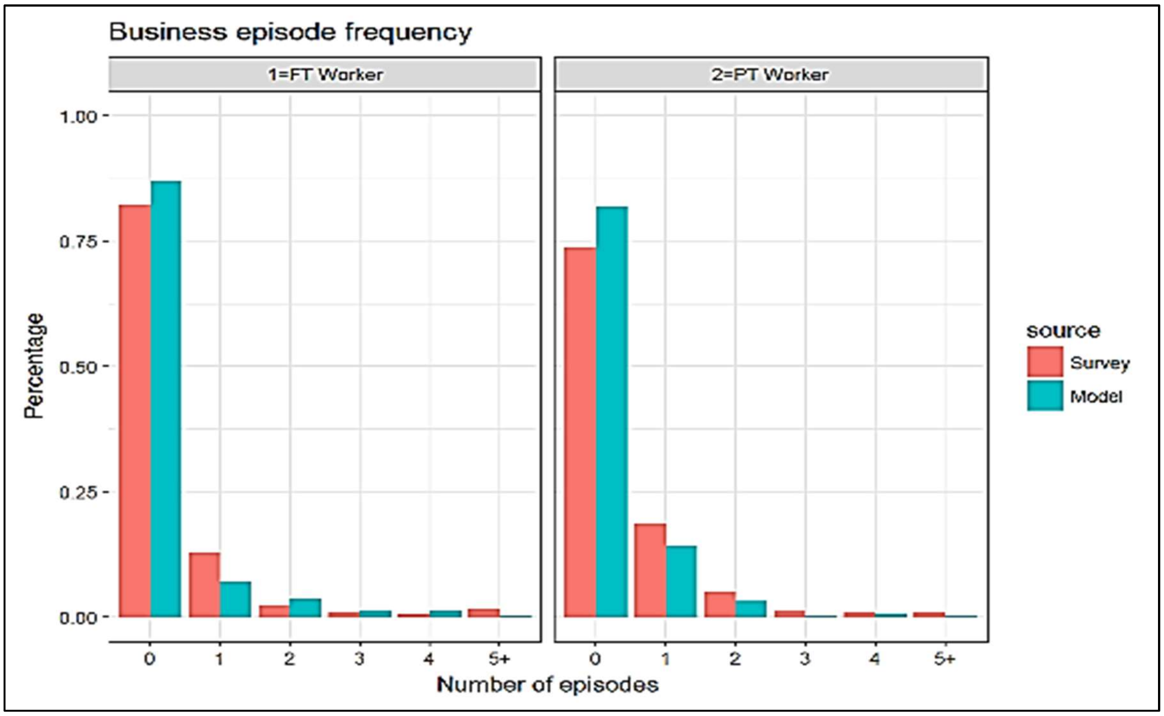


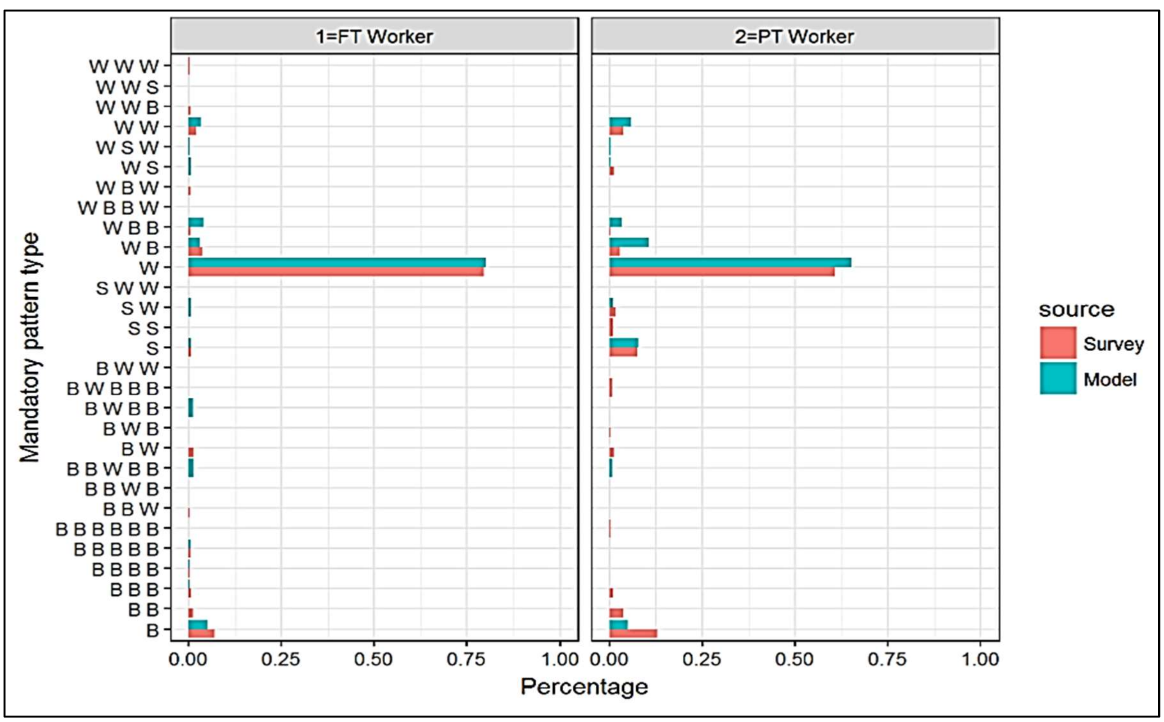
Figure 7-4: Mandatory Activity Episode Frequency, Workers





A comparison of the frequency and ordering of work and business episodes is shown in Figure 7-5. Although many combinations of these types of activities are observed in the household survey, the simplest patterns predominate. Nonetheless, all patterns are considered because the low frequency business chains can be quite long (distance-wise).

Figure 7-5: Mandatory Activity Frequency and Ordering, Workers



The calibration of the mandatory activity time of day choice is shown in Figure 7-6 to Figure 7-11. These figures depict arrival time to the mandatory activity (work/school), departure time from the mandatory activity, and activity duration (exclusive of travel time). The model was calibrated to exhibit somewhat larger share of mandatory activity arrivals during the peak periods than observed in the 2011 CHTS. This is because the traffic count data for the region shows a more pronounced AM peak than the household survey.

Figure 7-6: Preliminary Work Episode Time of Day Choice, Full-time Workers

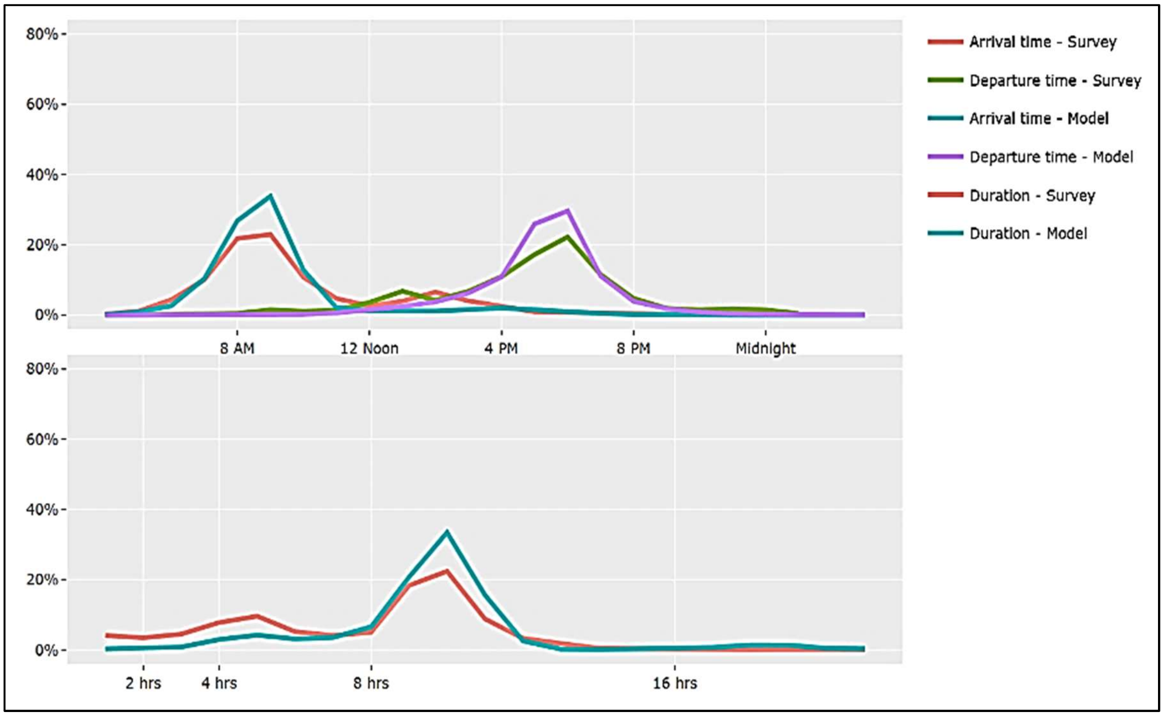


Figure 7-7: Preliminary Work Episode Time of Day Choice, Part-time Workers

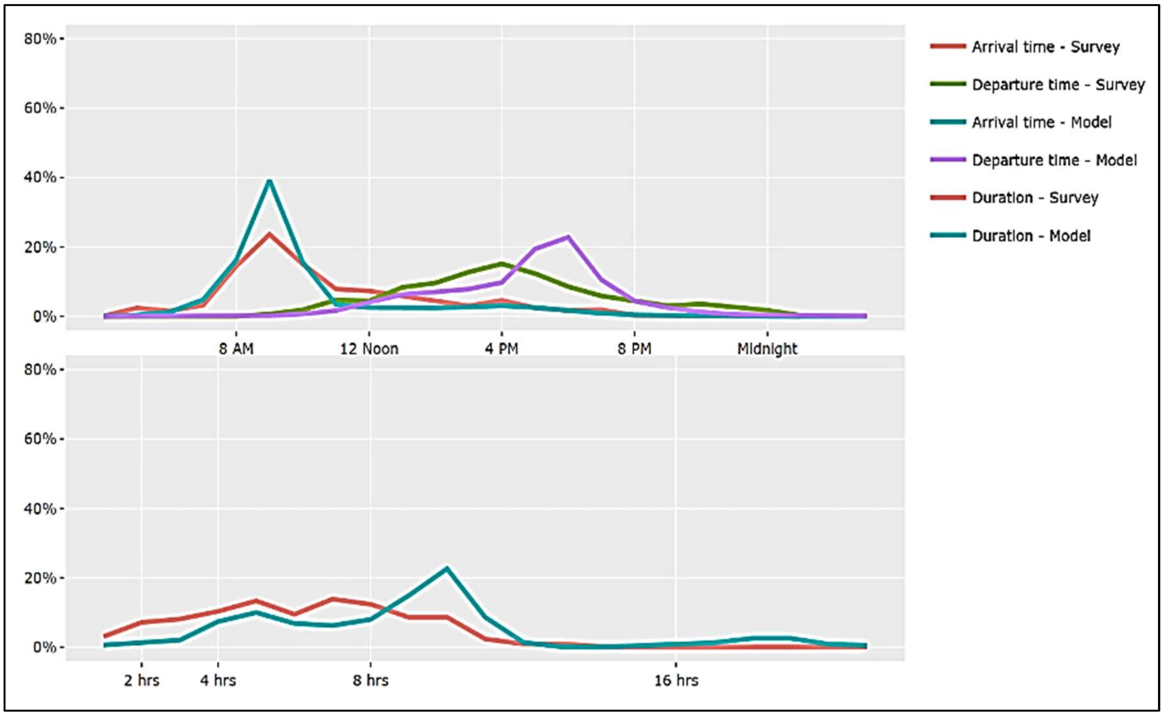


Figure 7-8: Preliminary School Episode Time of Day Choice, College Students

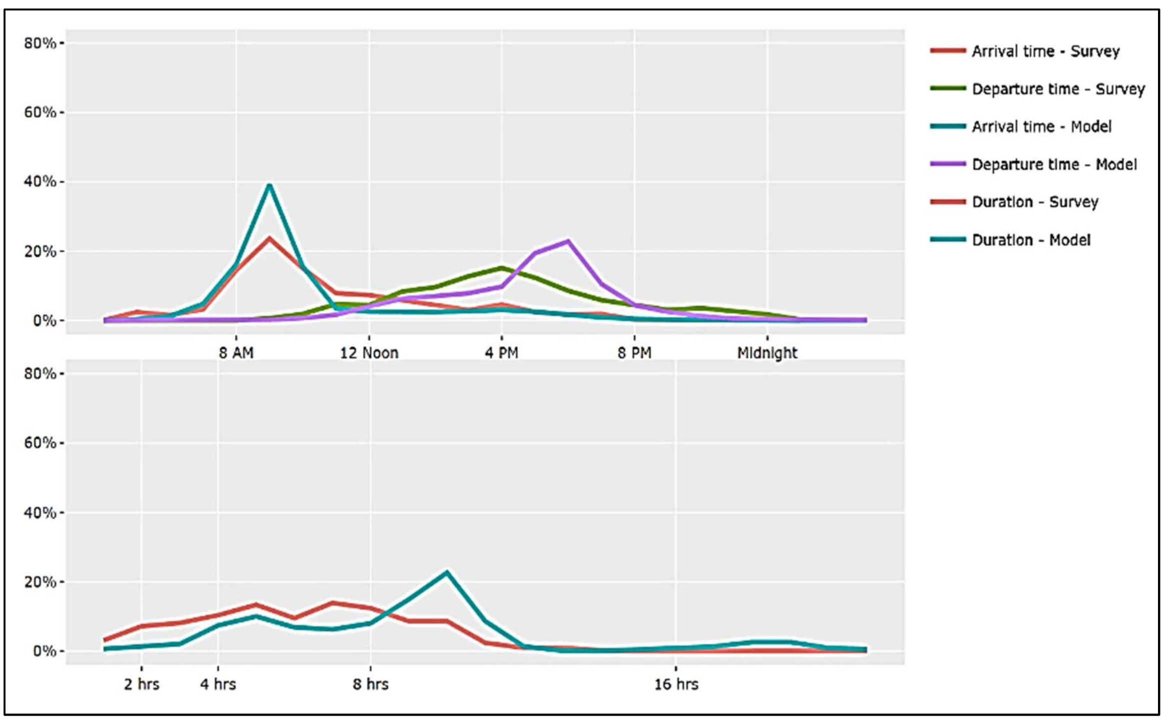


Figure 7-9: Preliminary School Episode Time of Day Choice, Driving-Age Children

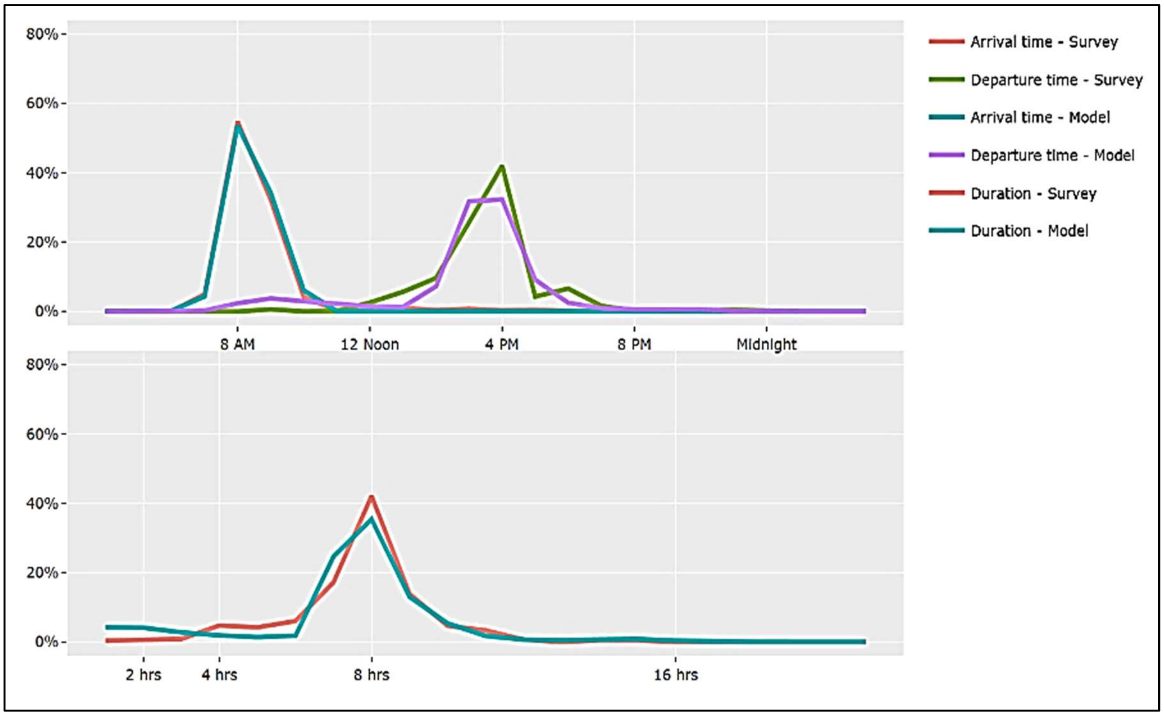


Figure 7-10: Preliminary School Episode Time of Day Choice, Pre-Driving Age Children

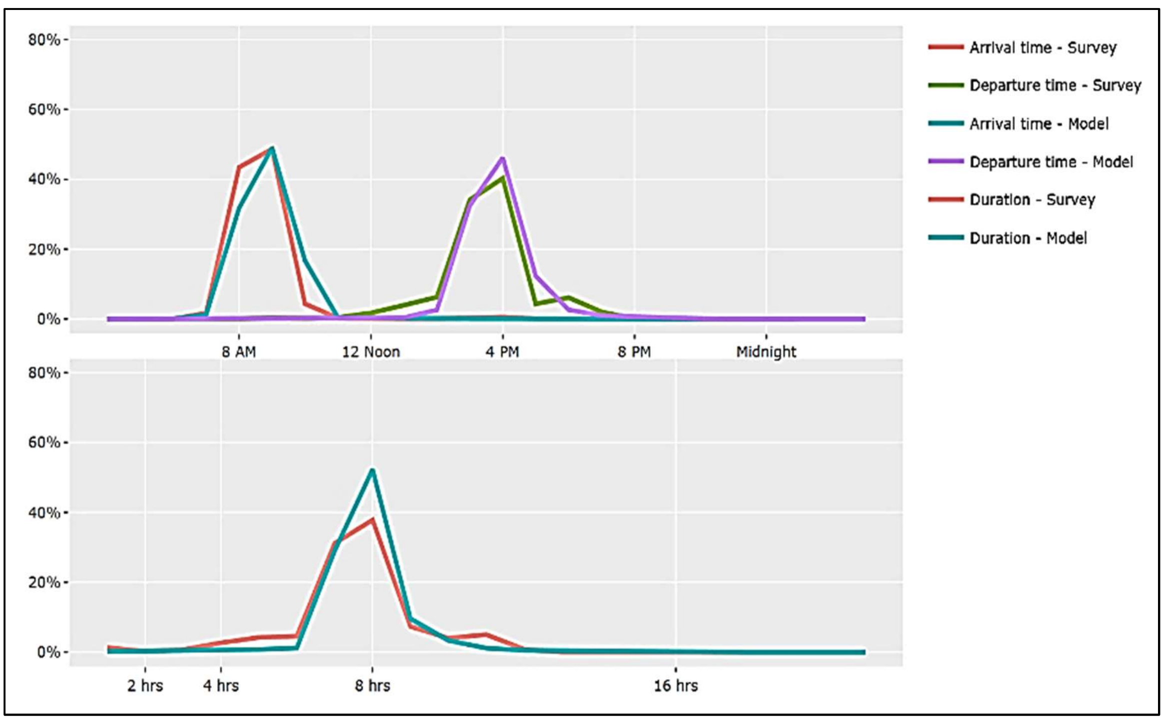
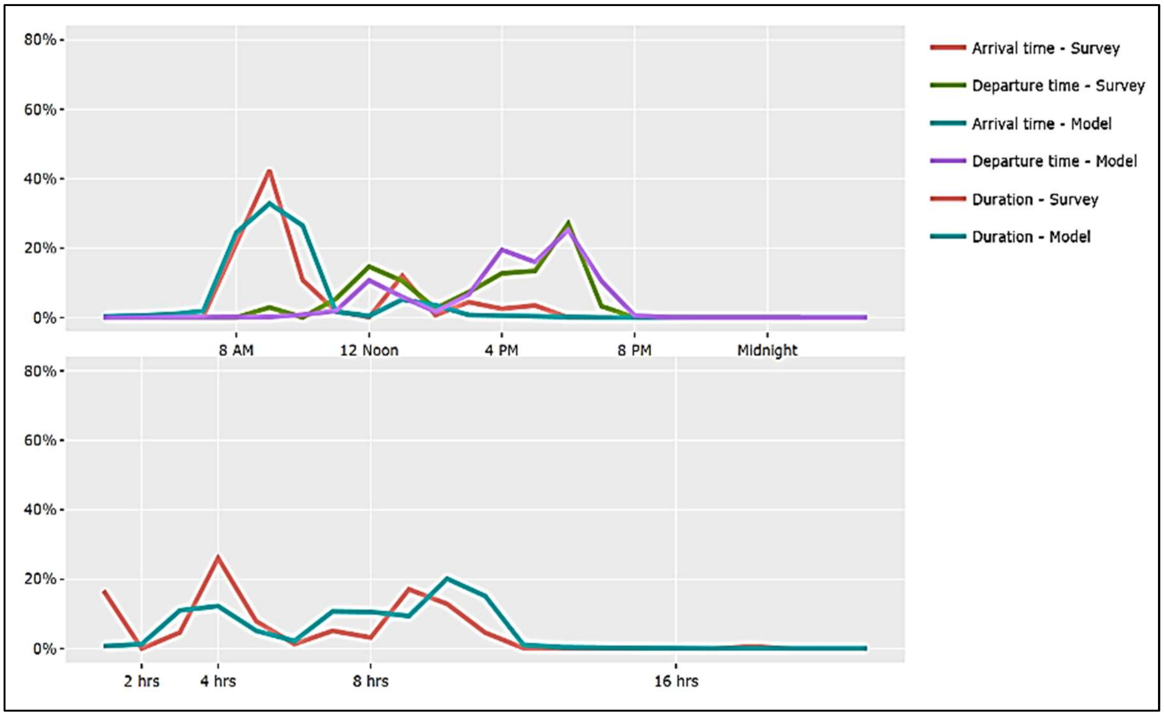


Figure 7-11: Preliminary School Episode Time of Day Choice, Pre-School Children



Chapter 8 Coordinated Daily Activity Pattern (CDAP)

MODEL OVERVIEW

In the CT-RAMP3 structure each person is assigned a daily activity pattern (DAP). The DAP predicts whether the person will stay home all day or travel, and in the case that some travel is predicted, whether it is for work or school. The DAP also indicates whether the household generates fully joint trips. The following DAPs are possible:

Mandatory pattern (M) that includes at least one of the three mandatory activities—work, university or school. This constitutes either a workday and/or a university/school day, and it may include additional non-mandatory activities such as separate home-based tours or intermediate stops on the mandatory tours.

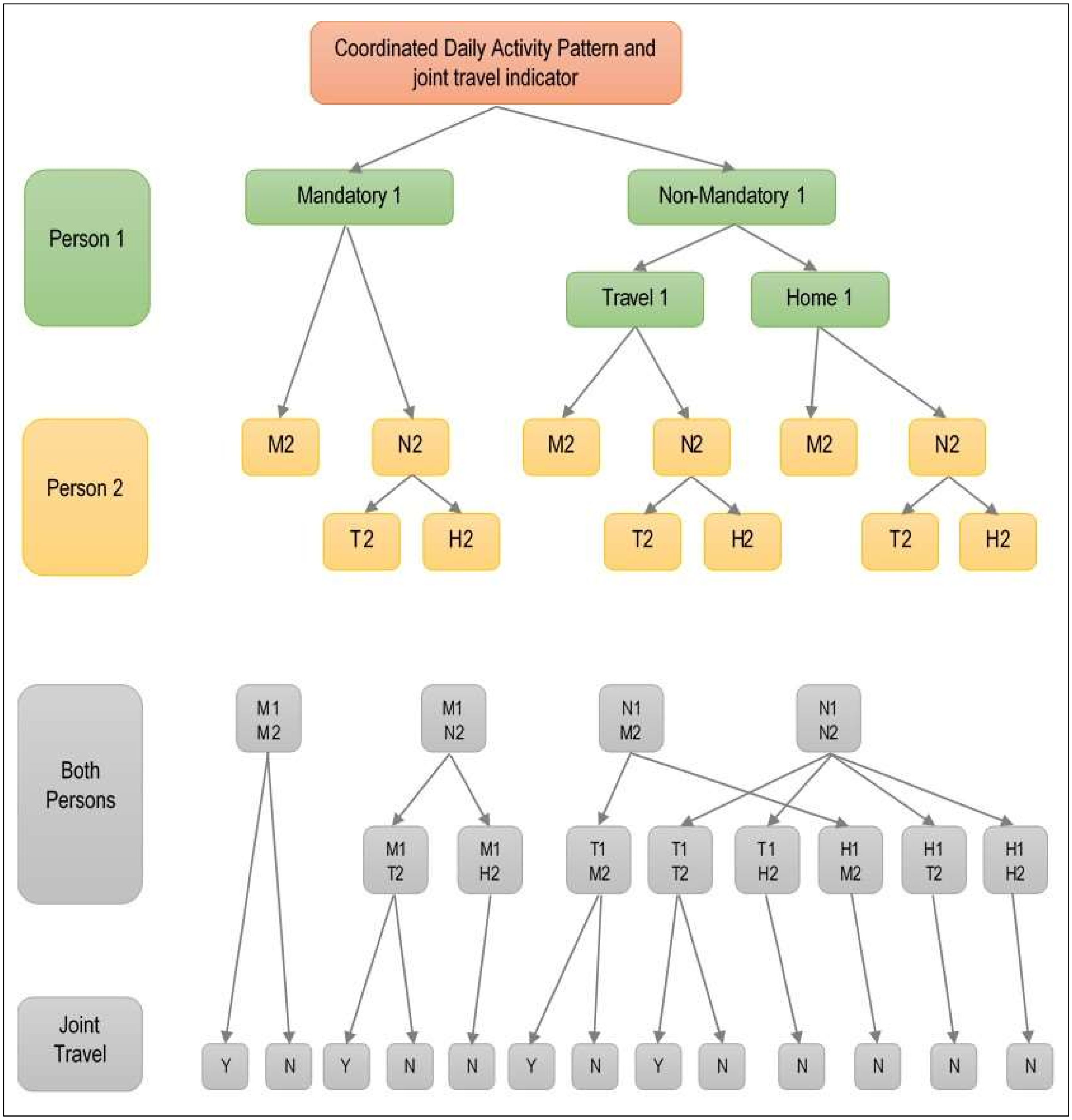
Non-mandatory pattern (NM) that includes only maintenance and discretionary activities and tours. By virtue of the tour primary purpose definition, maintenance and discretionary tours cannot include travel for mandatory activities.

Home pattern (H) that includes only in-home activities. At-home patterns are not distinguished by any specific activity (e.g., work at home, take care of child, being sick, etc.). Complete absence from the model area (e.g., business travel) are included in this category.

The DAP is predicted simultaneously for all members of a household. Along with the indicator for fully-joint travel, this simultaneity is what gives rise to the "coordinated" aspect of this submodel. The model takes the form of a nested logit model, with number of choices that depend on household size. The Coordinated Daily Activity Pattern (CDAP) model in the CT-RAMP3 design features simultaneous modeling of these trinary pattern alternatives for all household members with the subsequent modeling of individual alternatives, as shown in Figure 8-1.

The explanatory variables include person and household attributes, accessibility measures, and density/urban form variables. Since the model features intra-household interactions, several model parameters are specified as interaction terms. These terms are based on the contribution to the total utility of an alternative from either a two-person interaction, a three-person interaction, or an entire-household interaction. For example, the contribution of a two-worker interaction to the utility for each worker to stay home on the simulation day is positive, indicating that it is more likely that both workers will attempt to coordinate their days off to engage in recreational opportunities together. Similarly, the contribution of a pre-school child to a worker mandatory pattern is negative, indicating the likelihood that if a pre-school child stays at home, a worker also is more likely to stay at home with the child.

Figure 8-1: Coordinated Daily Activity Pattern Choice Structure (2-person household)



Model Calibration

The model was calibrated by adjusting the person-type constants so that the aggregate proportions of DAPs by person-type matched the calibration targets. The targets were derived based on data from the 2011 CHTS. The model calibration results are shown in the following tables and figures.

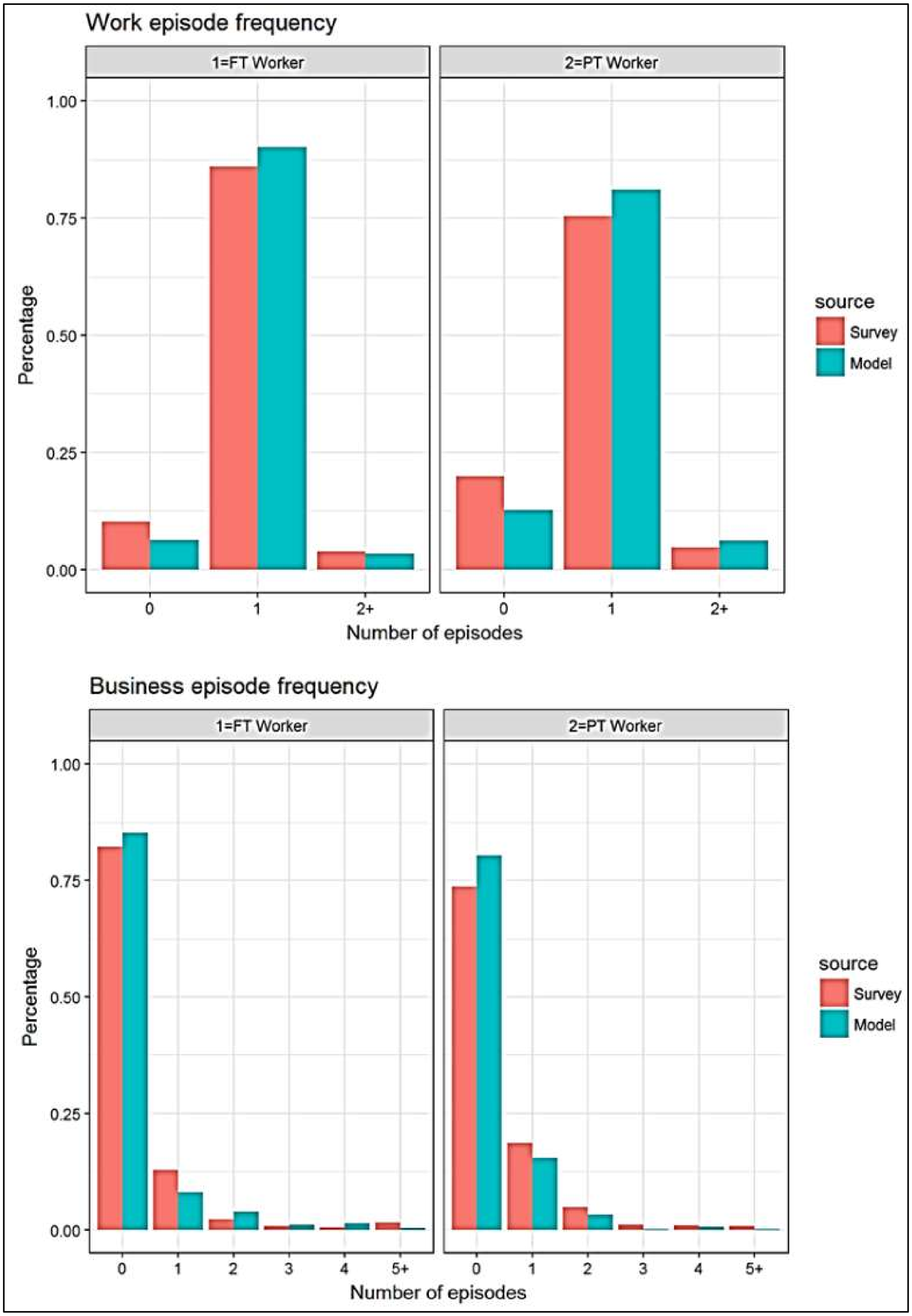
Table 8-1: Daily Activity Pattern Proportions by Person-Type

Observed DAP Share			
Person Type	**Mandatory**	**Non-Mandatory**	**Home**
1-Full Time Worker	81.0%	13.4%	5.6%
2- Part Time Worker	65.0%	26.4%	8.6%
3- University Student	59.8%	29.5%	10.7%
4- Non-Working Adult	0.0%	74.5%	25.5%
5- Retiree (Non-working elderly)	0.0%	69.1%	30.9%
6- Driving Age School Child	91.0%	6.0%	3.0%
7- Pre-driving Age School Child	93.0%	5.0%	2.0%
8- Preschool Child	37.0%	37.8%	25.2%
Predicted DAP Share			
Person Type	**Mandatory**	**Non-Mandatory**	**Home**
1-Full Time Worker	83.7%	11.7%	4.6%
2- Part Time Worker	67.9%	24.3%	7.8%
3- University Student	62.8%	28.6%	8.5%
4- Non-Working Adult	0.0%	77.8%	22.2%
5- Retiree (Non-working elderly)	0.0%	71.7%	28.3%
6- Driving Age School Child	92.1%	5.2%	2.7%
7- Pre-driving Age School Child	92.6%	4.8%	2.6%
8- Preschool Child	40.9%	35.8%	23.3%
Difference			
Person Type	**Mandatory**	**Non-Mandatory**	**Home**
1-Full Time Worker	2.7%	-1.7%	-1.0%
2- Part Time Worker	2.9%	-2.1%	-0.8%
3- University Student	3.0%	-0.8%	-2.2%
4- Non-Working Adult	0.0%	3.3%	-3.3%
5- Retiree (Non-working elderly)	0.0%	2.6%	-2.6%
6- Driving Age School Child	1.1%	-0.8%	-0.3%
7- Pre-driving Age School Child	-0.4%	-0.2%	0.6%
8- Preschool Child	3.9%	-2.0%	-1.9%

Table 8-2: Share of Households with Joint Travel, by Household Size

Household Size	% with Joint Travel	
	Target	Model
1	0%	0%
2	26%	25%
3	37%	37%
4	52%	52%
5+	53%	73%
All households	**32%**	**32%**

Figure 8-2: CDAP Calibration Results



Chapter 9 School Escorting and Schedule Consolidation

Introduction

The school escorting model predicts which children are escorted to school and by whom. This model is applied after the generation, primary destination choice, and usual time-of-day choice for mandatory activities for all household members. Thus, at this modeling stage, it is known for each child whether he/she goes to school, the location of school, and the school arrival and departure times. It is also known for each household adult whether he/she goes to work or university, the location of workplace or university, and the work arrival and departure time. From this perspective, the escorting model can be thought of as a matching model that predicts whether escorting occurs, and if so, which adult household members are chauffeurs and which children are escorted to school.

Children within the household are ordered and modeled by age from youngest to oldest. The behavioral assumption behind this decomposition rule is that, all else being equal, a younger child has more limited individual mobility than an older child; thus, in a household with more than one child, escorting the younger child is considered first in the household decision making process.

Choice Alternatives

The modeled choice alternatives for each school tour are shown in Figure 9-1 below. For each individual school tour, there are at most 7 outbound alternatives and 7 inbound alternatives including ride-sharing with one of the 3 potential chauffeurs, pure escorting by one of the 3 potential chauffeurs, and a non-escort option. At the level of the entire school tour this gives 7×7=49 escort alternatives. If less than 3 chauffeurs are available for either the outbound or inbound half-tour, the alternatives that correspond to non-available chauffeurs are blocked out in the choice model.

If the household has only one child, this model is used directly to generate the escorting arrangement for this child. However, if there are several children in the household with school activity episodes, then an additional "bundling" model is applied to predict the probability that several children are escorted by the same adult on the same tour.

Model Application

When applied to the SCAG region, the model under-estimated the share of pure escorting while over-estimating both shared ride and no escort options. The choice-specific constants were adjusted accordingly. The observed and estimated escorting proportions for the three children person-types are shown in Table 9-1 and Figure 9-1. As shown in Figure 9-2, the chauffer most often escorting children as shared-ride is a worker (as part of the work commute), while pure escort is most often associated with a non-working adult.

Table 9-1: School Escorting Mode Shares

	Outbound (Home to School)			Inbound (School to Home)		
	Driving Age Student	Pre-Driving Age Student	Pre-School Child	Driving Age Student	Pre-Driving Age Student	Pre-School Child
Observed						
Shared Ride	11%	12%	25%	9%	10%	24%
Pure Escort	43%	55%	56%	36%	53%	58%
No Escort	47%	32%	19%	56%	37%	18%
Estimated						
Shared Ride	15%	16%	16%	4%	5%	9%
Pure Escort	36%	48%	52%	25%	29%	27%
No Escort	49%	36%	33%	71%	66%	64%
Difference						
Shared Ride	4%	4%	-10%	-5%	-5%	-15%
Pure Escort	-7%	-7%	-4%	-11%	-24%	-31%
No Escort	3%	3%	14%	15%	29%	47%

Figure 9-1: School Escorting Mode Shares

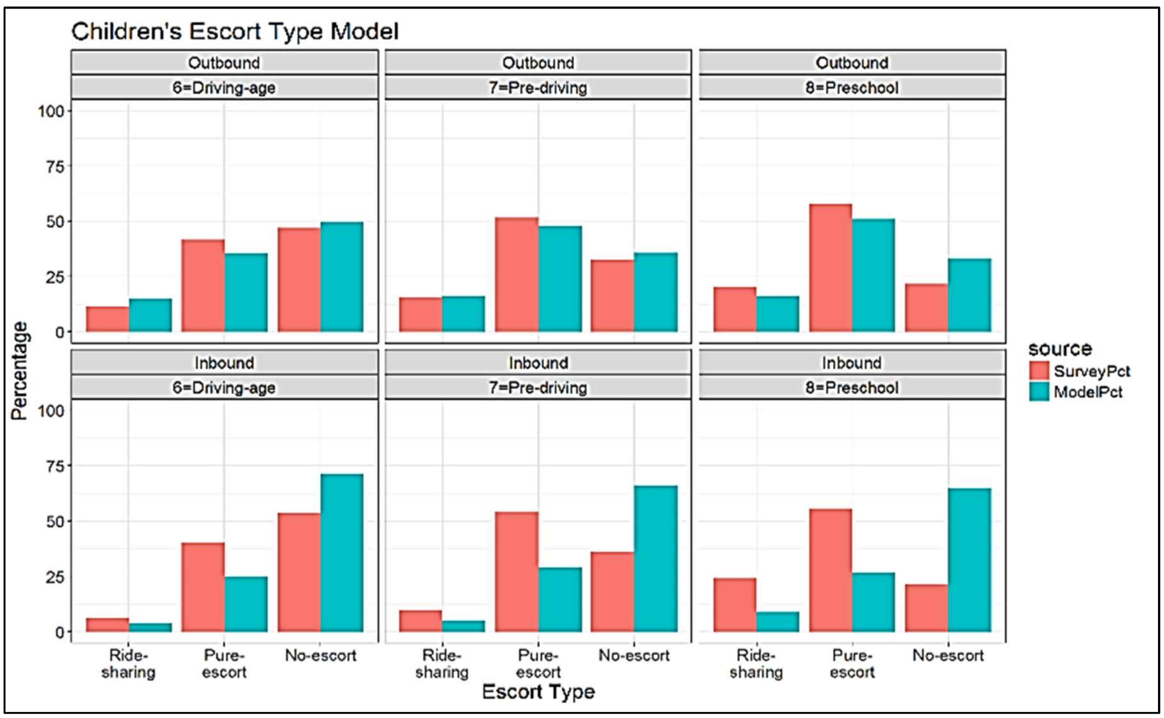
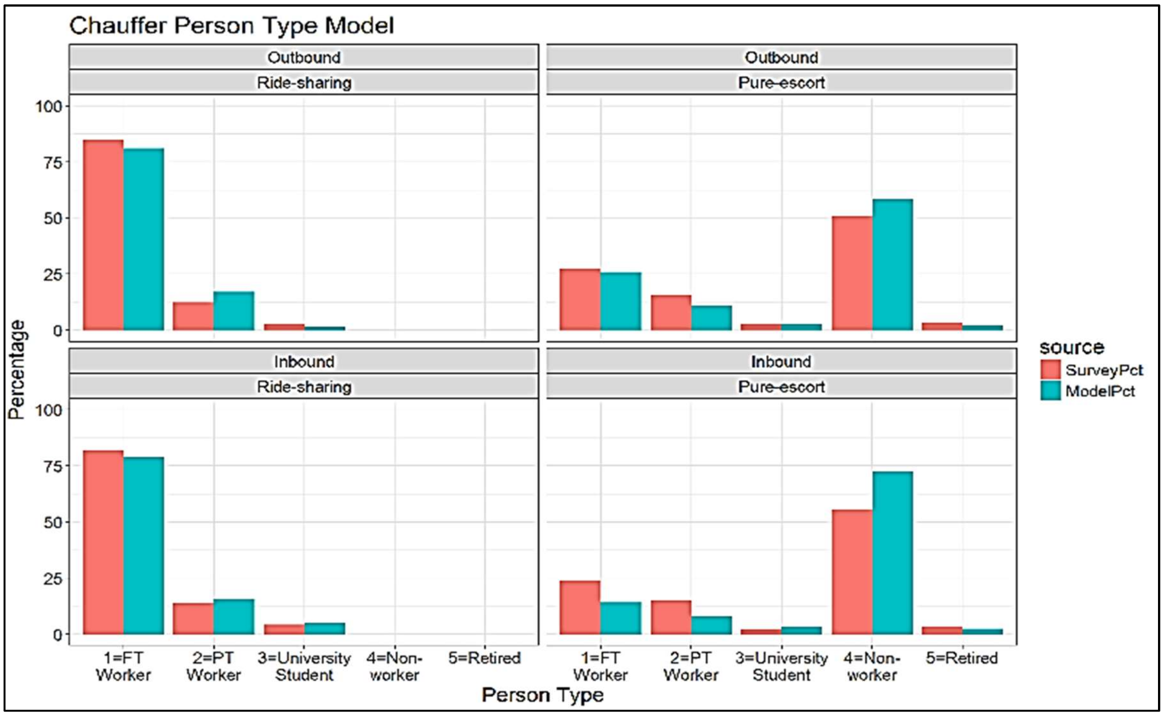


Figure 9-2: Allocation of Chauffer Person-Type to School Escorting



Chapter 10 FULLY JOINT TOUR ACTIVITY GENERATION AND SCHEDULING

Introduction

In the SCAG ABM, joint travel for non-mandatory activities is modeled explicitly in the form of fully joint tours. A fully joint tour occurs when all members of the travel party travel together from the very beginning to the end of the tour and participate in the same activities along the way. Each fully joint tour is considered a unit of modeling with group-wise decision-making for primary destination, mode, frequency, time-of-day, and location of stops. Joint tours are only modeled for households that include at least one joint activity predicted by the CDAP model.

Generation of joint activities

The generation of joint tour activities involves two linked stages:

- A tour generation stage that generates the number of joint tours by purpose/activity type made by the entire household.
- A tour participation stage at which the decision whether to participate or not in each joint tour is made for each household member.

Activity Location and Sequence

This model simultaneously predicts three choices: (a) the sequence of activities within each tour, (b) the location of all activities, and (c) whether to end the tour and go home. The location of the primary purpose of the fully joint tour is modeled first, followed by the sequence and location of additional stops within the tour relative to the primary destination. For each stop, there are two alternatives, "go directly" or "go through primary destination". Choosing the "go directly" alternative creates stops in the outbound direction while "go through primary destination" create stops in the inbound direction. The decision to end the tour and go back home is represented as the alternative corresponding to "not choosing any combination of purpose and location".

Tour Time of Day

The arrival and departure times for the primary joint activities are chosen simultaneously after fully joint activities have been generated, assigned a primary location, and the party composition is known. The model is conceptually like the mandatory activity time of day model described in Chapter 9. However, a unique condition applies when applying the time-of-day choice model to joint tours. The condition is that the arrival / departure interval combinations are restricted to only those available to all participants on the tour, after scheduling mandatory activities. Once the joint activity schedule is chosen, it is applied to all participants on the tour.

Model Calibration

Joint tour frequency was calibrated for household size segments. The observed and predicted proportions of households making zero, one and two joint tours are shown in Table 10-1.

Table 10-1: Joint Tour Frequency

	Household Size (persons per household)			
Observed	**2 persons**	**3 persons**	**4 persons**	**5+ persons**
No joint tours	82%	72%	69%	66%
One joint tour	18%	26%	27%	27%
Two joint tours	0%	2%	4%	7%
Predicted	**2 persons**	**3 persons**	**4 persons**	**5+ persons**
No joint tours	82%	68%	63%	39%
One joint tour	16%	26%	33%	48%
Two joint tours	2%	5%	4%	13%
Difference	**2 persons**	**3 persons**	**4 persons**	**5+ persons**
No joint tours	0%	-4%	-6%	-27%
One joint tour	-2%	0%	6%	21%
Two joint tours	2%	3%	0%	6%

The propensity to participate in joint tours is shown in Figure 10-2 for each person-type and party composition. Children are primarily involved in "mixed party" tours, while retired adults are primarily involved in "adult-only" joint tours. Among all other adults, the split is approximately 25% to 40% mixed-party joint tours, and 60% to 75% adult-only joint tours.

The distribution of joint tour party composition for each tour purpose is shown in Figure 10-3. Other model calibration results include the average distance from home to the primary joint tour destination (Figure 10-4), and the number of intermediate stops on joint tours (Figure 10-4). The total number of joint tours predicted for 2016 is shown in Table 10-2.

Figure 10-1: Joint Tour Participation by Person-Type

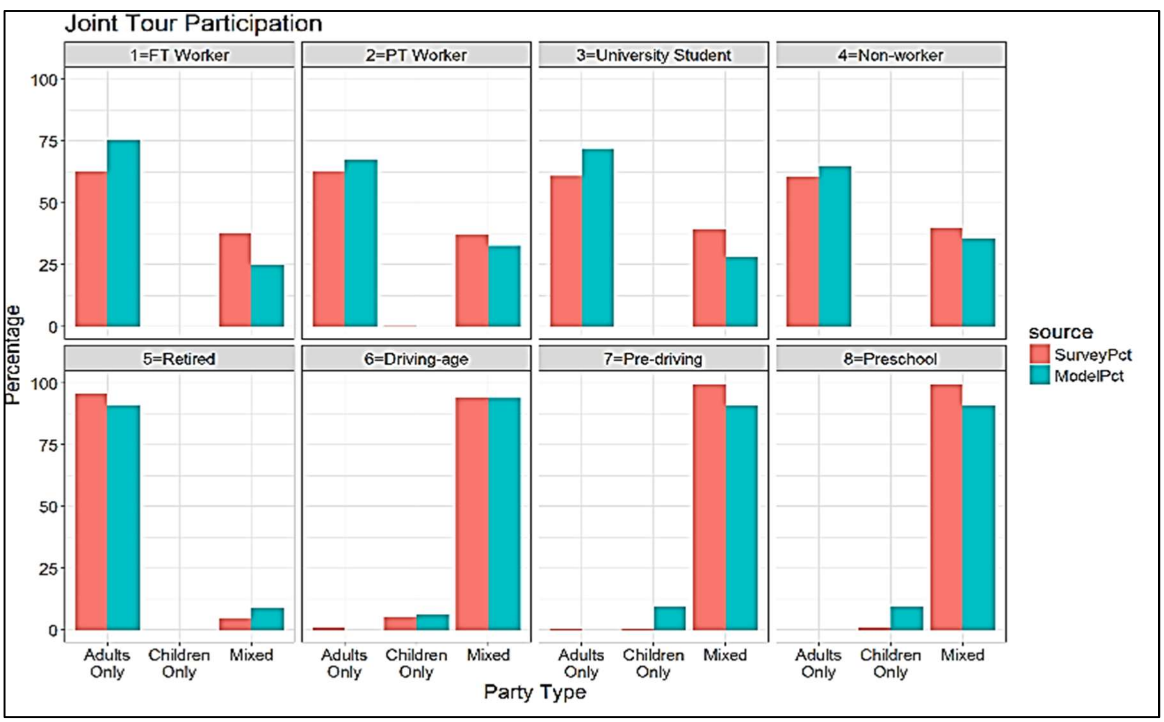


Figure 10-2: Joint Tour Purpose and Party Composition

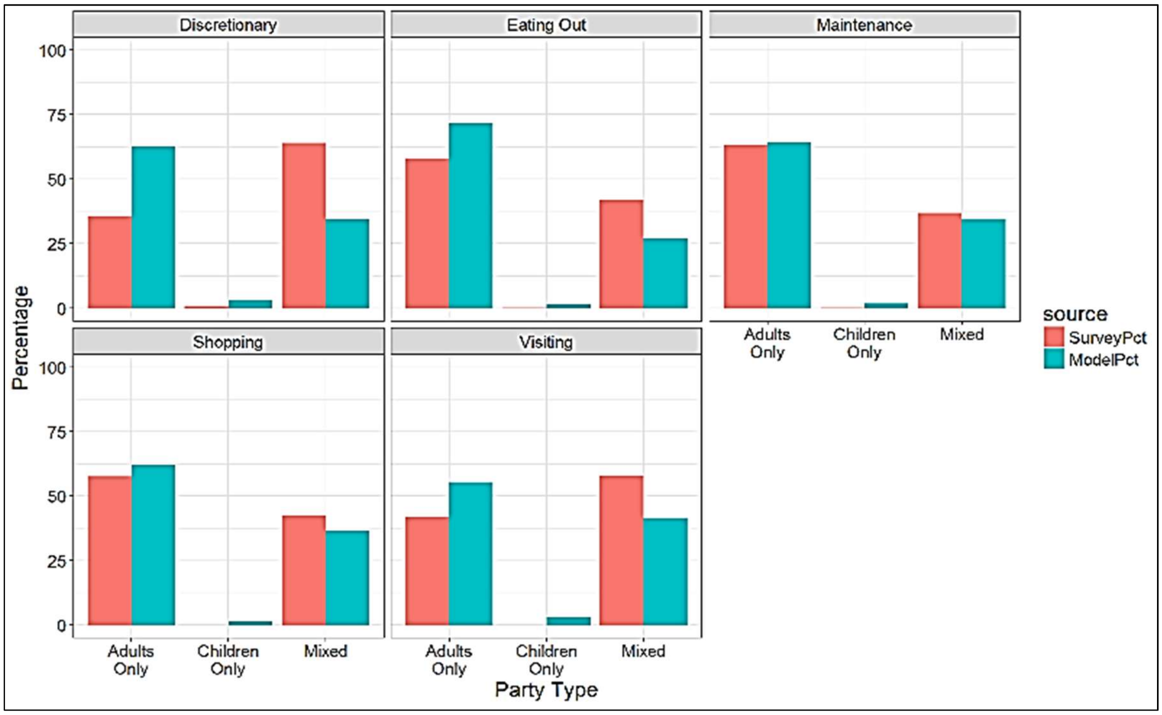


Figure 10-3: Joint Tour Average Trip Length

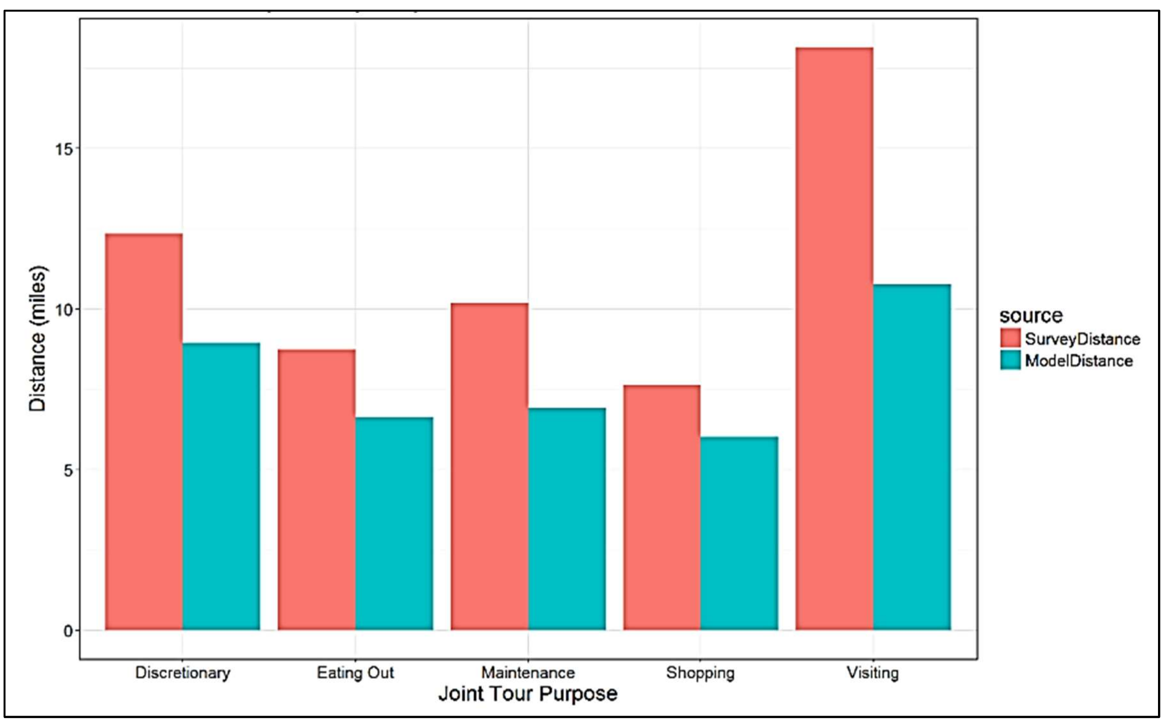


Figure 10-4: Joint Tour Stop Frequency

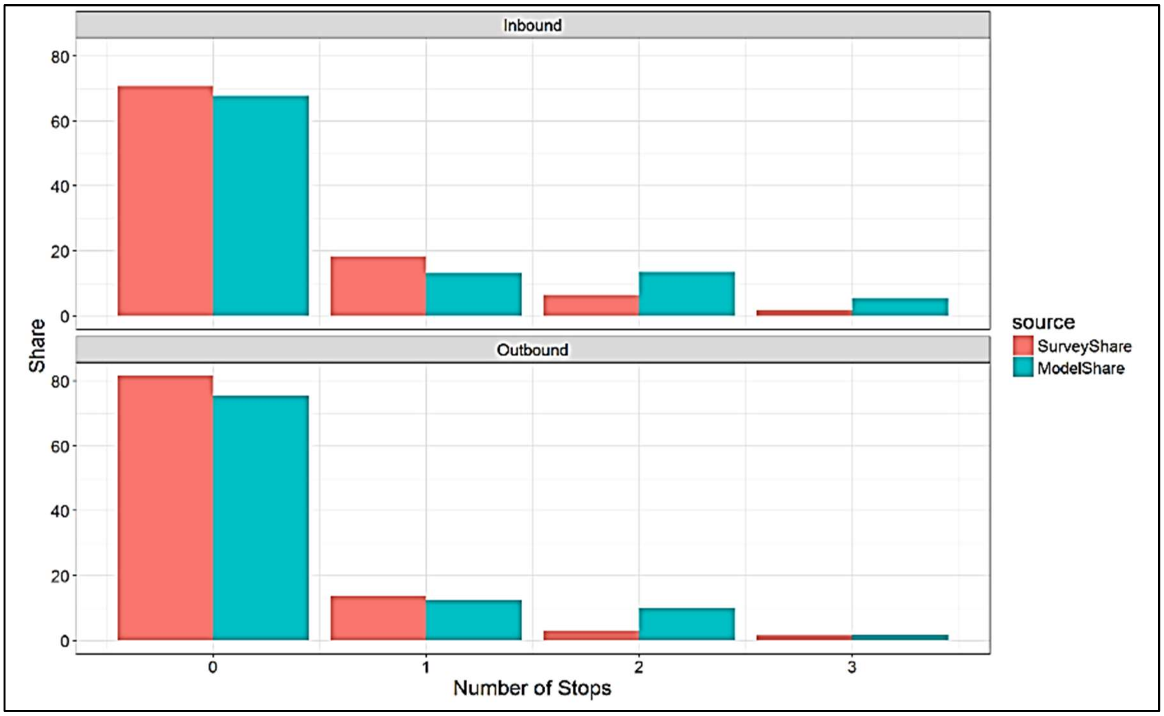


Table 10-2: Number of Joint Tours and Trips on Joint Tours, 2016

Observed			
Tour Purpose	**Number of Tours**	**Number of Trips**	**Trips per Tour**
Shopping	1,285,857	3,816,642	3.0
Maintenance	884,269	2,616,022	3.0
Eating Out	599,659	1,335,808	2.2
Visiting	534,437	1,357,870	2.5
Discretionary	1,097,393	2,716,868	2.5
Total	**4,401,615**	**11,843,210**	**2.7**
2016 Model			
Tour Purpose	**Number of Tours**	**Number of Trips**	**Trips per Tour**
Shopping	1,282,186	3,996,155	3.1
Maintenance	1,036,355	3,056,546	2.9
Eating Out	687,491	1,767,704	2.6
Visiting	274,749	925,918	3.4
Discretionary	861,247	2,537,893	2.9
Total	**4,142,028**	**12,284,216**	**3.0**

Chapter 11 Individual Non-mandatory Activity Generation

Introduction

In the SCAG ABM, household maintenance tasks are generated at the entire-household level and then allocated to household members to be carried-out individually. These tasks do not include joint maintenance activities and tours that are modeled earlier in the model system chain. Discretionary activities are generated at the individual level by model.

Household Maintenance Activity Frequency and Allocation

The *maintenance task frequency* model predicts the frequency of allocated maintenance tasks such as household errands, grocery shopping and escorting. These tasks are generated at the household-level and then allocated to one or more household members depending on their availability and schedule.

The propensity to participate in non-mandatory activities is a function of the time available. The model uses residual time windows as an explanatory variable, to measure time availability. Residual time windows are the time slots during the active time window available to carry out more activities, once the time dedicated to higher priority activities is blocked out. The active time frame for each person is determined after excluding sleep time from the 24-hour day. Once maintenance activities have been generated at the household level they are allocated to persons within the household.

Discretionary Activity Generation

The *discretionary activity generation* model predicts frequency of individual discretionary activity episodes for each person in the synthetic population. It treats five activity types in one integrated framework: 1=eating out/breakfast, 2=eating out/lunch, 3=eating out/dinner, 4=visiting relatives and friends, and 5=other discretionary activity. Each activity type has its own upper frequency bound, established based on observed frequencies. No more than six total discretionary activities are predicted for each person. The discretionary activity generation model takes the form of a MNL model. Utilities are a function of household attributes, person attributes, residual time windows, accessibilities and urban form.

Model Application and Calibration

The household maintenance activity frequency and allocation model was calibrated across the frequency dimension and the allocation dimension. The frequency distribution of the household maintenance activities (by the three activity purposes) at a household level was calibrated to the observed frequency distribution. The model was calibrated separately by household size. Table 11-1 shows the observed and predicted distribution of household maintenance activities to person types by activity purpose. The model prediction matches the observed distribution well. Pre-school kids are not shown in the table since household maintenance activities cannot be allocated to them. Table 11-2 shows the observed and predicted distribution of individual discretionary activities to person types by activity purpose. Again, the predicted distribution matches the observed distribution well.

The observed and predicted frequency distribution for the three household maintenance purposes is shown in Figure 11-1, Figure 11-3 and Figure 11-5. The allocation of the household maintenance activities to persons was calibrated by adjusting the frequency distribution of activities by person type at a person level, for each of the three activity purposes. These results are shown in Figure 11-2, Figure 11-4 and Figure 11-6.

The individual discretionary activities were calibrated at the person level by person type segmentation for each of the six individual discretionary activities. In addition, the overall person level individual discretionary activity frequency was also calibrated by person type. The results of this calibration are shown in Figure 11-7.

Table 11-1: Household Maintenance Activity Frequency

Observed Share of Activities (%)			
Person type	**Shopping Activities**	**Household Errands**	**Escorting Activities**
1 Full-Time Worker	31.1	33.5	41.5
2 Part-Type Worker	10.3	10.0	13.2
3 College Student	4.1	5.4	7.4
4 Non-Worker	30.6	26.9	24.5
5 Retired	20.4	21.2	8.9
6 Driving Age Child	0.9	1.1	4.5
7 Pre-Driving Age Child	2.6	1.9	0.0
Model Predicted Share of Activities (%)			
Person type	**Shopping Activities**	**Household Errands**	**Escorting Activities**
1 Full-Time Worker	26.0	40.4	38.5
2 Part-Type Worker	8.8	9.0	9.6
3 College Student	7.1	6.1	6.6
4 Non-Worker	33.8	26.9	32.3
5 Retired	18.5	13.8	8.6
6 Driving Age Child	2.0	2.2	4.2
7 Pre-Driving Age Child	3.7	1.6	n/a

Table 11-2: Individual Discretionary Activity Frequency

Observed Share of Activities (%)						
Person Type	**Breakfast**	**Lunch**	**Dinner**	**Visiting**	**Discre-tionary**	**Personal Maint.**
1 Full-Time Worker	38.0	42.0	42.6	24.5	25.9	33.5
2 Part-Type Worker	9.3	9.6	9.4	10.4	9.3	9.4
3 College Student	4.9	7.0	6.3	9.4	4.9	7.1
4 Non-Worker	21.8	19.8	14.4	22.0	21.5	25.3
5 Retired	20.9	15.7	11.6	13.8	14.6	14.8
6 Driving Age Child	0.3	1.4	3.2	3.0	3.7	1.7
7 Pre-Driving Age Child	2.0	2.4	8.7	9.5	14.7	4.7
8 Pre-School Child	3.6	2.0	3.8	7.5	5.3	3.7

Model Predicted Share of Activities (%)						
Person Type	Breakfast	Lunch	Dinner	Visiting	Discre-tionary	Personal Maint.
1 Full-Time Worker	43.8	40.7	34.9	28.4	29.9	27.9
2 Part-Type Worker	9.6	9.4	8.2	7.6	7.4	7.1
3 College Student	6.1	6.1	6.1	6.4	6.0	5.9
4 Non-Worker	17.9	18.8	19.1	25.0	23.0	24.1
5 Retired	9.8	10.6	10.6	13.6	12.9	13.7
6 Driving Age Child	2.1	2.4	3.1	2.4	2.4	2.4
7 Pre-Driving Age Child	5.5	6.4	12.1	10.0	12.1	12.8
8 Pre-School Child	5.0	5.4	5.9	6.5	6.0	6.0

Figure 11-1: Frequency of Allocated Household Shopping Tasks

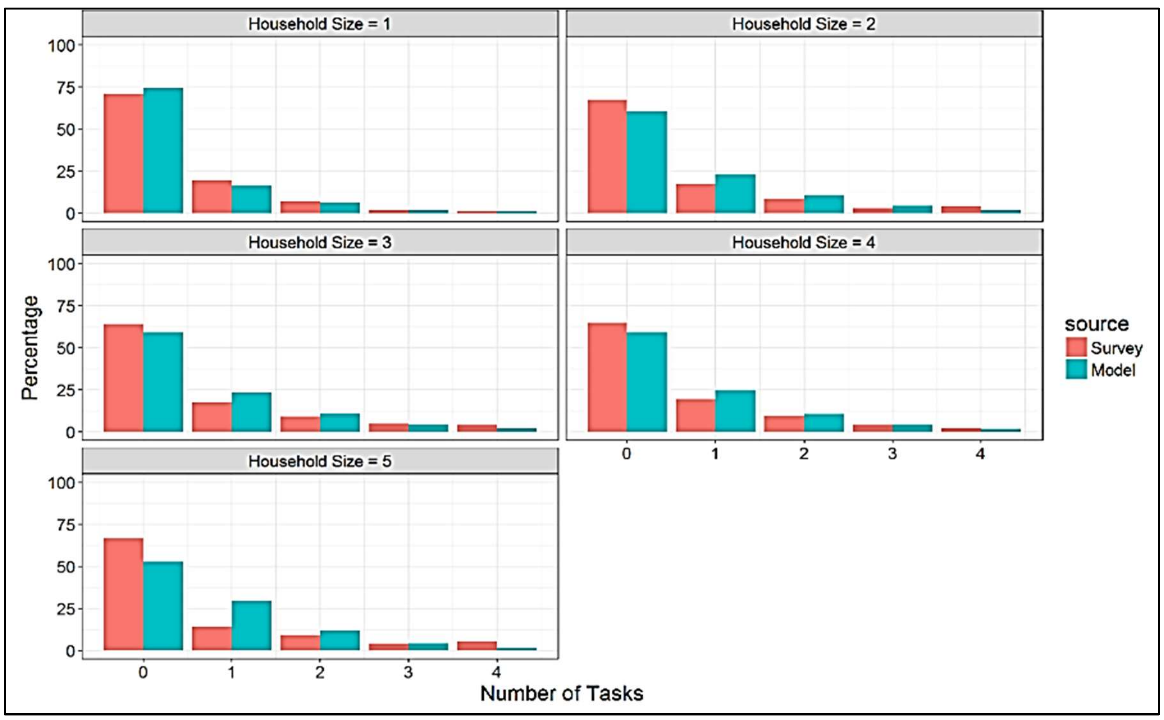


Figure 11-2: Allocation of Shopping Tasks to Household Members

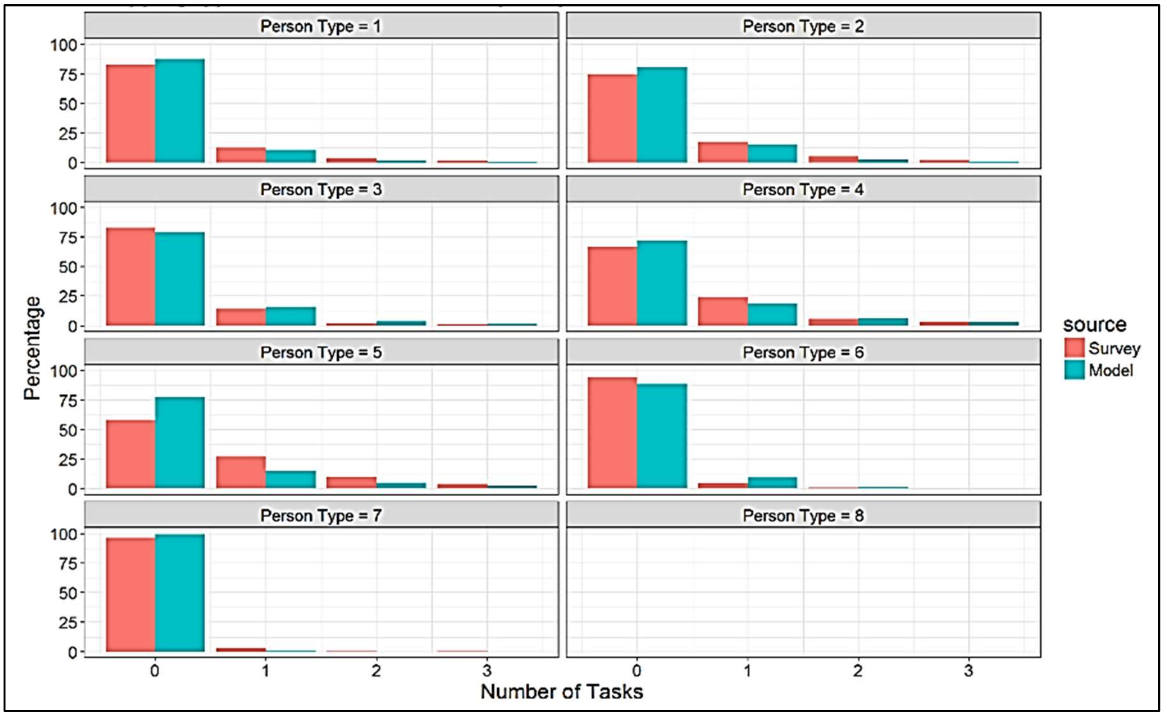


Figure 11-3: Frequency of Allocated Household Errands

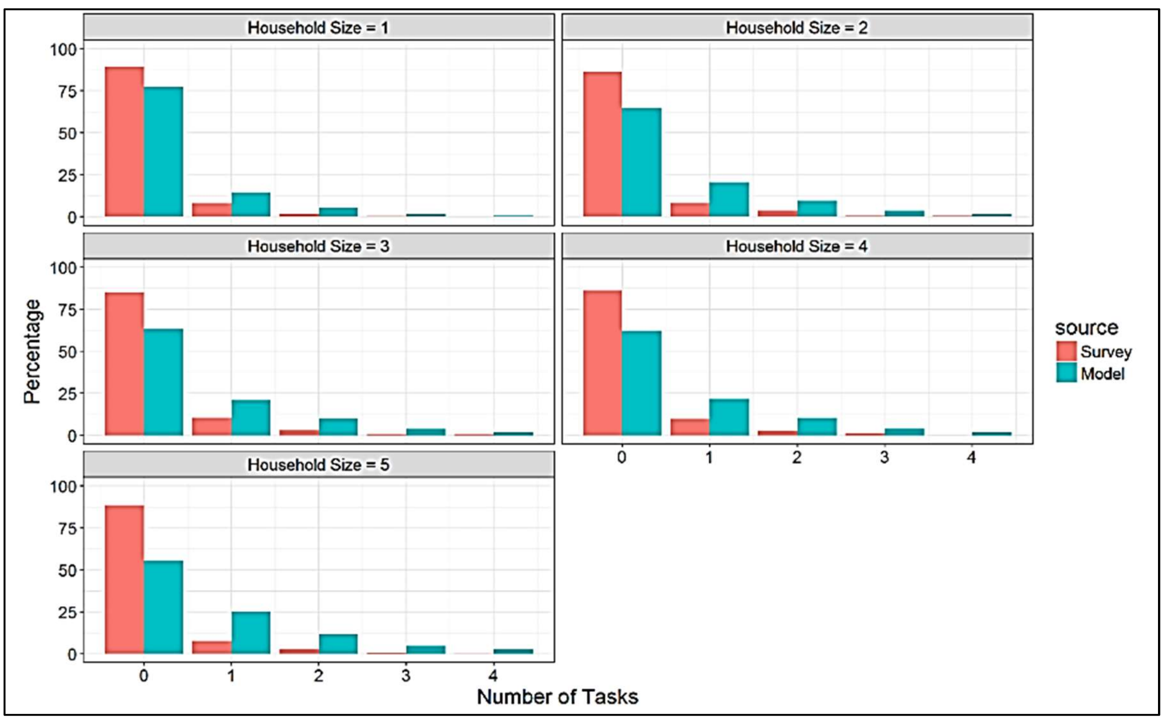


Figure 11-4: Allocation of Household Errands Tasks to Household Members

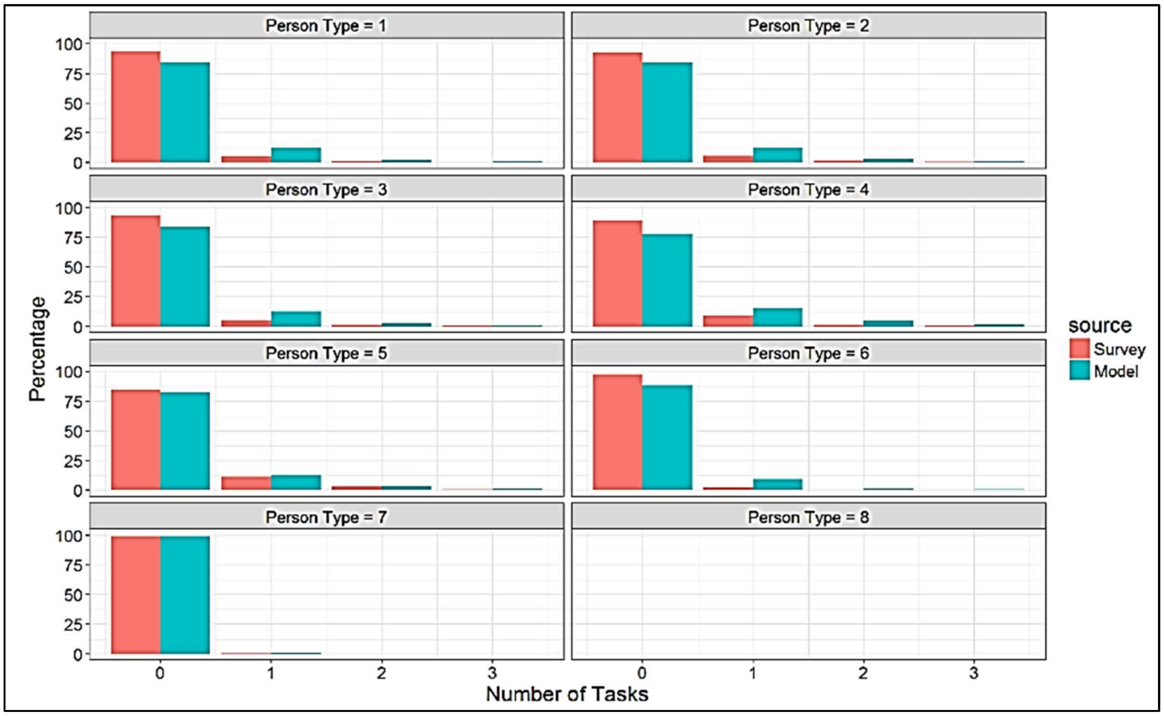


Figure 11-5: Frequency of Allocated Household Escorting Tasks

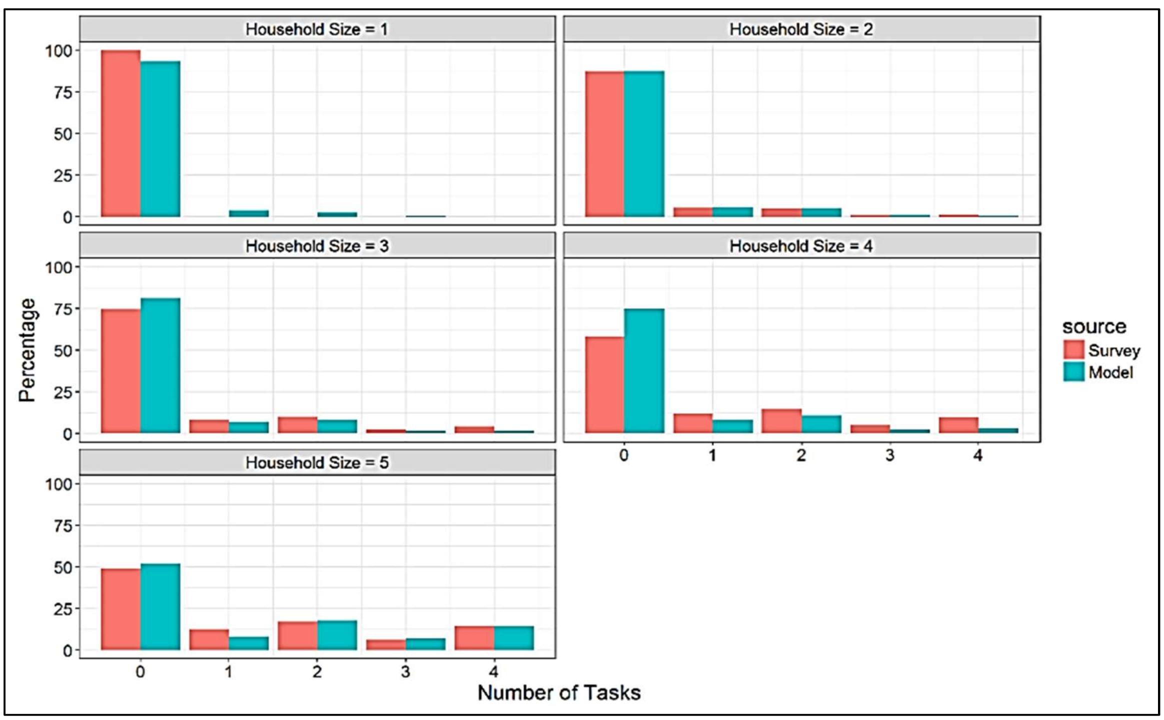


Figure 11-6: Allocation of Escorting Tasks to Household Members

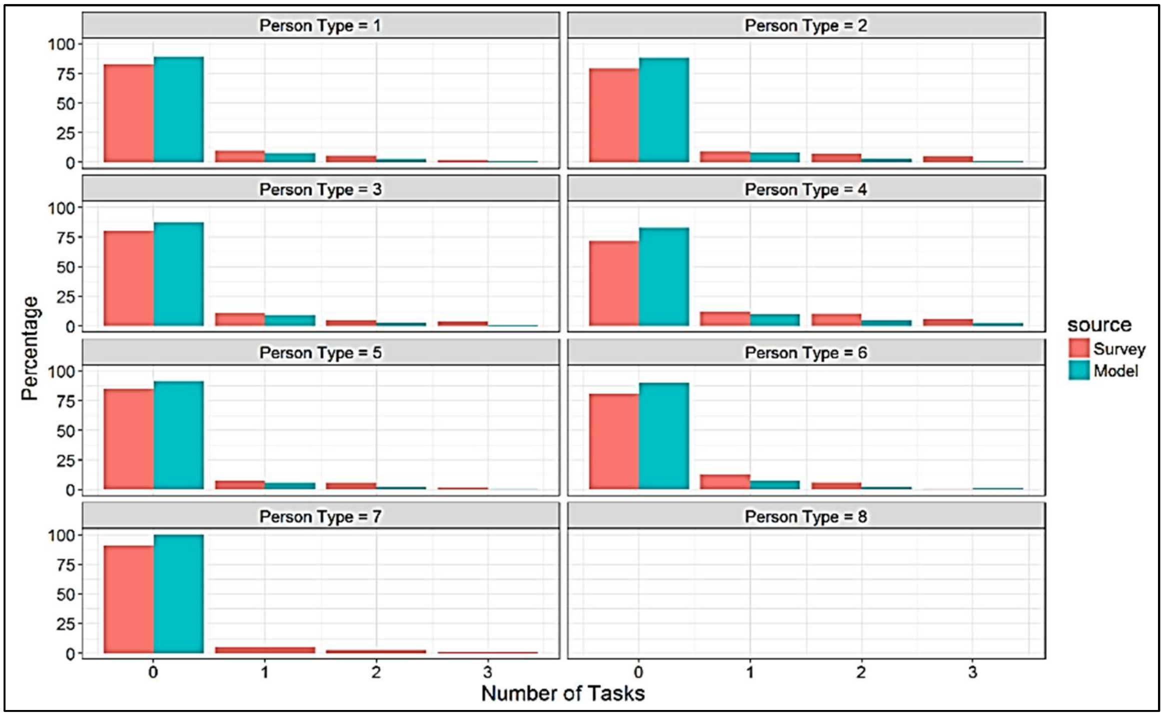
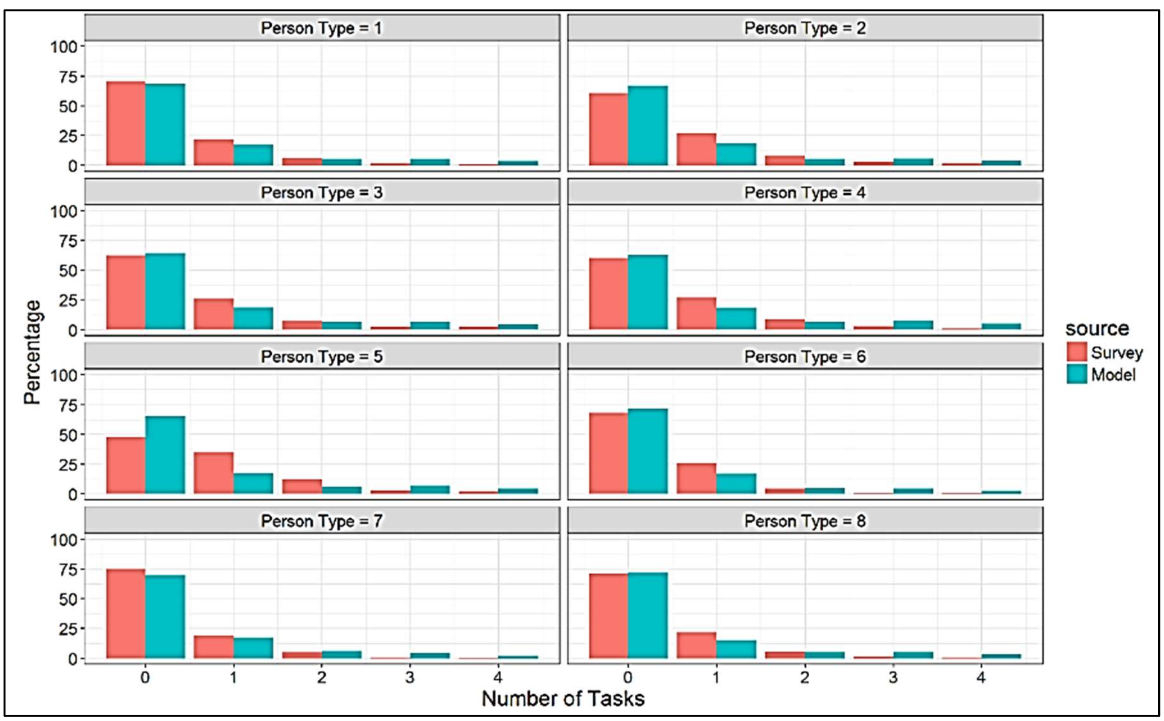


Figure 11-7: Frequency of Individual Discretionary Activities



Chapter 12 Tour Formation

Introduction

A preliminary schedule of the prioritized activities and associated tours has already been predicted at this stage of the model chain. Given this preliminary schedule, the entire day can be characterized as consisting of day segments created by the prioritized activities. This approach of creating day segments is important because different day segments are associated with different temporal and spatial constraints.

Allocation of Individual Non-Mandatory Activities to Day Segments

The day segments to which non-prioritized activities are allocated can be classified into the following three types:

Type 1: Segment between the prioritized activity tours. These allocations generate individual non-mandatory tours.

Type 2: Outbound and inbound legs of prioritized tours. These allocations do not result in any new tours but increase the number of stops in the prioritized tours. For multiple commute tours, Type 2 refers to the outbound leg of first commute tour and inbound leg of last commute tour.

Type 3: This category corresponds to at-work sub-tours that start and end at the workplace. For example, a worker going out for lunch during office hours is categorized as a Type 3 allocation.

Model Application and Calibration

The tour formation model was calibrated to match the observed activity segment allocation by person type and the observed tour frequency and observed stop frequency by segment type. Tour frequency is a function of the number of tour breaks, but also a function of the total number of activities. For this reason, this model and the non-mandatory activity frequency model are calibrated simultaneously. Figure 12-1 and Figure 12-2 show the tour frequency calibration and stop frequency calibration, respectively. Figure 12-3 shows the tour length by number of stops in the tour.

Figure 12-1: Tour Formation by Day-Segment

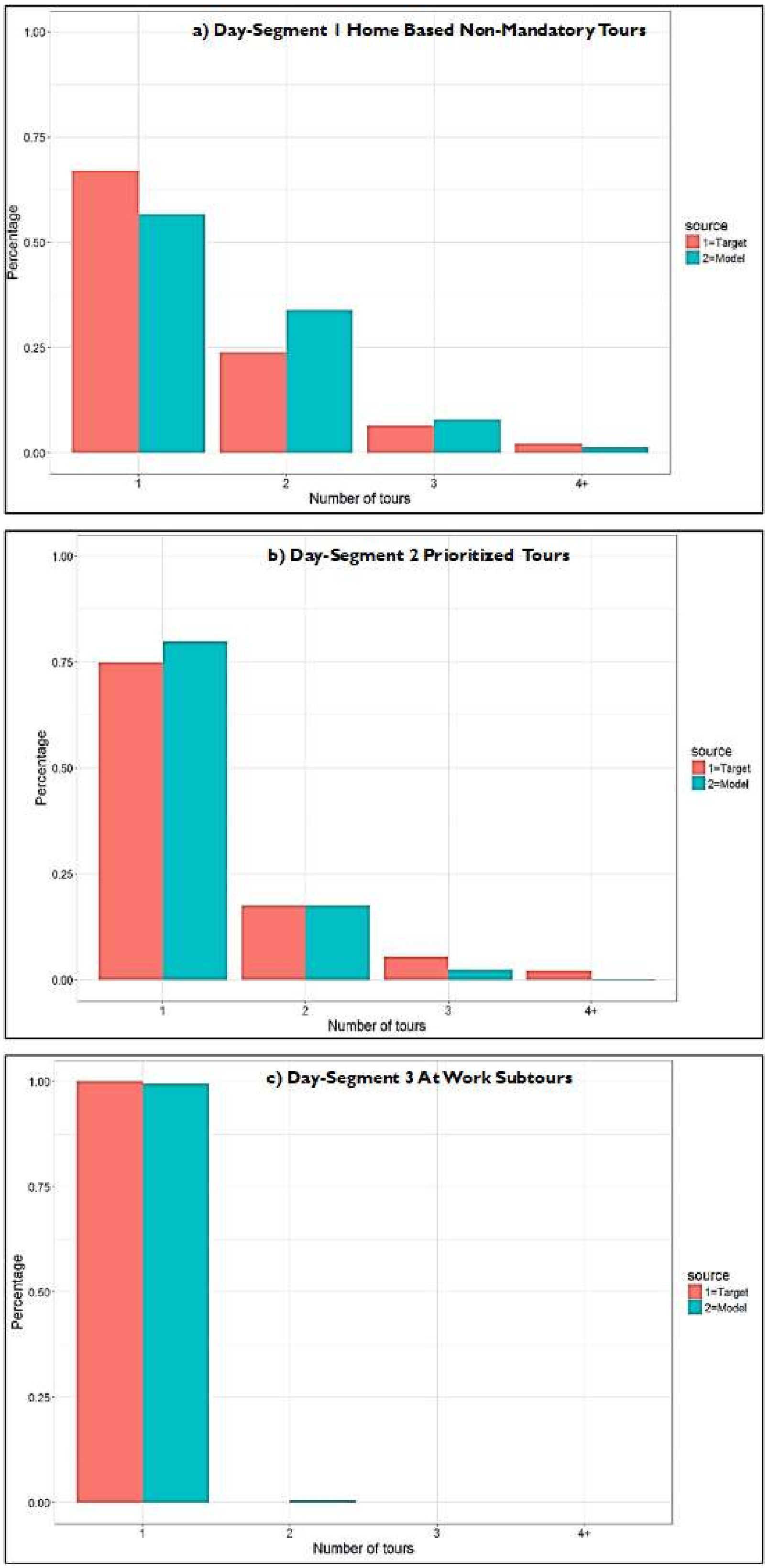


Figure 12-2: Stop Frequency on Tours by Day-Segment

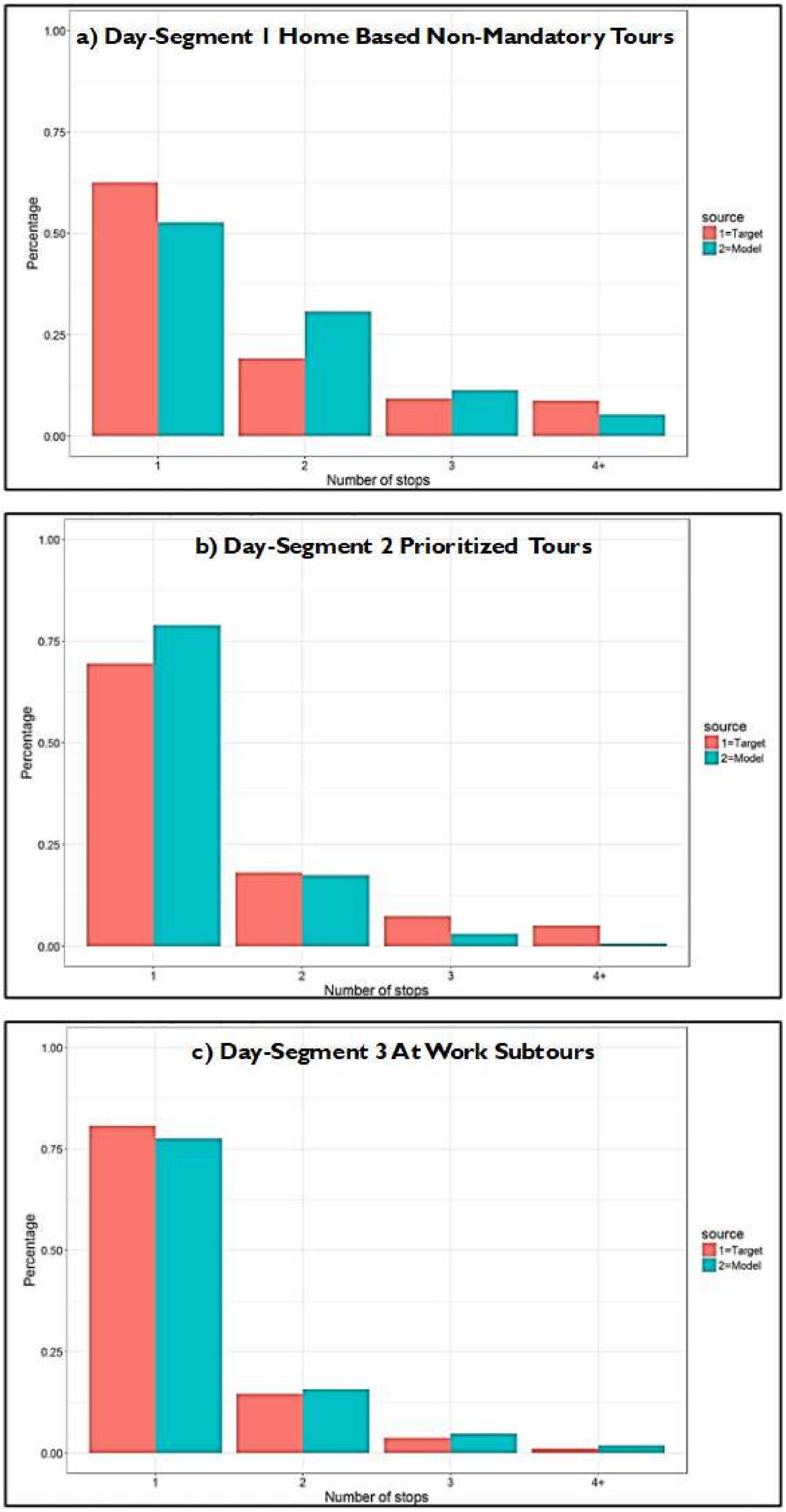


Figure 12-3: Average Tour Length by Day-Segment

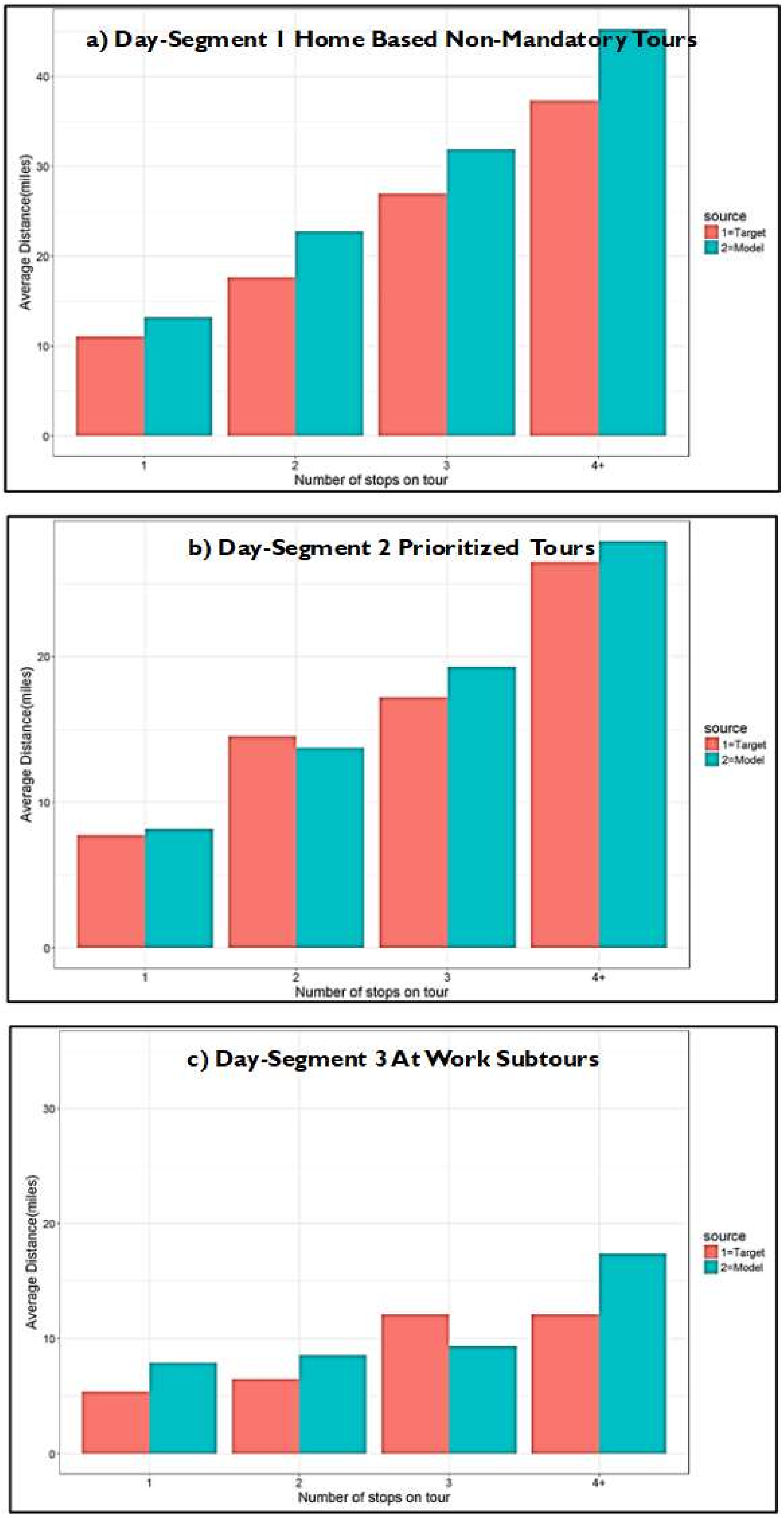


Table 12-1: Average Number of Tours per Person

Tour Purpose					
Observed	**Work**	**School**	**Household Maintenance**	**Individual**	**Total**
1 Full-Time Worker	0.86	0.00	0.14	0.40	1.39
2 Part-Type Worker	0.64	0.08	0.22	0.71	1.65
3 College Student	0.11	0.50	0.15	0.66	1.42
4 Non-Worker	0.00	0.02	0.39	1.10	1.50
5 Retired	0.00	0.00	0.34	0.79	1.14
6 Driving Age Child	0.05	0.88	0.04	0.36	1.33
7 Pre-Driving Age Child	0.00	0.93	0.09	0.37	1.39
8 Pre-School Child	0.00	0.36	0.38	0.48	1.21
Predicted	**Work**	**School**	**Household Maintenance**	**Individual**	**Total**
1 Full-Time Worker	0.81	0.01	0.08	0.60	1.50
2 Part-Type Worker	0.64	0.06	0.14	0.69	1.52
3 College Student	0.01	0.62	0.18	0.77	1.57
4 Non-Worker	0.00	0.00	0.44	1.05	1.49
5 Retired	0.00	0.00	0.41	0.86	1.27
6 Driving Age Child	0.01	0.92	0.11	0.71	1.75
7 Pre-Driving Age Child	0.00	0.92	0.01	0.80	1.74
8 Pre-School Child	0.00	0.41	0.00	0.92	1.33
Difference	**Work**	**School**	**Household Maintenance**	**Individual**	**Total**
1 Full-Time Worker	-0.05	0.01	-0.06	0.20	0.11
2 Part-Type Worker	0.00	-0.02	-0.08	-0.02	-0.13
3 College Student	-0.10	0.12	0.03	0.11	0.15
4 Non-Worker	0.00	-0.02	0.05	-0.05	-0.01
5 Retired	0.00	0.00	0.07	0.07	0.13
6 Driving Age Child	-0.04	0.04	0.07	0.35	0.42
7 Pre-Driving Age Child	0.00	-0.01	-0.08	0.43	0.35
8 Pre-School Child	0.00	0.05	-0.38	0.44	0.12

Table 12-2: Total Tours by Person Type

Person Type	Observed Tours			
	Mandatory Tours	Household Maintenance Tours	Other Non-Mandatory Tours	Total Tours
1 Full-Time Worker	5,431,526	856,308	2,535,934	8,823,768
2 Part-Type Worker	1,047,719	315,969	1,039,993	2,403,681
3 College Student	609,809	147,323	650,673	1,407,805
4 Non-Worker	0	1,277,755	3,713,878	4,991,633
5 Retired	0	684,603	1,586,851	2,271,454
6 Driving Age Child	575,093	26,257	225,164	826,514
7 Pre-Driving Age Child	2,494,591	241,777	995,788	3,732,157
8 Pre-School Child	468,688	495,100	634,515	1,598,303
Total Tours	**10,690,478**	**4,045,092**	**11,320,000**	**26,060,000**

Person Type	Model Estimated Tours (2016)			
	Mandatory Tours	Household Maintenance Tours	Other Non-Mandatory Tours	Total Tours
1 Full-Time Worker	5,719,116	633,125	2,399,434	8,751,675
2 Part-Type Worker	1,086,619	192,937	837,992	2,117,548
3 College Student	622,864	168,156	598,850	1,389,870
4 Non-Worker	0	1,194,487	4,386,956	5,581,443
5 Retired	0	646,316	1,811,697	2,458,013
6 Driving Age Child	572,158	61,159	211,091	844,408
7 Pre-Driving Age Child	2,431,650	261,232	800,051	3,492,933
8 Pre-School Child	529,209	150,071	599,142	1,278,422
Total Tours	**10,961,616**	**3,307,483**	**11,645,213**	**25,914,312**

Table 12-3: Total Trips by Person Type

Person Type	Observed Trips			
	Mandatory Tours	**Household Maintenance Tours**	**Other Non-Mandatory Tours**	**Total Tours**
1 Full-Time Worker	17,358,807	1,417,978	6,283,364	25,060,149
2 Part-Type Worker	3,340,979	448,560	2,273,955	6,063,494
3 College Student	1,909,033	393,372	1,623,358	3,925,763
4 Non-Worker	0	2,932,564	12,673,841	15,606,405
5 Retired	0	1,611,864	5,106,776	6,718,640
6 Driving Age Child	1,559,712	133,705	500,745	2,194,162
7 Pre-Driving Age Child	6,521,140	569,064	1,943,395	9,033,599
8 Pre-School Child	1,377,651	330,595	1,541,818	3,250,064
Total Trips	**32,067,322**	**7,837,702**	**31,947,252**	**71,852,276**
Person Type	**Model Estimated Trips (2016)**			
	Mandatory Tours	**Household Maintenance Tours**	**Other Non-Mandatory Tours**	**Total Tours**
1 Full-Time Worker	17,358,807	2,271,792	6,513,233	26,143,832
2 Part-Type Worker	3,340,979	887,617	2,748,123	6,976,719
3 College Student	1,909,033	404,998	1,770,295	4,084,326
4 Non-Worker	0	3,459,110	9,704,058	13,163,168
5 Retired	0	2,067,010	4,393,489	6,460,499
6 Driving Age Child	1,559,712	74,953	554,117	2,188,782
7 Pre-Driving Age Child	6,521,140	589,781	2,321,971	9,432,892
8 Pre-School Child	1,377,651	1,192,323	1,663,642	4,233,616
Total Trips	**32,067,322**	**10,947,584**	**29,668,928**	**72,683,834**

Chapter 13 Final Time of Day

Introduction

The time-of-day choice model is a hybrid discrete-choice and duration construct that operates with tour departure-from-home and arrival-back-home time combinations as alternatives. The utility structure is identical to the structure of the mandatory activity time-of-day model. The model uses availability rules for each subsequently scheduled tour, to be placed in the residual time window left after scheduling tours of higher priority. This conditionality ensures full consistency of the individual entire-day activity and travel schedule as an outcome of the model.

The model uses household, person, and zonal characteristics, most of which are generic across time alternatives. Network LOS variables vary by time of day and are specified as alternative-specific based on each alternative's departure and arrival time. By using generic coefficients and variables associated with the departure period, arrival period, or duration, a compact structure of the choice model is created, where the number of alternatives can be arbitrarily large depending on the chosen time unit scale, but the number of coefficients to estimate is limited to a reasonable number. Duration variables can be interpreted as "continuous shift" factors that parameterize the termination rate. Positive coefficients mean that duration tends to increase, while negative coefficients shift the time-of-day distributions toward shorter durations.

The tour-scheduling model is placed after destination choice (tour formation) and before mode choice. Thus, the destination of the tour and all related destination and origin-destination attributes are known and can be used as explanatory variables.

For work and school activities, the time-of-day choice model is applied twice. It is first applied to define start and end times of the work and school activity episodes (see Chapter 9). At this stage, the details of work and school tours (and details of the other activities of the person day) are not known except for possible participation in a fully joint tour. If there are several activity episodes allocated to several tours, the start time of the first one and the end time of the last one is modeled. Once all the details of the tours are known (except for trip mode), then the entire work and school tour time of day choice is modeled conditional upon the work / school activity schedule, other intermediate stops assigned to the work / school tour, and other activities and tours planned by the person.

The final time-of-day model predicts start and end time for each tour from the departure from home for the first activity until arrival back home after the last activity. The model has a 15-minute temporal resolution, and it ensures that the time of day choices for any person are consistent throughout the day (i.e., without gaps or overlaps).

Model Calibration and Application

The model was calibrated by adjusting the time-specific constants and/or shift variables, based on comparisons of the tour departure, tour arrival and tour duration predictions to diurnal distributions obtained from the 2011 CHTS. A top-down check was also applied, which consisted of verifying the trip time-of-day shares (aggregated for the five highway assignment periods) to targets from the 2011 CHTS. Some adjustments to the time of day distributions were also made to improve the overall traffic assignment by time period. The final time of day distributions are shown in Figure 13-1 to Figure 13-5, aggregated to one-hour intervals to smooth out lumpiness due to small sample size.

Figure 13-1: Work Tour Time of Day Choice

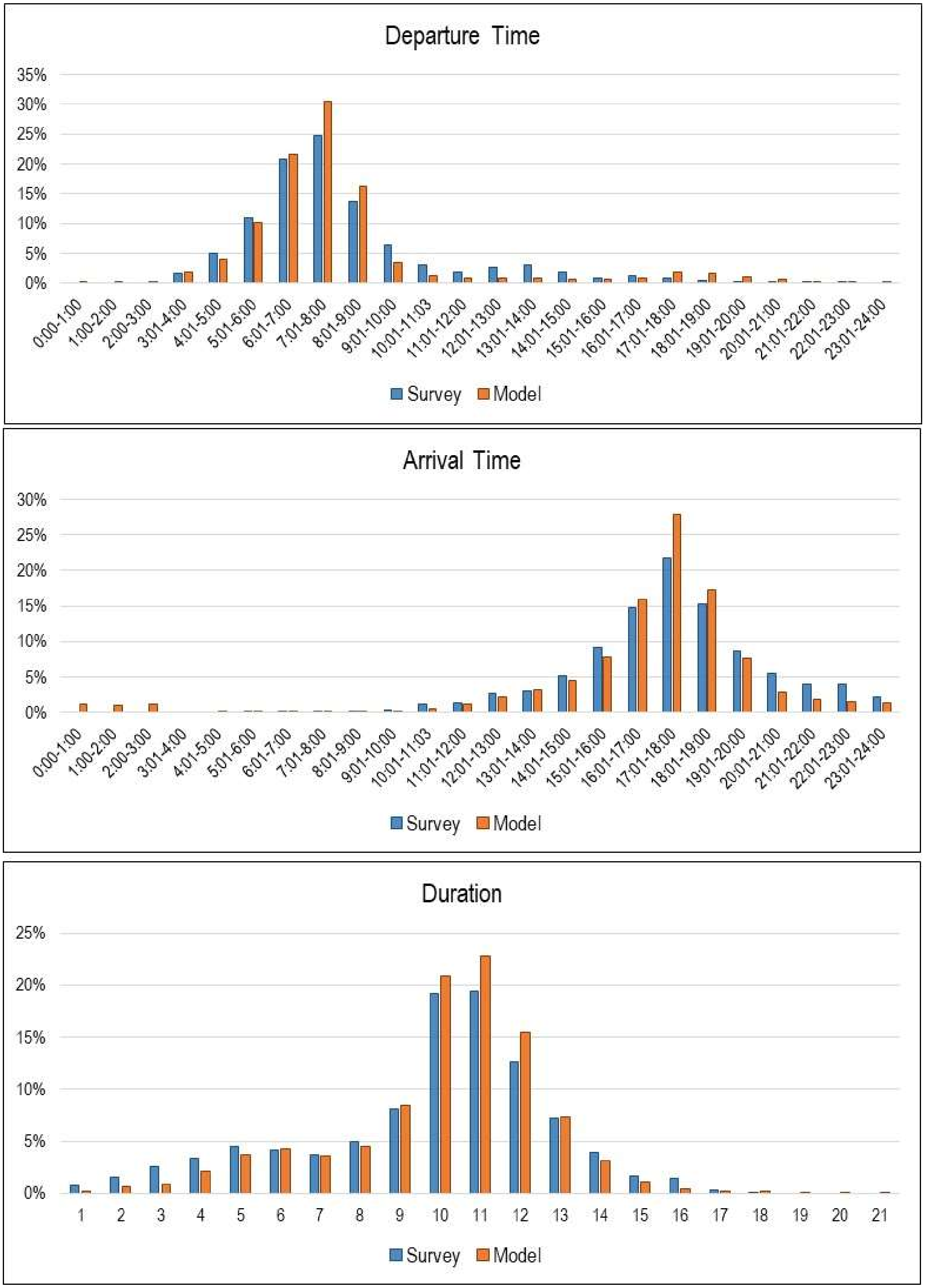


Figure 13-2: College/University Tour Time of Day Choice

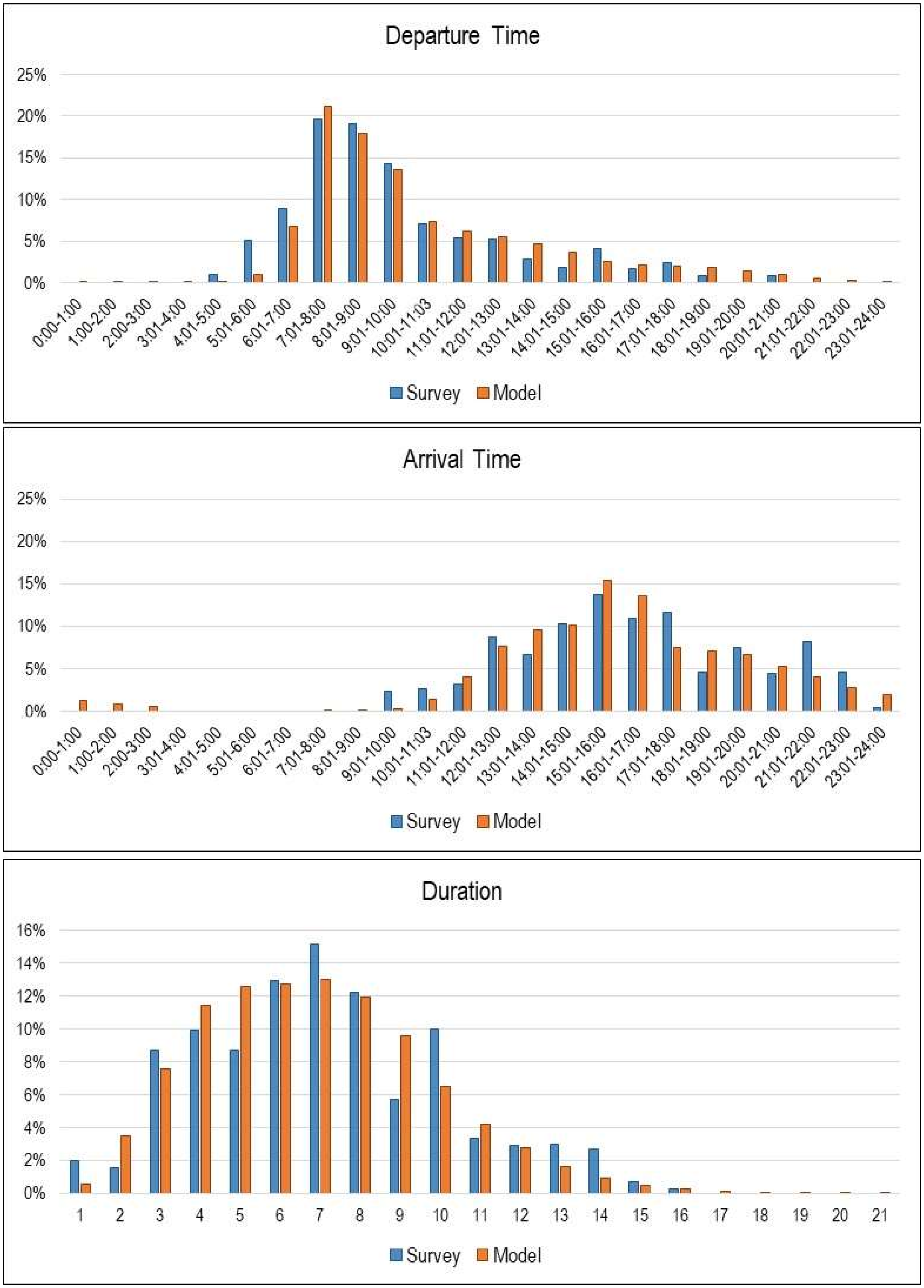


Figure 13-3: School Tour Time of Day Choice

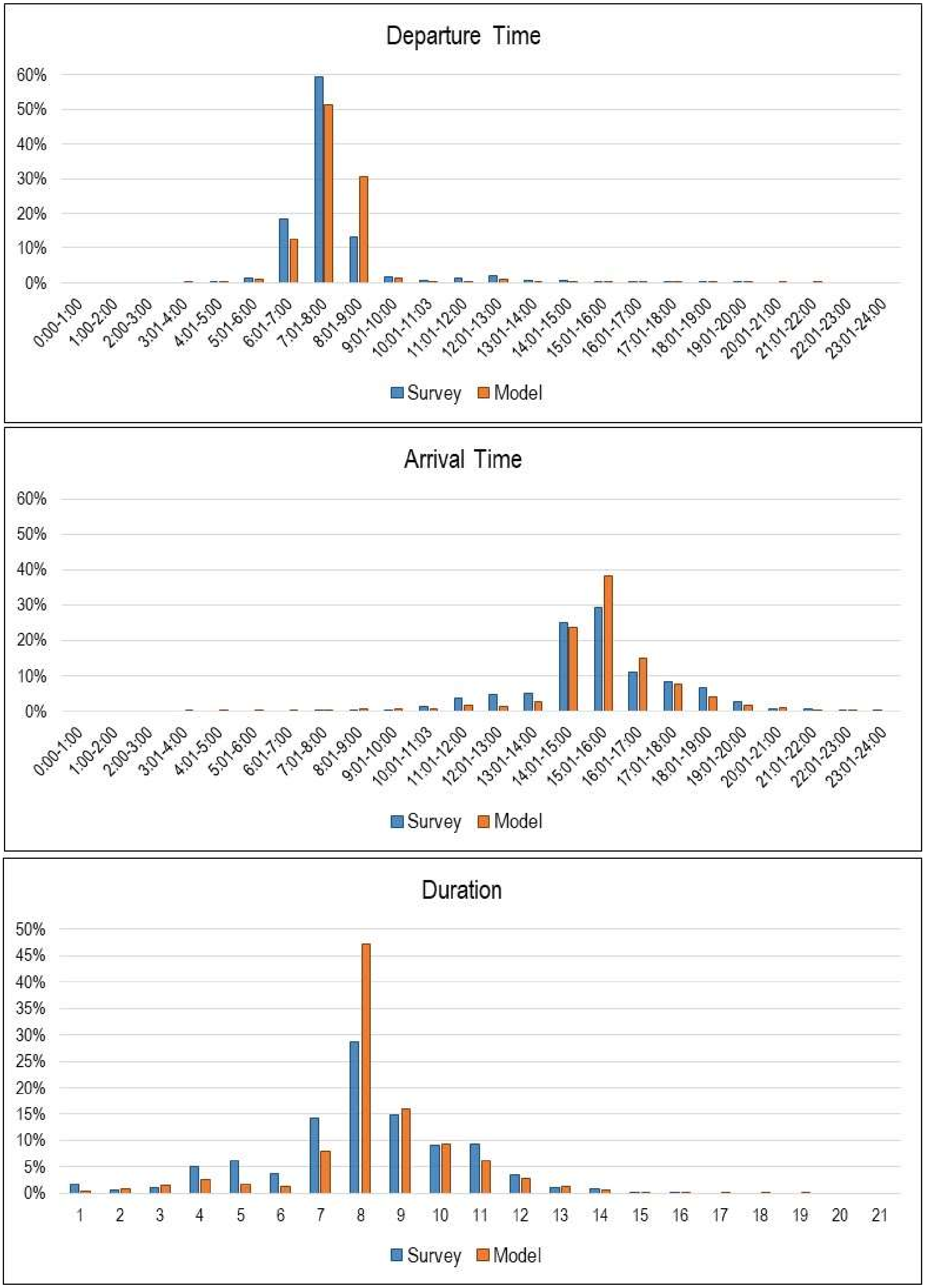
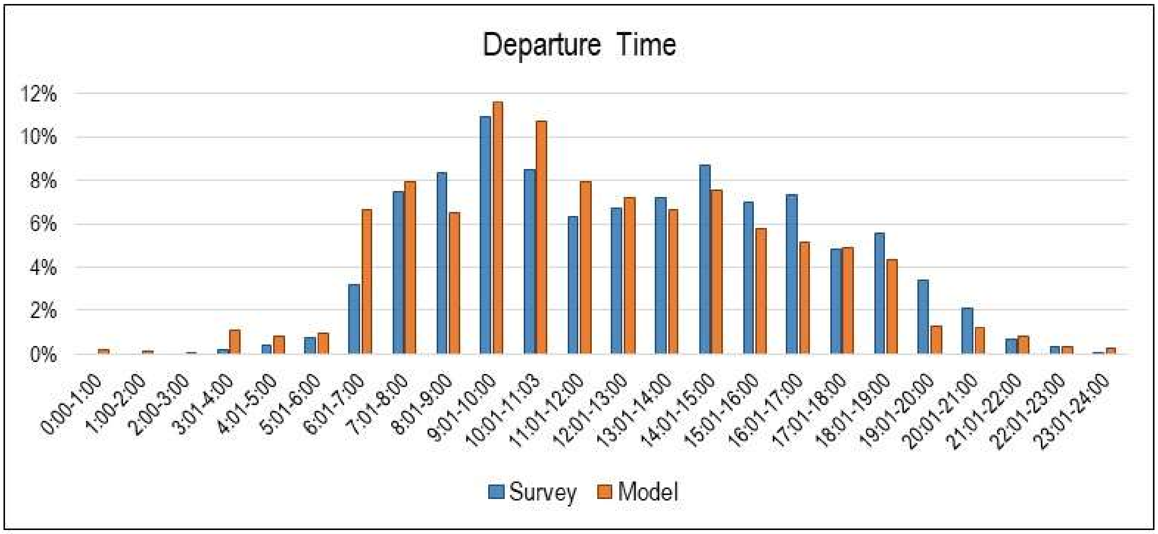
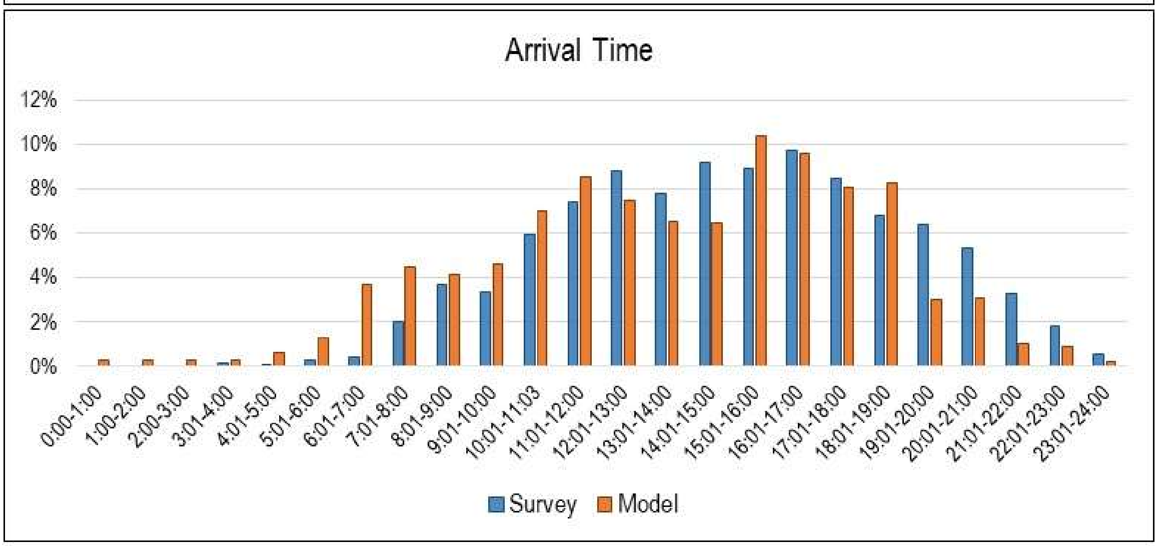


Figure 13-4: Maintenance Tour Time of Day Choice





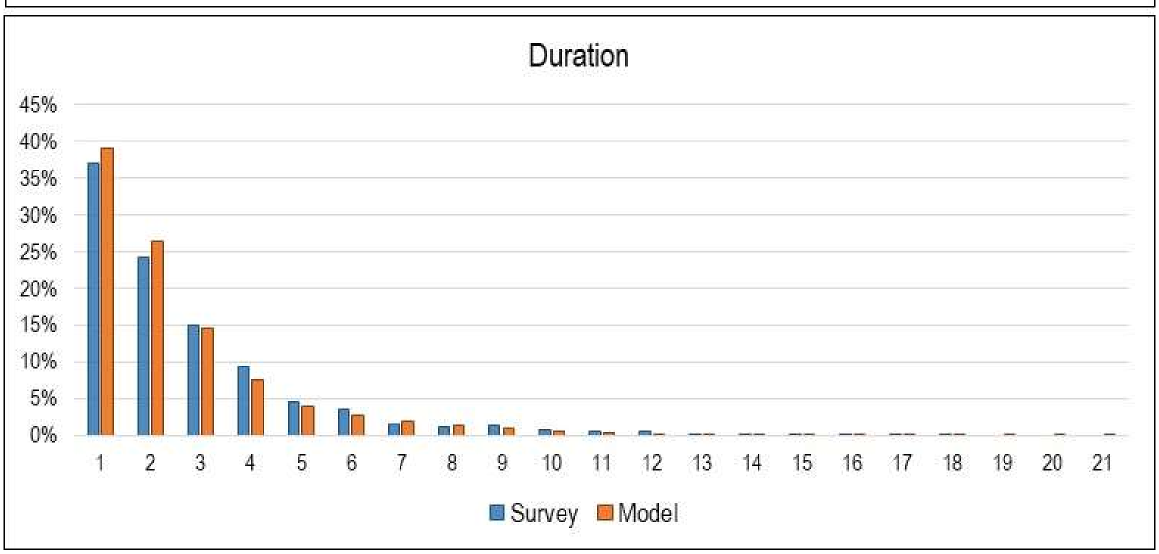
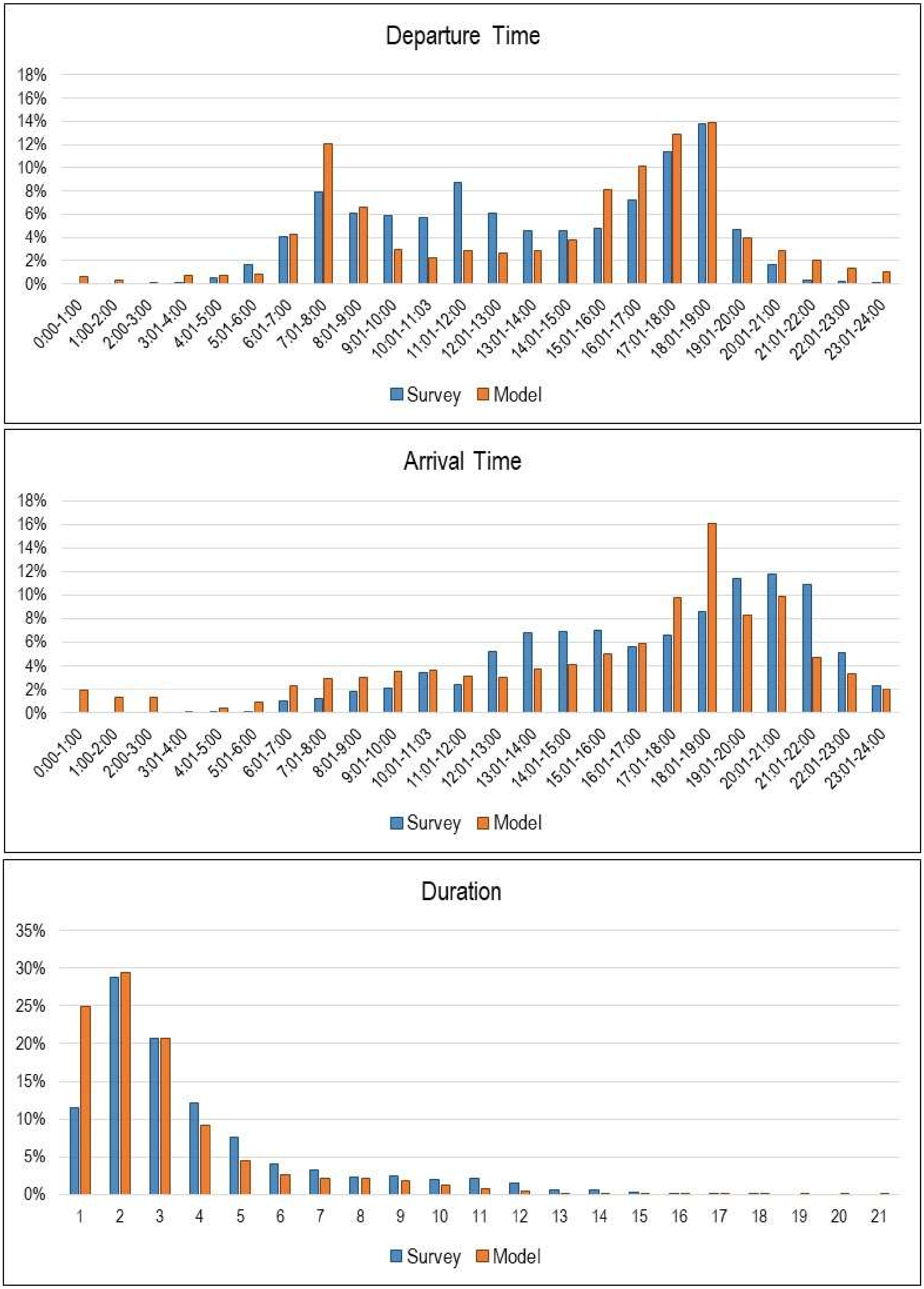


Figure 13-5: Discretionary Tour Time of Day Choice



Chapter 14 MODE CHOICE

Introduction

In the SCAG ABM, the tour-level and trip-level mode choices are integrated in a network combinatorial representation that considers all feasible trip mode combinations on the tour. The model exhibits the following desirable properties:

- Ensures full consistency between the tour-level and trip-level mode choices considering the locations of all stops on the tour,
- Accounts for multiple combinatorial constraints on available trip modes by explicitly tracking car status at each trip end,
- Integrates multi-modal combinations, and specifically, PNR lot location choices into the trip mode choice structure in a consistent way for the entire tour,
- Avoids explicit enumeration of all possible trip mode combinations by applying an efficient network shortest path algorithm, and a parsimonious choice set structure for each trip in model estimation,
- Accounts for similarities among trip mode combinations by simulating correlated error terms for tour modes from trip-mode error terms.

Observed Tour Mode Combinations

The model considers a total of 14 trip modes (m), shown in Table 14-1. The mode of a tour depends on the modes observed in all trips that comprise the tour, and it is defined using priority rules. Typically, more than 70% of all trips in a tour exhibit the same mode. This is especially so for simple one-destination tours (i.e., two trips in the tour). There remains, however, many cases, especially complex multi-destination tours, where the tour mode combination includes more than one mode.

In the combinatorial mode choice model, consistent tour mode combinations emerge by tracking car status through the trip chain. At any trip origin or destination, the car status (s) is classified into four possible states:

1. "Car from home", which means that until this point the car was used on all preceding trips and has never been parked outside the home, hence the car is available for the subsequent trip.
2. "Car parked", which means that the car was used originally (at least for the first trip from home) but it was subsequently parked outside home on one of the preceding trips, and hence the car is not available for the subsequent trip.
3. "Car from parking", which means that car was parked earlier on this tour but then it was taken upon return trip to the parking lot and is available for the subsequent trip.
4. "No car on tour", which means that a car was not used for the very first trip on the tour and hence it is not available for any subsequent trip.

As shown in in Table 14-1, car status defines many logical constraints on the trip mode choice.

Table 14-1: Feasible Combinations of Trip Origin Car Status, Trip Mode, and Trip Destination Car Status

Car Status at Trip Origin				Trip Mode	Car Status at Trip Destination			
Car from home (1)	Car from parking (3)	Car parked (2)	No car on tour (4)		1	3	2	4
✓	✓			1=SOV/driver	✓	✓	✓	
✓	✓			2=HOV2/driver	✓	✓	✓	
✓	✓			3=HOV3+/driver	✓	✓	✓	
			✓	4=HOV/passenger				✓
		✓	✓	5=Conventional transit/walk		✓	✓	✓
			✓	6=Conventional transit/KNR				✓
		✓		7=Conventional transit/PNR		✓		
		✓	✓	8=Premium transit/walk		✓	✓	✓
			✓	9=Premium transit/KNR				✓
		✓		10=Premium transit/PNR		✓		
		✓	✓	11=Walk		✓	✓	✓
		✓	✓	12=Bike		✓	✓	✓
			✓	13=Taxi/TNC				✓
			✓	14=School bus				✓

Formulation of Feasible Tour Mode Combinations

A tour mode combination is considered feasible if it obeys the system of logical constraints imposed across multiple dimensions. Basic feasibility rules are applied in a framework of sequential joint choice of mode and destination car status for each trip, conditional upon the car status at the trip origin. The application of feasibility rules for the entire sequence of trips in a tour ensures that no trip sequence includes impossible trip mode combinations.

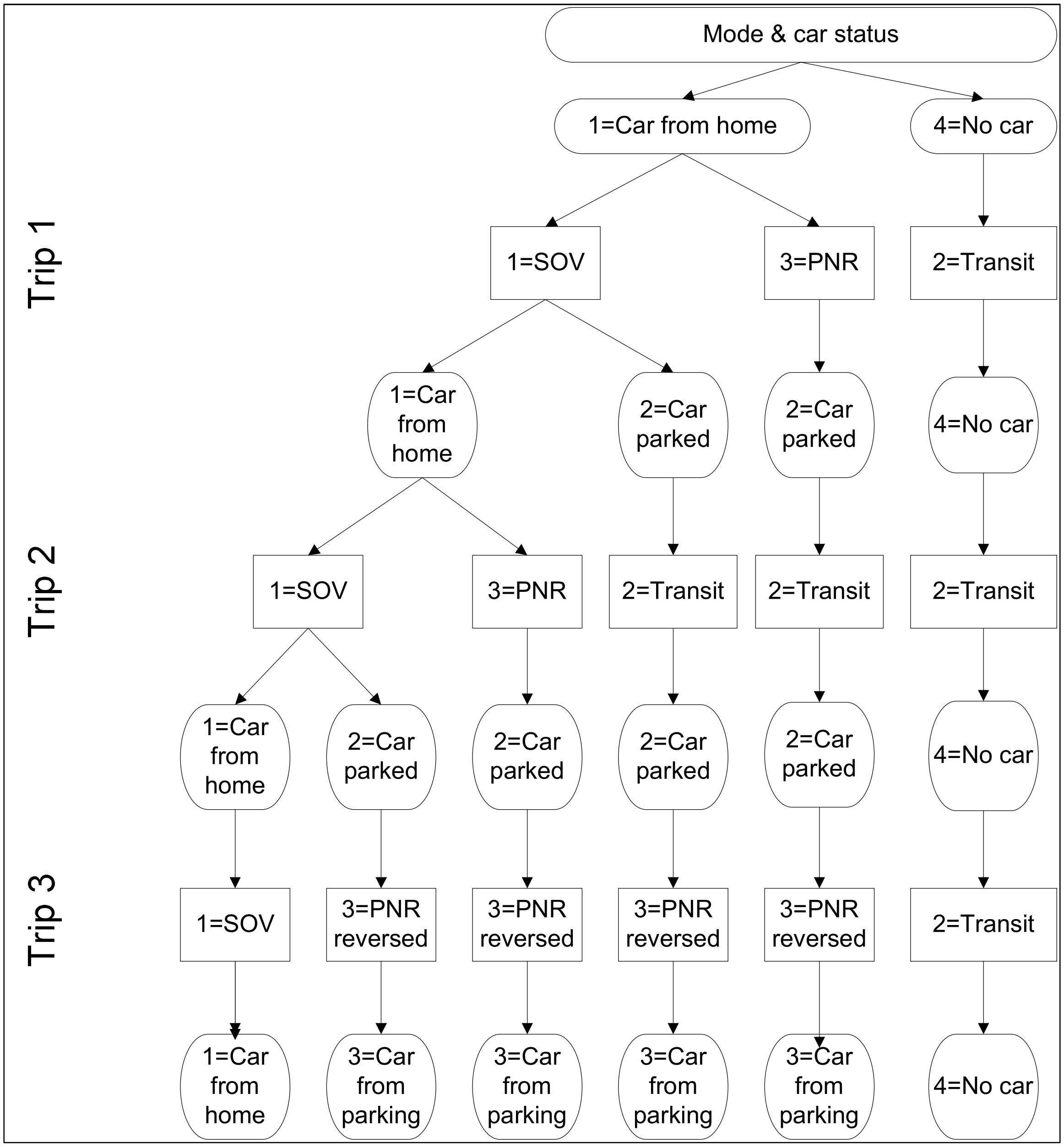
There are additional rules that further truncate the possible trip mode combinations, imposed using the same technique. These feasibility rules are applied separately for outbound and inbound half-tours, they constrain the number of car status switches from "car parked" to "car from parking" and vice-versa, and they ensure that the car taken from home always arrives back home. The usual set of trip-level mode constraints are also applied, such as transit availability based on level-of-service. Person-level constraints further truncate the set of possible mode combinations. Person-level constrains include for example car availability, driver license, participation in joint travel, etc.

The feasibility constraints can be viewed as a decision-making tree, where the modes available for each subsequent trip are branched out of the chosen modes and car statuses for the previous trips. For illustration purposes, consider the example of a 3-trip home-based tour with three possible modes (1=SOV, 2=Walk to transit, 3=PNR to transit), shown in Table 14-1. The example assumes that the first two trips (Trip 1 and Trip 2) occur in the outbound direction while the third trip occurs in the inbound direction (Trip 3). For the outbound trips, there is the option of PNR switching to car status 2 (essentially, leaving the car at the PNR lot and continuing by transit), while for the inbound trip the corresponding option is riding transit and picking up the car from the PNR lot, which is identified as reverse PNR with a switch to car status 1.

At the beginning of the tour (origin of Trip 1) only two car status are possible (1=car from home and 4=no car on tour). The possible modes for Trip 1 are SOV and PNR to transit (conditional on car status 1) and Walk to transit (conditional on car status 4). At the end of Trip 1, all possible car status can be readily identified, based on the possible Trip 1 modes. Car status at the destination of Trip 1 defines the possible trip modes for Trip 2. The end of Trip 2 is the primary destination, so as indicated above, the next trip is in the inbound direction and therefore only reverse PNR is available. At the end of the tour, only three car statuses (1, 3, and 4) are available.

This example illustrates the importance of a properly constraining trip mode and car status combinations. While a simplified Cartesian consideration of all possible trip mode and car status combinations results in 3^3=27 combinations, the actual number of feasible combinations given logical car tracking is only 6.

Figure 14-1: Feasible Combinations of Trip Modes and Car Statuses on a 3-Trip Tour



TRIP MODE UTILITY FUNCTION

The combinatorial trip mode utility exhibits two important differences relative to the utility of a standard (logit) mode choice model.

First, the combinatorial trip mode utility includes entire-tour effects and transaction costs associated with mode switches. Utility $V_t(m)$ is dependent on the choices implied by previous trips in the feasible mode and car status combination. The most statistically significant mode transaction effects include:

- Transit mode switching penalties that reflect fare discounts and/or transit pass consideration and make transit mode fare for the given trip a function of the previously chosen transit modes.

- Car occupancy switching penalties that reflect systematic car occupancy changes by direction where passenger drop-offs happen mostly in the direction from home, while passenger pick-ups happen mostly in the direction towards home.
- PNR symmetry, i.e., taking a car from the same parking lot it was originally parked; this utility component is not a statistically estimated penalty but a constraint on how LOS variables are calculated for the reversed PNR trip. Distance, travel time, and cost for inbound reversed PNR are conditional upon the chosen parking location in the outbound PNR trip. Since choice of both the outbound and reversed PNR trips are part of the feasible entire-tour alternative, the choice of PNR lot is also somewhat optimized.

Second, the utility function for each trip and mode is structured in such a way that it is always negative $(V_t(m) < 0)$. This is essential for an efficient application algorithm that borrows from the network shortest path techniques. For this reason, the mode utility structure is specified to have only negative constants and negative coefficients on positive variables (such as travel time and cost).

As in the case of a logit model, trip mode utility has both deterministic and random components. The deterministic component is a function of LOS, mode-specific constants, and person, household or trip attributes. The random component is assumed to be Gumbel-distributed.

Several tour mode combinations have common components, and therefore cannot be considered as independent alternatives. For example, in Table 14-1, three of the six feasible tour mode combinations include reverse PNR for Trip 3. These common components are known as overlapping routes in the network literature. Overlapping routes will have common random terms and will be more correlated with each other than with non-overlapping routes. This correlation is addressed with an additive-by-link error term, rather than through a complex entire-route random term.

Model Calibration and Application

Pre-Mode Choice Checks

Various checks were performed on the person trips produced by all steps prior to mode choice, to verify their reasonableness. Since there is more experience in the SCAG region with trip-based (i.e., four-step) model outputs, the ABM person trips were compared against 2011 CHTS metrics produces as if for the trip-based model (TBM). For these comparisons, the ABM person trips were re-categorized using the standard TBM trip purpose definitions.

The person trip checks include the following:

- Trip purpose composition of the regional person trips. Figure 14-2 shows that the ABM generates home-based work (HBW), home-based shop (HBSH), etc., trips that follow approximately the same distribution as the TBM.
- Trip distance. Table 14-3 shows that the ABM predicts, on aggregate, similar average trip lengths for mandatory activities (work and school) as the TBM. The trip lengths for non-mandatory activities are also comparable
- Trip distance by trip mode.

- Person and vehicle trips by time period.

Figure 14-2: Trips by Trip Purpose

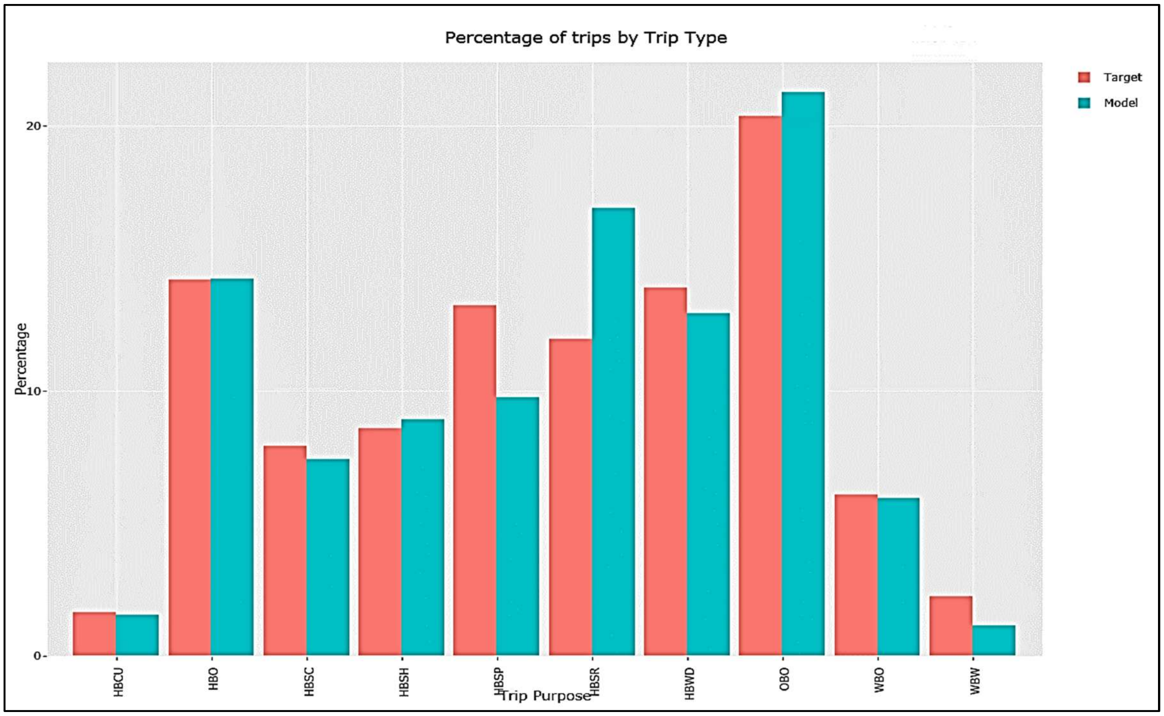


Figure 14-3: Average Trip Distance by Trip Purpose

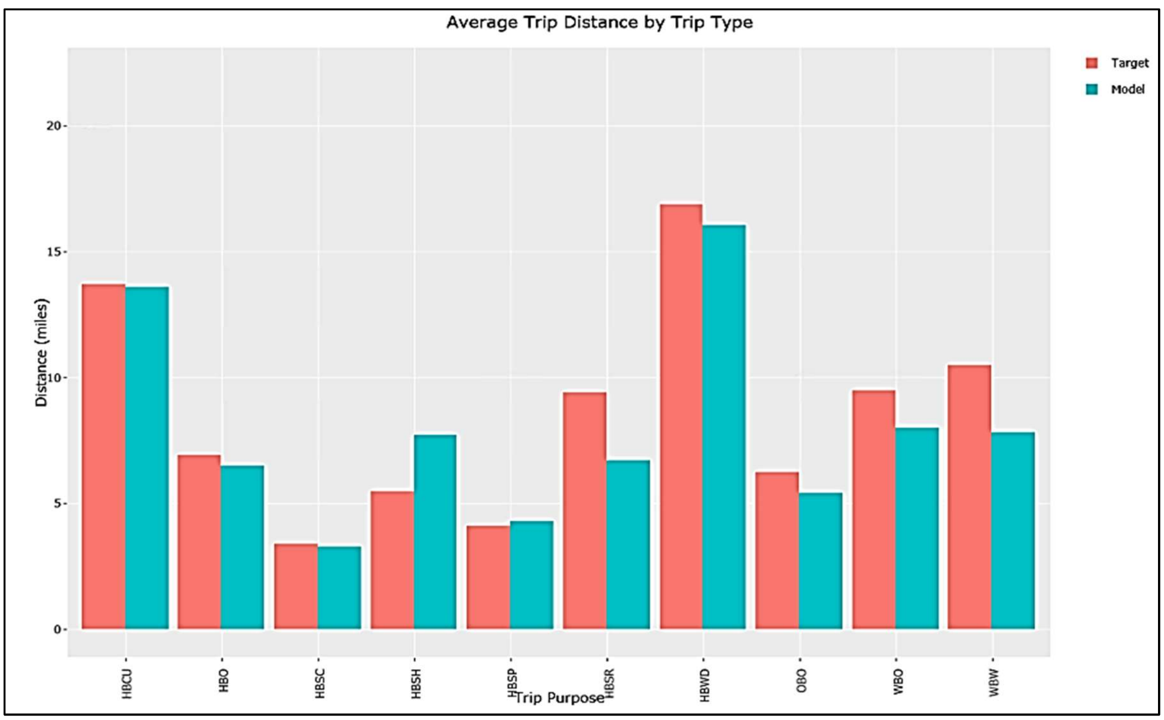


Table 14-2: Average Trip Distance by Trip purpose

Trip Purpose		Average Trip Length (miles)		Trip Length Coincidence
		Observed	Predicted	
HBWD	Home-based work	16.9	15.9	88%
HBCU	Home-based college	13.7	13.3	80%
HBSC	Home-based school	3.4	3.2	94%
HBSH	Home-based shop	5.5	7.7	73%
HBSP	Home-based serve passenger	4.1	4.2	91%
HBSR	Home-based social and recreational	9.4	6.7	89%
HBO	Home-based other	6.9	6.5	85%
OBO	Non-home-based other	6.2	5.4	93%
WBO	Non-home-based work	9.4	8.1	85%

Table 14-3: Person and Vehicle Trip Diurnal Distribution

Time Period	Person Trips			Vehicle Trips		
	Total Predicted	Predicted Share	Observed Share	Total Predicted	Predicted Share	Observed Share
AM	16,967,000	24%	20%	9,975,000	23%	21%
MD	25,053,000	35%	34%	16,440,000	38%	34%
PM	21,321,000	30%	31%	11,925,000	27%	30%
EV	4,371,000	6%	8%	2,389,000	5%	7%
NT	4,139,000	6%	7%	2,734,000	6%	8%
Total	**71,852,000**	**100%**	**100%**	**43,463,000**	**100%**	**100%**

Built Environment Effects

Several built environment variables were added to the mode choice model, with coefficients calibrated using the 2011 CHTS. These variables are important because they give the model sensitivity to the land use strategies that will be examined as part of the 2020 RTP/SCS. The calibration results for the built environment variables are shown in Figure 14-4 to Figure 14-5 respectively for population density, and bike lane density.

Figure 14-4: Mode Share by Residential Population Density

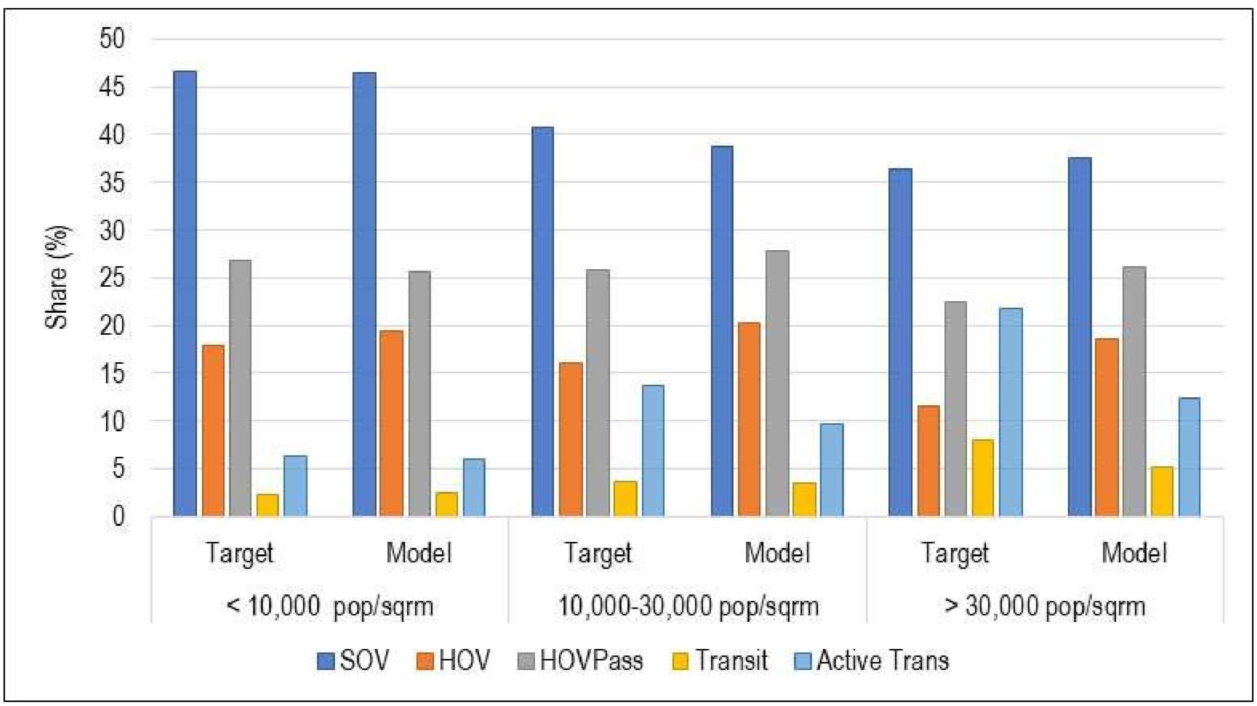
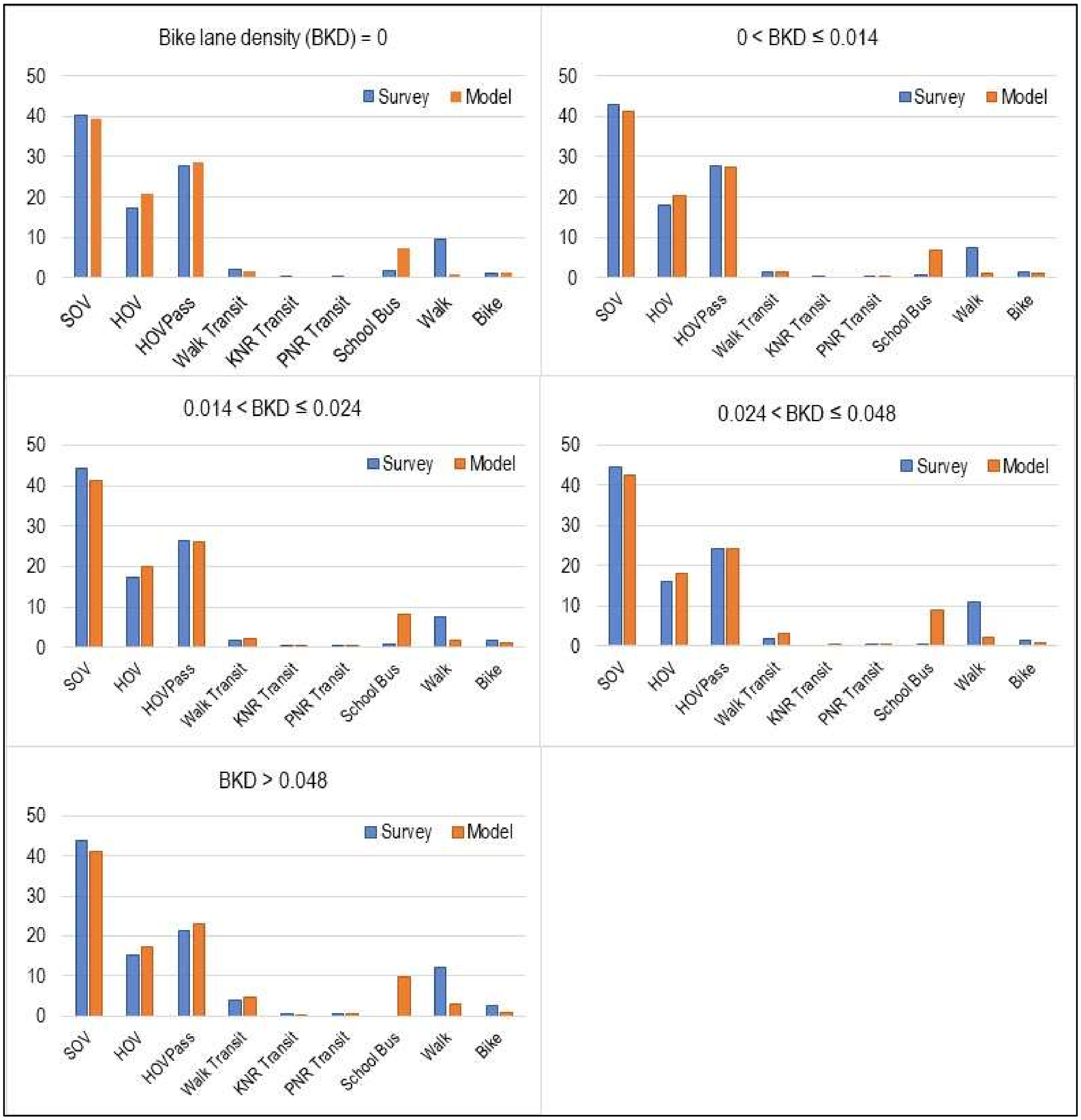


Figure 14-5: Mode Share by Bike Lane Density



A comparison of the observed and estimated mode shares is shown in Table 14-4 to Table 14-6, for the major tour purpose classifications.

Table 14-4: Trip Mode Shares by Tour Purpose (%)

Trip mode	Work Tours		School Tours		College Tours		Non-Mand. Tours		All Tours	
	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
Driver, 1-person	76.6	76.6	1.4	2.5	52.6	53.4	33.5	33.3	42.1	41.0
Driver, 2-persons	5.6	6.7	0.5	0.3	3.5	4.3	16.2	17.4	11.0	12.0
Driver, 3+ persons	2.6	3.6	<0.1	0.4	1.1	2.1	10.2	11.0	6.6	7.4
Passenger and taxi	8.0	6.8	69.9	70.4	20.5	19.1	27.9	26.1	27.3	26.4
Transit, walk access	2.3	1.7	2.2	1.1	12.3	0.7	2.3	2.1	2.5	1.8
Transit, drive access	0.7	0.6	n/a	n/a	1.4	2.1	<0.1	<0.1	0.3	0.3
Walk	3.4	2.3	17.8	13.8	6.7	11.8	8.2	8.8	8.0	7.9
Bike	0.3	1.6	1.2	2.5	1.8	6.3	1.5	1.0	1.3	1.6
School bus	n/a	n/a	6.7	9.1	n/a	n/a	n/a	n/a	0.8	1.2

Table 14-5: Trip Mode Share by Car Sufficiency (%)

Trip mode	Zero Cars		Car Insufficient		Car Sufficient		Car Over-Sufficient	
	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
Driver, 1-person	0.0	0.0	29.3	35.2	39.6	48.4	43.9	40.2
Driver, 2-persons	2.0	0.0	11.2	9.0	9.9	10.6	11.3	14.1
Driver, 3+ persons	1.3	0.0	4.3	8.5	8.4	5.9	6.6	8.3
Passenger	28.3	37.3	28.5	29.1	33.4	22.3	26.3	27.5
Transit, walk access	27.5	27.2	8.4	3.6	0.8	2.0	1.7	0.2
Transit, drive access	0.3	1.1	0.6	0.2	0.1	0.4	0.3	0.3
Walk	34.5	23.0	11.4	10.2	5.2	7.3	7.3	7.0
Bike	3.5	7.2	3.1	2.7	0.5	1.6	1.3	1.0
Taxi	1.1	0.5	1.1	0.3	0.1	0.0	0.3	0.5
School bus	1.5	3.8	2.0	1.3	1.9	1.5	0.9	0.9

Table 14-6:Trip Mode Share by Household Income (%)

Trip mode	Low Income < $50,000		Medium Income $50,000-$100,000		High Income > $100,000	
	Obs.	Est.	Obs.	Est.	Obs.	Est.
Driver, 1-person	34.2	35.1	44.3	41.7	48.2	46.8
Driver, 2-persons	10.2	12.5	11.0	12.0	11.6	11.6
Driver, 3+ persons	6.3	7.9	6.9	7.7	6.5	6.7
Passenger	27.7	28.2	27.8	26.5	25.3	24.5
Transit, walk access	5.5	3.0	1.6	1.3	1.0	1.0
Transit, drive access	0.2	0.5	0.3	0.2	0.3	0.2
Walk	12.2	9.2	6.4	7.7	5.3	6.7
Bike	1.4	2.0	1.3	1.4	1.2	1.3
Taxi	0.4	0.3	0.3	0.3	0.5	0.3
School bus	2.0	1.5	0.5	1.1	0.4	0.9

Chapter 15 Heavy Duty Truck Model

INTRODUCTION

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 2016 HDT Model results[1].

HDT MODEL STRUCTURE

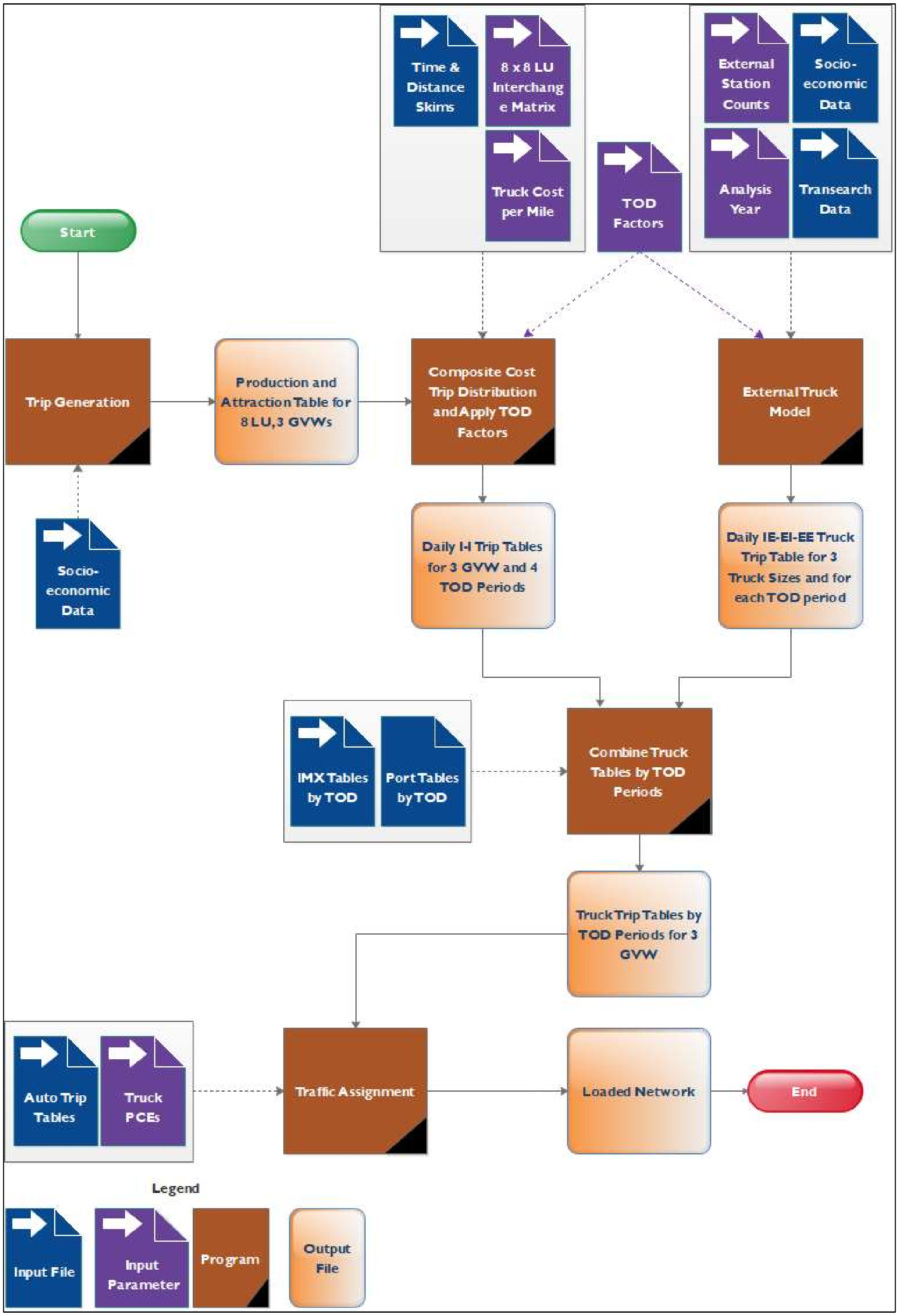
Figure 15-1 provides a flow chart of the overall structure of the HDT model. The model forecasts trips for three HDT weight classes: light-heavy (8,500 to 14,000 lbs. gross vehicle weight (GVW); medium-heavy (14,001 to 33,000 lbs. GVW); and heavy-heavy (>33,000 lbs. GVW). The key components of the HDT Model are the following:

- ***External Trip Generation and Distribution Model.*** This component estimates the trip table for all interregional truck trips that link Southern California with the rest of the nation. The external HDT model is based on variations of disaggregate supply chain models to better represent differences in the movements of each commodity and the linkage to industries within the SCAG region. The model includes a firm synthesis within the model region, includes commodity origins and destinations outside the model region, and simulates the shipments to and from these firms by distribution channel, shipment size, mode, and truck type.
- ***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. The trip rates were derived from establishment surveys and GPS data.

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.

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

Figure 15-1: Final HDT Model Structure



Special Generator Trip Generation and Distribution Models. These models include the port model and the intermodal rail model. All input parameters to the port trip generation model were updated to reflect current port capacity improvements and throughput forecasts. The model 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 a gravity model.

- ***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[2] (HCM); they 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 services. 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 15-1. These stratified employment types, plus households, support ten land use purposes for the HDT trip generation model:

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

Table 15-1: 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.

households, agriculture/mining/construction, retail, governments, manufacturing, transportation and utility, general warehousing, high cube warehousing, wholesale, and other services. The warehousing land use categories were separated from the transportation and utility category using data from secondary establishment surveys and warehousing studies.

Internal HDT Trip Rates

Trip rates derived from establishment surveys and GPS data for each truck type and land use are shown in Table 15-2. All rates are defined per employee.

Table 15-2: Internal HDT Trip Rates

Category	Light HDT Trip Rate	Medium HDT Trip Rate	Heavy HDT Trip Rate
Households	0.0146	0.0046	0.0072
Agriculture/Mining/Construction	0.0739	0.0716	0.0658
Retail	0.0667	0.0666	0.0708
Government	0.0301	0.0153	0.0151
Manufacturing	0.0612	0.0654	0.0924
Transportation/Utility	0.1530	0.1759	0.3100
General Warehousing (Employment)	0.1436	0.1651	0.2917
High Cube Warehousing (Employment)	0.1463	0.1682	0.2964
Wholesale	0.0902	0.0954	0.1296
Other (Service)	0.0095	0.0111	0.0151

Table 15-3 shows the 2016 HDT trip generation estimates. As expected, households in the region generate a high number of trip ends, especially for Light HDT. This is because of the goods delivery and services that land uses such as transportation and warehousing, utilities, service and retail provide 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 15-3: 2016 Internal HDT Trip Generation Estimates

Land Use	Light HDT Trip Ends	Medium HDT Trip Ends	Heavy HDT Trip Ends	Total Trip Ends	% of Total Trip Ends
Households	88,004	27,572	43,417	158,994	15%
Ag/Min/Construction	35,104	33,984	31,245	100,333	10%
Retail	56,030	55,950	59,402	171,382	16%
Governments	7,955	4,046	3,978	15,979	2%
Manufacturing	40,171	42,911	60,598	143,680	14%
Transportation/Utility	65,389	75,163	132,467	273,019	26%
General Warehousing	8,685	9,988	7,642	36,315	3%
High Cube Warehousing	4,542	5,220	9,200	18,962	2%
Wholesale	35,509	37,535	51,017	124,061	12%
Other	3,281	3,823	5,210	12,314	1%
Total	**344,671**	**296,191**	**414,175**	**1,055,037**	**100%**

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[3]. 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 15-4.

$$Composite\ Cost\ = Cost\ per\ hour\ *\ Congested\ time +$$
$$\left(\frac{Fuel\ Price}{Fuel\ efficiency} * Cost\ per\ mile\ (excluding\ fuel)\right) * Distance$$

[3] 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.

Table 15-4: Composite Truck Unit Costs

Truck Type	LHDT	MHDT	HHDT
Cost per Hour	$14.31	$19.86	$19.86
Fuel Efficiency (MPG)	8.50	7.00	6.0
Cost per Mile (excluding fuel)	$0.14	$0.24	$0.27
Fuel Price per Gallon (a)	$3.38	$3.42 (b)	$3.42 (b)

(a) Assumes all MHDT and HHDT trucks are diesel-powered, while LHDTs are a fleet mix of 60% gasoline and 40% diesel-powered trucks.
(b) Fuel prices based on average 2016 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 15-2 to 15-4 show the trip length calibration performed for the 2008 HDT model update, respectively for each truck class. Calibrated model parameters have been retained in the 2016 base year model.

Figure 15-2: LHDT Internal Truck Trip Length Calibration

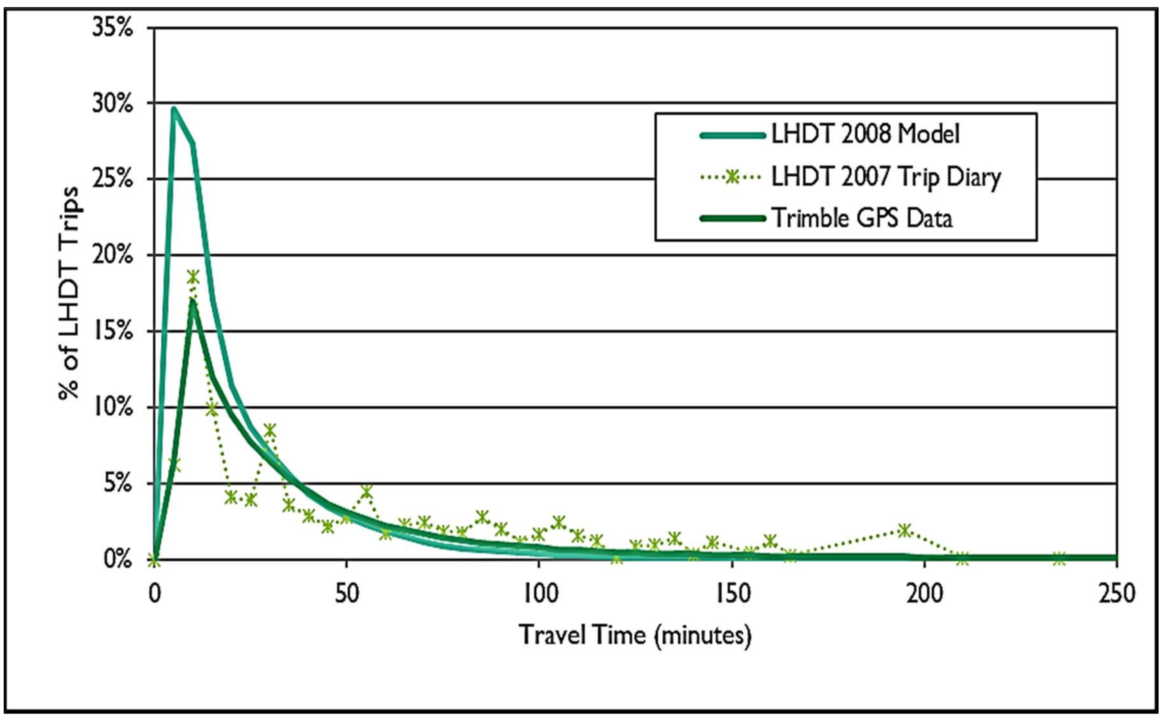


Figure 15-3: MHDT Internal Truck Trip Length Calibration

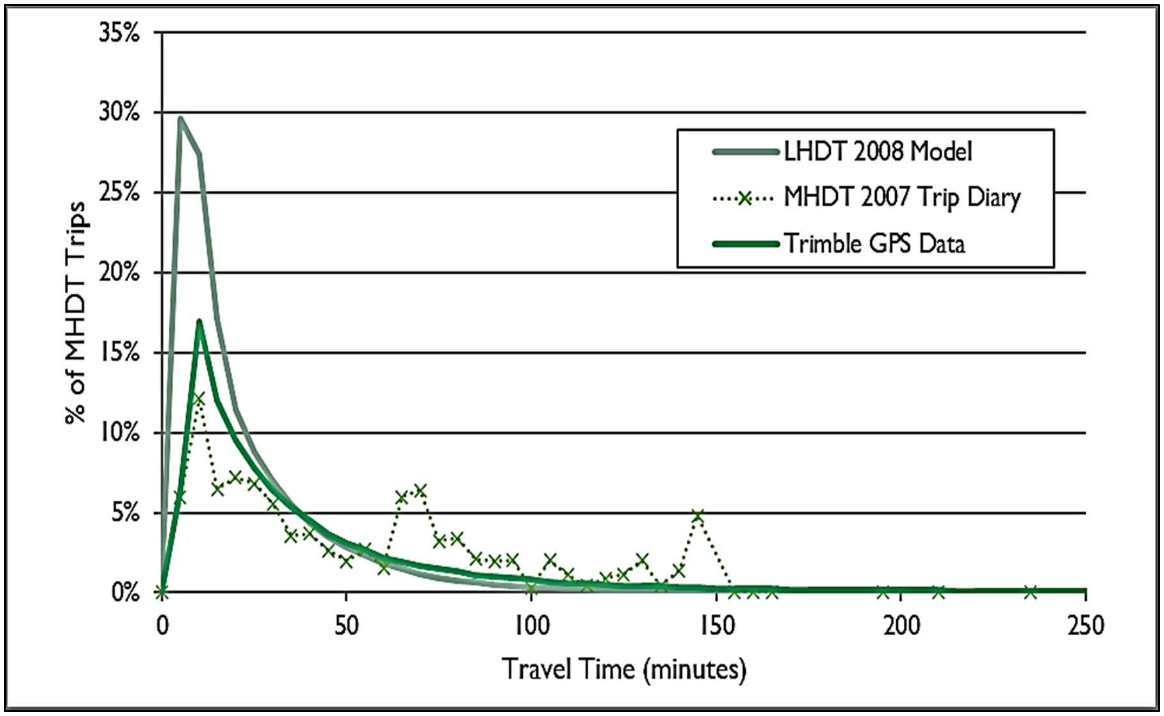
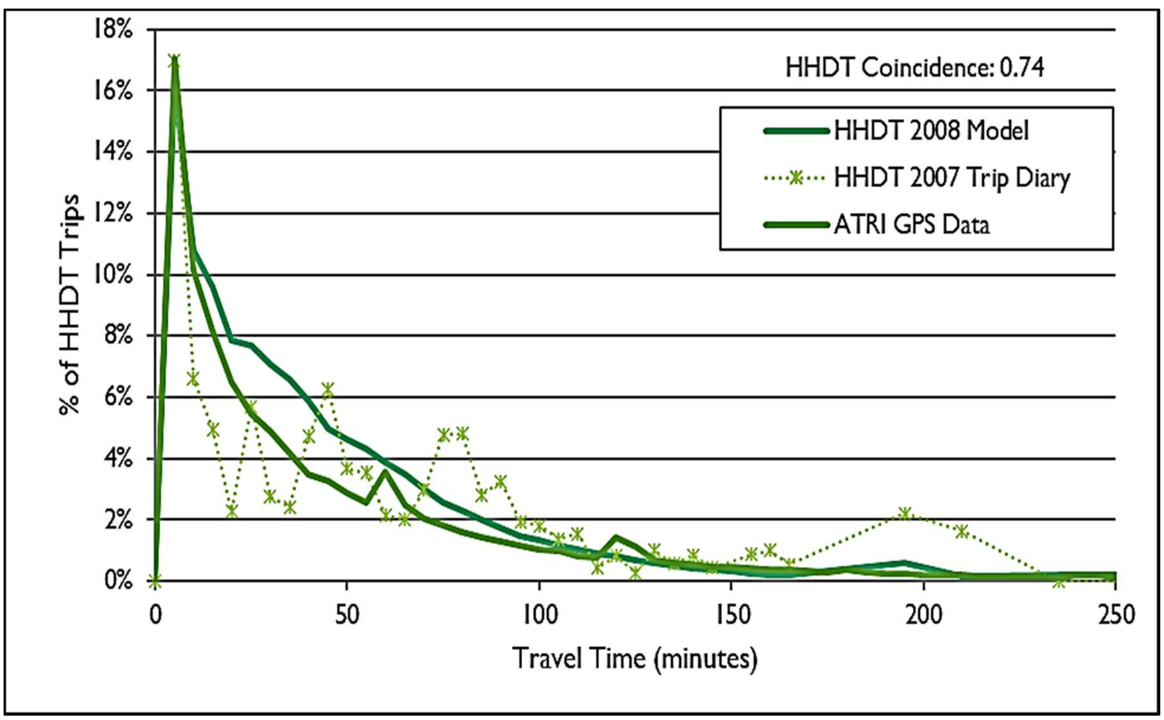


Figure 15-4: HHDT Internal Truck Trip Length Calibration



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 15-5. 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 ends of the outbound commodity flows are allocated to external cordon stations using survey data from the SCAG region. The internal trip ends of the outbound commodity flows are 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 ends 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.

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 like 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 trucks 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.

Supply Chain Analysis

Concurrent with the 2016 model validation, SCAG conducted a new analysis for external truck model. Two modules are developed: 1) a firm synthesis model, and 2) a supply chain model. These models will be included with future truck model updates and enhancements.

- Firm Synthesis Model

  The firm synthesis model generates a list of synthetic business establishments within the model region. It requires as input a list of current business establishments and data by industry, location, size, and zonal-level employment data. For future years, it updates the business establishment data to match the zonal-level employment forecasts.

- Supply Chain Model

  The supply chain model characterizes annual production and consumption by business establishments in the region and allocates commodity flows into and out of the SCAG region to specific business establishments. The supply chain model also identifies movements that involve a warehouse or distribution center on the way into or out of the region.

Table 15-5: 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

Port HDT Model

Ports TAZ Development

The SCAG Tier 1 TAZ system consists of 4,192 TAZs, including 42 TAZs that represent Port 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 15-6 below provides a summary breakdown of the 4,253 TAZ system.

Table 15-6: 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 O-D 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 15-7 and 15-8 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 and 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 15-7: 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 15-8: 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 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 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. Some 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 O-D 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 O-D trip tables for use in the Port area travel demand model. The stated trip O-D from every valid survey was correlated with the travel demand model TAZ system. The survey results were then used to develop port truck O-D 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, corresponding to 5 time periods (AM, MD, PM, EV and NT) by 3 vehicle classes (bobtails, chassis and container truck trips). The time periods are consistent with those used by the passenger model, combining 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 tripends within the same terminal.

Base Year Port Trip Tables Summary

Summaries of 2016 Port truck trips are shown in Table 15-9 and Table 15-9.

Table 15-9: 2016 Port HDT Trips by Truck Type

Time Period	Bobtails	Chassis	Containers	Total
AM	1,347	405	2,299	4,052
MD	6,190	1,671	11,409	19,270
PM	3,088	823	5,524	9,435
EV	1,542	433	3,128	5,103
NT	3,432	963	6,963	11,359
Daily	15,600	4,295	29,324	49,219

Table 15-10: 2016 Port HDT Trips by Time Period and County

County	Time Period					
	AM	MD	PM	EV	NT	Total
Imperial	3	12	6	3	7	32
Los Angeles	3,541	17,249	8,420	4,598	10,235	44,044
Orange	158	618	310	152	338	1,576
Riverside	84	329	165	80	179	838
San Bernardino	232	923	465	234	522	2,375
Ventura	16	66	32	17	37	168
External Stations	18	72	36	18	40	185
Total	4,052	19,270	9,435	5,103	11,359	49,219
% of Daily Trips	8.2%	39.2%	19.2%	10.4%	23.1%	100%

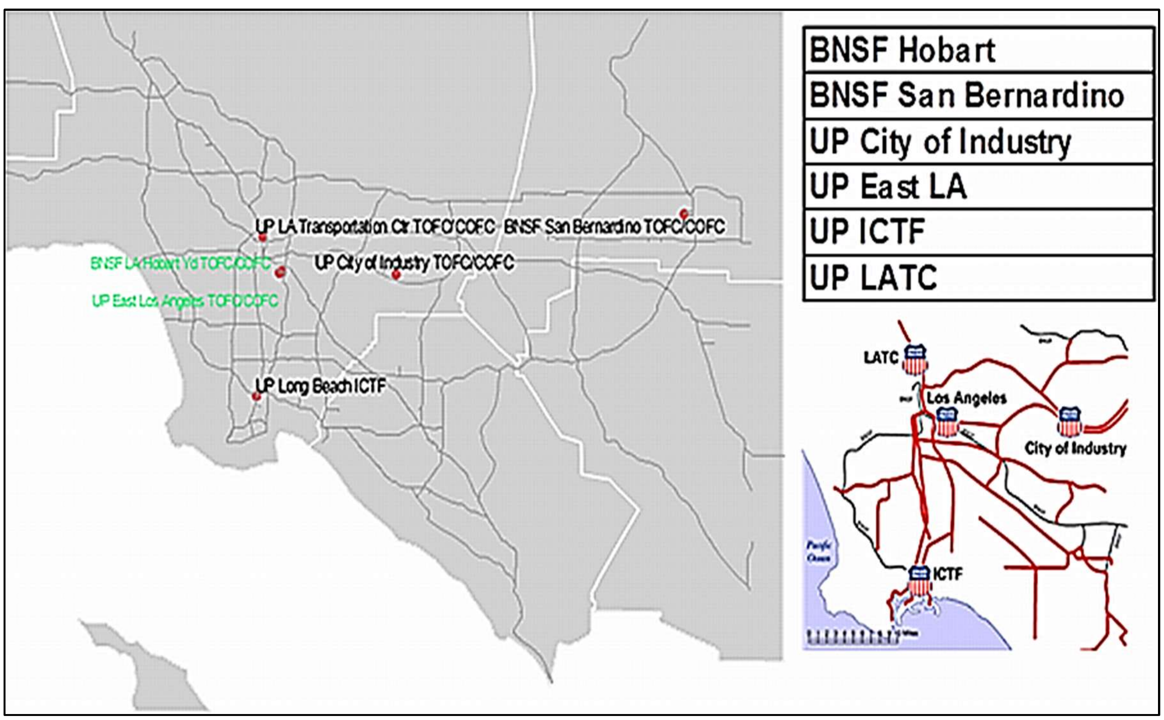
Intermodal HDT Trips

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 15-5. The intermodal (IMX) trip tables were developed from the IMX surveys conducted for Metro in 2005[4]. 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 15-11 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 15-12.

Figure 15-5: Intermodal Facilities in the SCAG Region



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

Table 15-11: 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 15-12: 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-foot 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 transported 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 15-13 presents a summary of the total wholesale HHDT trips in the region that are computed from three models – internal HDT, Port and IMX.

Table 15-13: 2016 Wholesale and Warehousing HDT Trips

Truck Type/PA	Internal HDT	Port Model HHDT	IMX HHDT Trips	Total Wholesale/ Warehouse HHDT
LHDT Productions	36,112	N/A		
LHDT Attractions	36,112			
MHDT Productions	38,172			
MHDT Attractions	38,172			
HHDT Productions	51,883	12,885	3,405	68,173
HHDT Attractions	51,883	12,254	3,570	67,707

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)[5] 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 15-14.

Table 15-14: 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 16– 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 15-15.

Table 15-15: 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

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

Chapter 16 TRIP ASSIGNMENT

Introduction

This Chapter describes the various trip assignment methodologies and 2016 validation results. Assignments used in the 2016 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 2016 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 (HPMS). An acceptable tolerance level is mandatory for regional air quality planning and conformity purposes. Specifics regarding the comparative analyses are summarized in this Chapter, along with assignment statistics for the SCAG region.

The multi-class highway assignment simultaneously loads the passenger vehicles 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 O-D trip tables loaded to the highway network include the following vehicle classes:

- Drive Alone
- Shared Ride 2 Non HOV
- Shared Ride 3+ Non 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 and shared-ride trip tables. The next section briefly describes the methodology used to generate the external 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 2016 cordon volumes. Previous cordon survey results were then used to split total external trips into: 1) External-to-External (i.e., through) trips, 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 O-D 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 2016 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 three-loop feedback procedure is used in the 2016 model. The following describes the travel time feedback process:

Step 1. The core demand model is 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 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 two more times for a total of three feedback loops.

Step 3. During the final, 3rd loop assignment, all highway assignments are performed: AM peak, midday, PM peak, evening and night times.

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 2016 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:

$$GenCost = (travel\ time) + (HOT\ penalty) + \frac{auto\ operating\ cost + tolls}{cost\ conversion\ factor}$$

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

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

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

iii. 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 16-1.

iv. The auto operating cost measures the contribution of distance to the generalized cost; for 2016 the auto operating cost is 16.82 cents per mile (in constant $2011); its derivation is shown in Appendix B.

v. 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 16-1 below.

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

Table 16-1: Generalized Cost Function Parameters

Vehicle Class	HOT Penalty (min/mile)	Distance Cost Conversion Factor ($/hr)	AM	Midday	PM	Evening	Night
			VOT Multiplier (toll/HOT)				
Drive Alone	0	33.9	1.5/2.5	1.25/2	1.5/2.5	1.5/2	1/1.5
Shared Ride 2	0	40.5	1.5/2.5	1.25/2	1.5/2.5	1.5/2	1/1.5
Shared Ride 3+	0.2	40.5	1.5/2.5	1.25/2	1.5/2.5	1.5/2	1/1.5
Light-Duty Trucks	0	52.4	1.0	1.0	1.0	1.0	1.0
Medium-Duty Trucks	0	65.8	1.0	1.0	1.0	1.0	1.0
Heavy-Duty Trucks	0	70.7	1.0	1.0	1.0	1.0	1.0
			Cost Multiplier				
Auto			0.9	0.55	0.75	0.55	0.55
Truck			1.0	1.0	1.0	1.0	1.0

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:

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

t_i = free flow travel time on link i

C_i = capacity of link i

x_i = flow on link i

α, β = constants

If $\frac{x_i}{C_i} \leq 1$ then β is set to the specific value of 4.0. 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 as shown in Table 16-2.

Table 16-2: Volume-Delay Function Parameters

Facility Type	Posted Speed	Area Type	Alpha	Beta
Freeways and HOV	All	All	0.8	8.0
Expressways	≤ 45mph	1-5	0.8	5.0
Expressways	≤ 45mph	6-7	0.8	6.0
Expressways	> 45mph	All	0.8	8.0
All Others	All	1-5	0.8	5.0
All Others	All	6-7	0.8	6.0

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

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

L_i = length on link *i* (miles)
FFS_i = free flow speed on link (mph)
C_i = capacity of link *i*
x_i = flow on link *i*
$PLPHx_i$ = per-lane-per-hour flow on link *i*

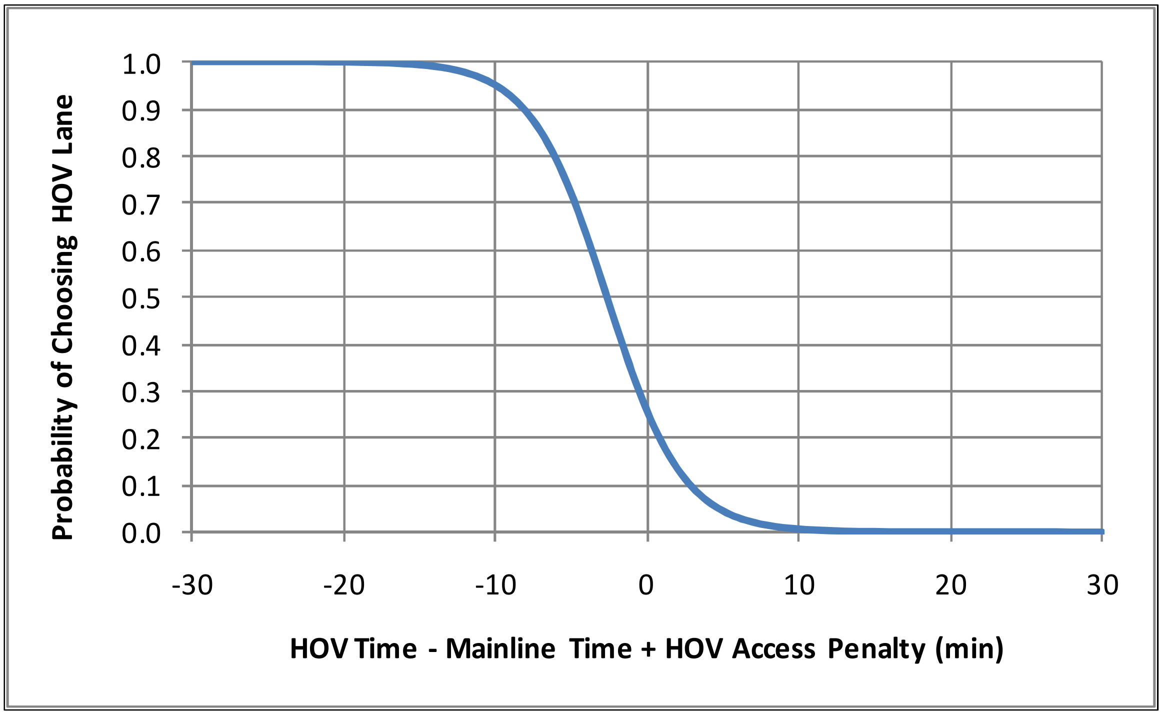
HOV Diversion

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 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 0.5 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 16-1: 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 2016 Regional Model's highway trip assignment module has been validated to observed conditions. It includes results for heavy-duty trucks and passenger vehicles. Figure 16-2 and Figure 16-3 provide a visual representation of the SCAG regional screenlines.

Figure 16-2: Screenlines (Regional)

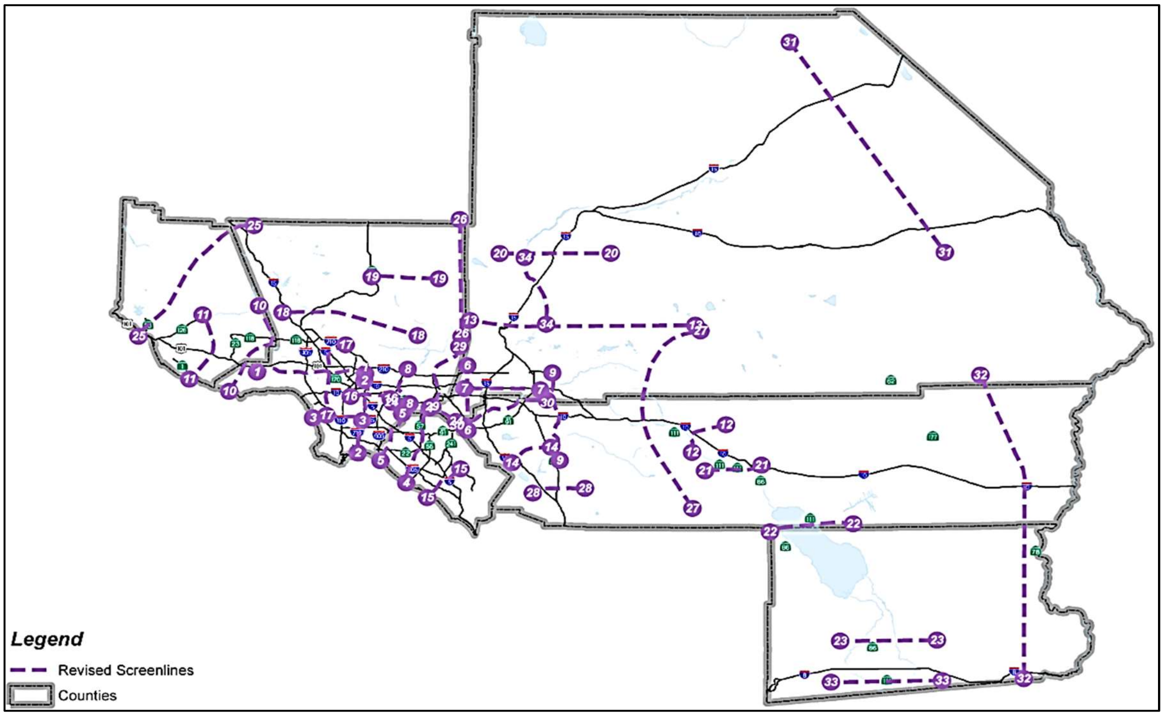
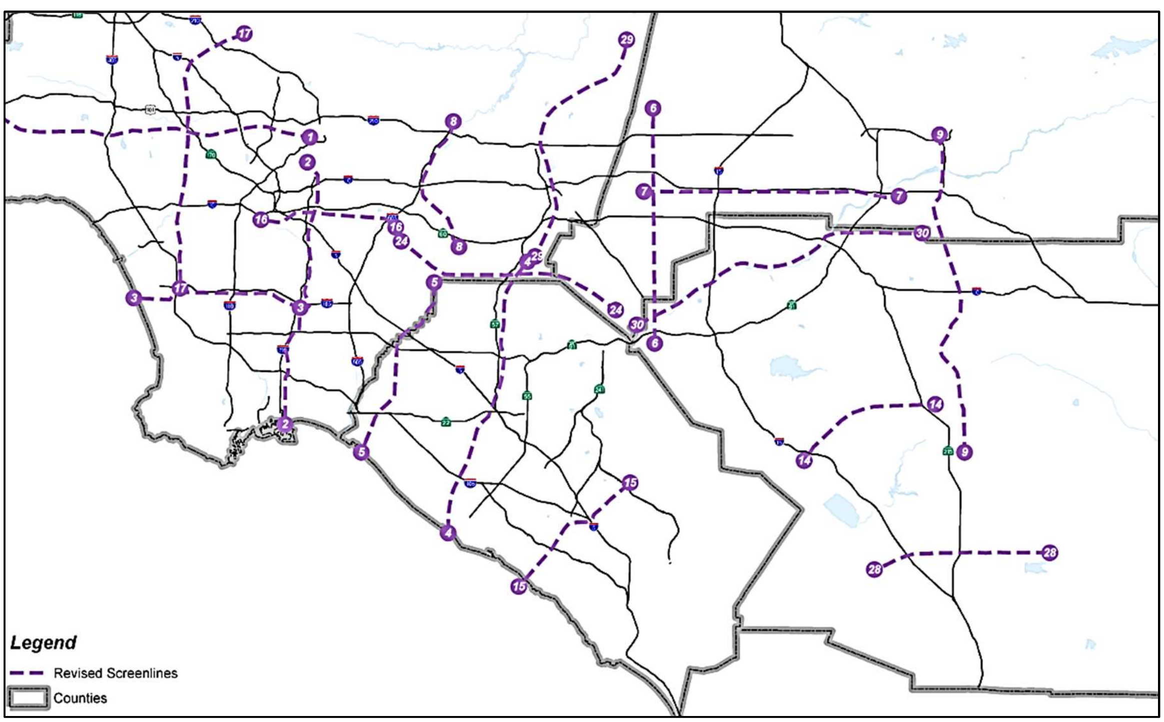


Figure 16-3: Screenlines (Detail)



A comparison of 2016 model speeds to National Performance Management Research Data (NPMSDS) speed data is shown in Figure 16-5 to Figure 16-12.

Table 16-3: Year 2016 Loaded Highway Network Summary

From Assignment						
Light and Medium Duty Vehicles	**AM Peak**	**PM Peak**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	31.1	28.9	29.9	43.4	50.3	**31.9**
Vehicle Miles Traveled (,000)	89,129	128,072	135,410	24,494	47,372	**424,477**
Vehicle Hours Traveled (,000)	2,863	4,427	4,522	564	941	**13,318**
Vehicle Hours Delay (,000)	798	1,513	1,316	25	13	**3,664**
Heavy Duty Vehicles	**AM Peak**	**PM Peak**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	40.7	38.1	48.3	57.0	59.0	**47.1**
Vehicle Miles Traveled (,000)	4,934	5,747	12,568	2,078	7,348	**32,676**
Vehicle Hours Traveled (,000)	121	151	260	36	125	**693**
Vehicle Hours Delay (,000)	34	49	43	2	2	**129**
All Vehicles Combined	**AM Peak**	**PM Peak**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	31.5	29.2	30.9	44.3	51.4	**32.6**
Vehicle Miles Traveled (,000)	94,063	133,819	147,978	26,572	54,721	**457,153**
Vehicle Hours Traveled (,000)	2,985	4,578	4,782	600	1,066	**14,011**
Vehicle Hours Delay (,000)	831	1,562	1,358	27	14	**3,793**
After HPMS Adjustment						
Light and Medium Duty Vehicles	**AM Peak**	**PM Peak**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	32.3	31.2	36.2	43.9	50.6	**35.1**
Vehicle Miles Traveled (,000)	90,070	129,397	136,950	24,747	47,822	**428,986**
Vehicle Hours Traveled (,000)	2,790	4,154	3,782	563	945	**12,234**
Vehicle Hours Delay (,000)	703	1,211	542	19	8	**2,484**
Heavy Duty Vehicles	**AM Peak**	**PM Peak**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	41.8	39.4	50.1	56.9	58.4	**48.3**
Vehicle Miles Traveled (,000)	4,720	5,494	12,007	1,989	7,043	**31,254**
Vehicle Hours Traveled (,000)	113	139	240	35	121	**647**
Vehicle Hours Delay (,000)	30	43	34	2	4	**112**
All Vehicles Combined	**AM Peak**	**PM Peak**	**Midday**	**Evening**	**Night**	**Total**
Average Speed (mph)	32.7	31.4	37.0	44.7	51.5	**35.7**
Vehicle Miles Traveled (,000)	94,791	134,892	148,958	26,736	54,865	**460,240**
Vehicle Hours Traveled (,000)	2,903	4,293	4,021	598	1,066	**12,881**
Vehicle Hours Delay (,000)	733	1,254	576	21	12	**2,596**

Table 16-4: Year 2016 VMT Comparison by County and by Air Basin (in Thousands)

County		VC SCCAB		SCAB		MDAB		SSAB		Total		County
		Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck	Auto	Truck	Total
Imperial	Model	-	-	-	-	-	-	4,533	518	4,533	517.91	5,051
	HPMS							5,477	976	5,477	976	6,453
Los Angeles	Model	-	-	214,404	14,049	7,580	449	-	-	221,984	14,498	236,482
	HPMS			212,348	11,991	8,374	612			220,723	12,603	233,326
Orange	Model	-	-	71,967	3,773	-	-	-	-	71,967	3,773	75,740
	HPMS			75,689	3,481					75,689	3,481	79,170
Riverside	Model	-	-	44,738	3,324	1,387	765	9,481	1,378	55,606	5,467	61,073
	HPMS			42,353	3,654	1,562	711	9,715	1,597	53,630	5,963	59,593
San Bernardino	Model	-	-	34,966	2,913	18,068	4,103	-	-	53,034	7,016	60,050
	HPMS			36,353	3,130	18,461	4,150			54,814	7,280	62,094
Ventura	Model	17,352	1,404	-	-	-	-	-	-	17,352	1,404	18,757
	HPMS	18,693	952							18,693	952	19,645
Total	**Model**	**17,352**	**1,404**	**366,075**	**24,059**	**27,036**	**5,317**	**14,014**	**1,896**	**424,477**	**32,676**	**457,153**
	HPMS	**18,693**	**952**	**366,743**	**22,256**	**28,397**	**5,473**	**15,192**	**2,573**	**429,026**	**31,255**	**460,281**
	Ratio	**0.928**	**1.475**	**0.998**	**1.081**	**0.952**	**0.971**	**0.922**	**0.737**	**0.989**	**1.045**	**0.993**

Figure 16-4: Year 2016 Screenline Location Volumes

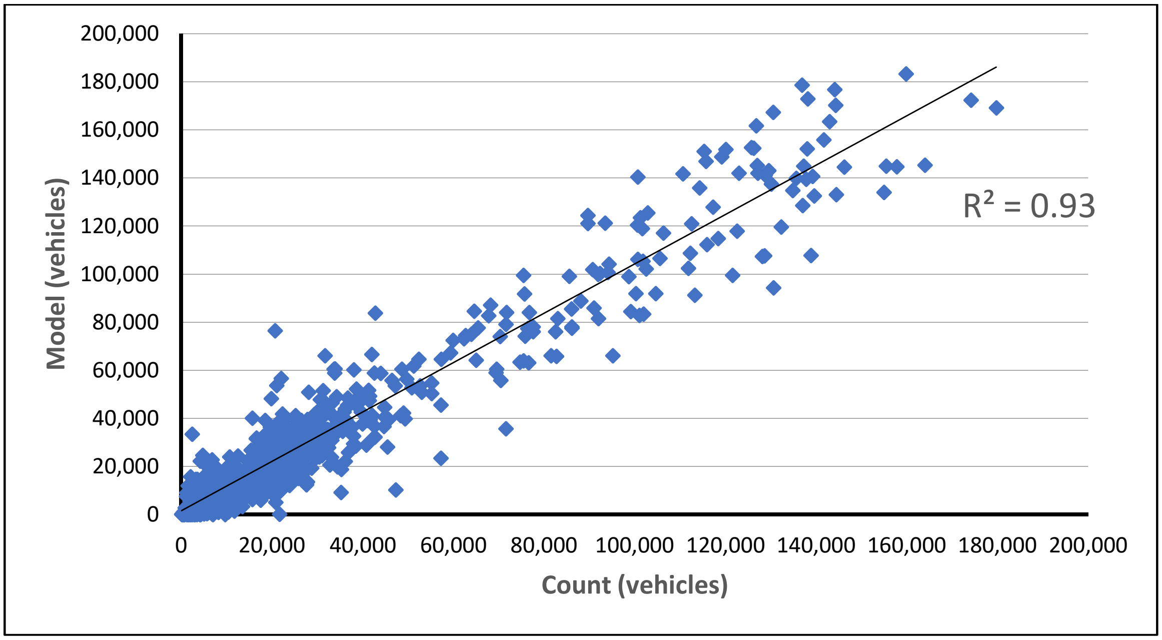


Table 16-5: Year 2016Screenline Comparison of Model Weekday ADT and Ground Counts

Screen line	Location	Dir	Obs	Light & Medium Duty Vehicles				Heavy Duty Vehicles				Total		
				Model	Count	Ratio	RMSE	Model	Count	Ratio	RMSE	Model	Count	Ratio
1	Los Angeles	EW	33	1,635,003	1,370,599	1.19	30.4	97,015	65,059	1.49	197.2	1,734,938	1,430,666	1.2
2	Los Angeles	NS	67	2,806,969	2,570,097	1.09	30.2	202,238	162,585	1.24	127.2	3,017,631	2,732,683	1.1
3	Los Angeles	EW	40	1,357,829	1,401,247	0.97	27.4	92,144	75,016	1.23	145.0	1,453,397	1,476,263	1.0
4	Orange	NS	48	2,060,011	1,834,224	1.12	32.6	113,674	194,909	0.58	99.5	2,177,300	2,029,133	1.1
5	Los Angeles/ Orange	NS	32	1,489,029	1,362,030	1.09	33.8	111,090	76,959	1.44	170.3	1,601,142	1,438,989	1.1
6	San Bernardino/ Riverside	NS	43	1,305,841	1,096,654	1.19	47.2	137,875	172,302	0.80	105.6	1,444,528	1,268,956	1.1
7	San Bernardino	EW	28	796,149	802,635	0.99	36.8	57,803	93,275	0.62	66.1	854,808	895,909	1.0
8	Los Angeles	NS	28	1,130,476	1,158,032	0.98	25.6	102,710	84,801	1.21	123.0	1,235,123	1,242,834	1.0
9	San Bernardino/ Riverside	NS	30	490,847	512,630	0.96	34.7	38,151	44,882	0.85	85.6	529,960	557,512	1.0
10	Ventura/ Los Angeles	NS	11	431,572	360,093	1.20	31.9	39,945	50,488	0.79	37.9	471,682	410,581	1.1
11	Ventura	NS	9	245,631	221,346	1.11	20.8	27,845	20,307	1.37	163.2	273,572	241,652	1.1
12	Riverside	NS	8	186,049	195,367	0.95	26.0	22,980	16,716	1.37	153.2	209,389	212,083	1.0
13	San Bernardino	EW	8	158,214	143,353	1.10	18.9	33,157	20,361	1.63	151.2	191,449	163,714	1.2
14	Riverside	EW	10	295,834	285,183	1.04	26.2	25,960	25,916	1.00	63.9	322,090	311,099	1.0
15	Orange	NS	16	634,043	591,426	1.07	62.7	18,051	30,233	0.60	68.0	652,501	621,659	1.0
16	Los Angeles	EW	33	1,360,154	1,171,218	1.16	34.7	110,843	101,732	1.09	74.9	1,474,635	1,272,951	1.2
17	Los Angeles	NS	68	2,597,467	2,354,474	1.10	34.0	134,407	100,529	1.34	136.0	2,739,977	2,455,003	1.1
18	Los Angeles	EW	17	353,112	422,436	0.84	44.1	38,409	39,751	0.97	66.7	392,187	462,187	0.8
19	Los Angeles	EW	21	177,919	207,941	0.86	79.9	9,515	21,043	0.45	89.8	187,822	228,984	0.8
20	San Bernardino	EW	5	69,126	61,557	1.12	19.6	22,364	10,217	2.19	184.3	91,516	71,773	1.3
21	Riverside	EW	12	169,808	176,491	0.96	53.6	19,060	22,993	0.83	142.6	189,198	199,484	0.9
22	Riverside/ Imperial	EW	3	17,385	14,413	1.21	50.1	2,835	4,778	0.59	44.6	20,220	19,191	1.1

Screen line	Location	Dir	Obs	Light & Medium Duty Vehicles				Heavy Duty Vehicles				Total		
				Model	Count	Ratio	RMSE	Model	Count	Ratio	RMSE	Model	Count	Ratio
23	Imperial	EW	14	51,083	34,910	1.46	106.1	3,020	9,022	0.33	96.9	54,159	43,932	1.2
24	Los Angeles/ San Bernardino	EW	10	481,987	361,880	1.33	40.3	30,640	19,980	1.53	135.1	512,733	381,860	1.3
25	Ventura/ Los Angeles	NS	8	173,338	155,355	1.12	31.1	29,881	29,768	1.00	85.6	203,355	185,123	1.1
26	Los Angeles	NS	4	31,108	20,520	1.52	68.2	4,372	3,480	1.26	42.2	35,480	24,000	1.5
27	San Bernardino/ Riverside	NS	3	123,529	143,638	0.86	25.2	25,342	13,021	1.95	115.2	148,876	156,659	1.0
28	Riverside	EW	12	302,535	288,173	1.05	33.5	19,742	25,305	0.78	60.0	322,449	313,478	1.0
29	Los Angeles	NS	26	1,011,888	986,095	1.03	24.0	107,843	66,456	1.62	152.9	1,120,665	1,052,551	1.1
30	Riverside	EW	24	770,766	804,596	0.96	24.7	63,092	68,327	0.92	42.9	834,260	872,923	1.0
31	San Bernardino	NS	5	40,459	46,299	0.87	15.7	17,420	15,623	1.12	21.3	57,879	61,922	0.9
32	San Bernardino/ Riverside/ Imperial	NS	6	27,980	34,451	0.81	33.6	16,165	9,107	1.77	185.1	44,161	43,558	1.0
33	Imperial	EW	15	75,438	65,885	1.15	71.7	4,935	14,140	0.35	101.1	80,410	80,025	1.0
34	San Bernardino	NS	7	172,234	148,335	1.16	27.3	21,817	38,798	0.56	87.7	194,257	187,133	1.0
35	Los Angeles	NS	15	285,788	288,294	0.99	27.2	9,160	25,252	0.36	82.5	295,744	313,546	0.9
Total			719	**23,797,292**	**21,691,876**	1.097	35.7	1,811,496	1,773,131	1.021	118.3	25,169,489	23,460,014	1.073

Table 16-6: Year 2016 Screenline Comparison of Model Weekday ADT and Ground Counts by Volume Group

	Volume Group	Obs	Daily Vehicle Volumes Light and Medium Duty Vehicles				Daily Vehicle Volumes Heavy-Duty Vehicles				Daily Vehicle Volumes Total		
			Model	Count	Ratio	RMSE	Model	Count	Ratio	RMSE	Model	Count	Ratio
1	0 - 4,999	91	374,013	198,799	1.88	260	12,948	25,932	0.50	110	387,661	224,731	1.73
2	5,000 - 24,999	343	5,445,587	4,690,274	1.16	57	176,350	315,069	0.56	125	5,638,961	5,005,343	1.13
3	25,000 - 49,999	159	5,433,439	4,951,939	1.10	35	261,975	377,493	0.69	75	5,716,632	5,329,432	1.07
4	50,000 - 99,999	59	4,029,814	4,023,765	1.00	20	480,692	387,334	1.24	74	4,512,078	4,411,099	1.02
5	100,000 - 199,999	67	8,033,748	7,827,099	1.03	17	879,531	667,303	1.32	75	8,914,157	8,489,410	1.05
	Total	**719**	23,316,602	21,691,876	1.075	36	1,811,496	1,773,131	1.022	118	25,169,489	23,460,015	1.07

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

Table 16-7: Year 2016 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	160	12,464,312	12,400,013	1.005	20	1,505,773	1,142,597	1.318	81	13,973,566	13,537,618	1.03
20	HOV	66	1,033,705	1,030,429	1.003	37	-	-	-	-	1,034,715	1,030,429	1.00
30	Expressway/Parkway	14	240,161	173,781	1.382	55	17,545	37,129	0.473	79	257,793	210,910	1.22
40	Principal Arterial	195	6,035,602	4,976,164	1.213	46	192,947	371,459	0.519	84	6,253,016	5,347,623	1.17
50	Minor Arterial	190	3,045,350	2,582,401	1.179	55	82,417	168,920	0.488	81	3,139,167	2,751,321	1.14
60	Major Collector	90	484,006	519,754	0.931	82	12,487	52,433	0.238	234	497,440	572,187	0.87
70	Minor Collector	4	13,466	9,334	1.443	154	327	593	0.552	123	13,793	9,927	1.39
Total		**719**	23,316,602	21,691,876	1.075	36	1,811,496	1,773,131	1.022	118	25,169,489	23,316,602	1.073

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

Table 16-8: Year 2016 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	156,082	119,999	1.301	48	2,709	3,956	0.685	36	159,364	123,955	1.286
3	Urban Business District	129	5,582,290	5,233,713	1.067	32	386,117	361,625	1.068	127	5,981,941	5,595,338	1.069
4	Urban	247	8,805,051	8,048,423	1.094	32	612,125	617,479	0.991	105	9,436,473	8,665,902	1.089
5	Suburban	223	6,913,517	6,622,675	1.044	37	551,337	567,280	0.972	123	7,471,886	7,184,963	1.040
6	Rural	102	1,628,028	1,479,396	1.100	54	223,055	199,541	1.118	111	1,851,961	1,678,937	1.103
7	Mountain	13	231,634	187,669	1.234	41	36,152	23,251	1.555	171	267,864	210,920	1.270
Total		761	**23,316,602**	**21,691,876**	**1.075**	**36**	**1,811,496**	**1,773,131**	**1.02**	**118**	**25,169,489**	**23,460,015**	**1.073**

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

Figure 16-5: Year 2016 Model Estimated Average AM Peak Period Speed (Freeway)

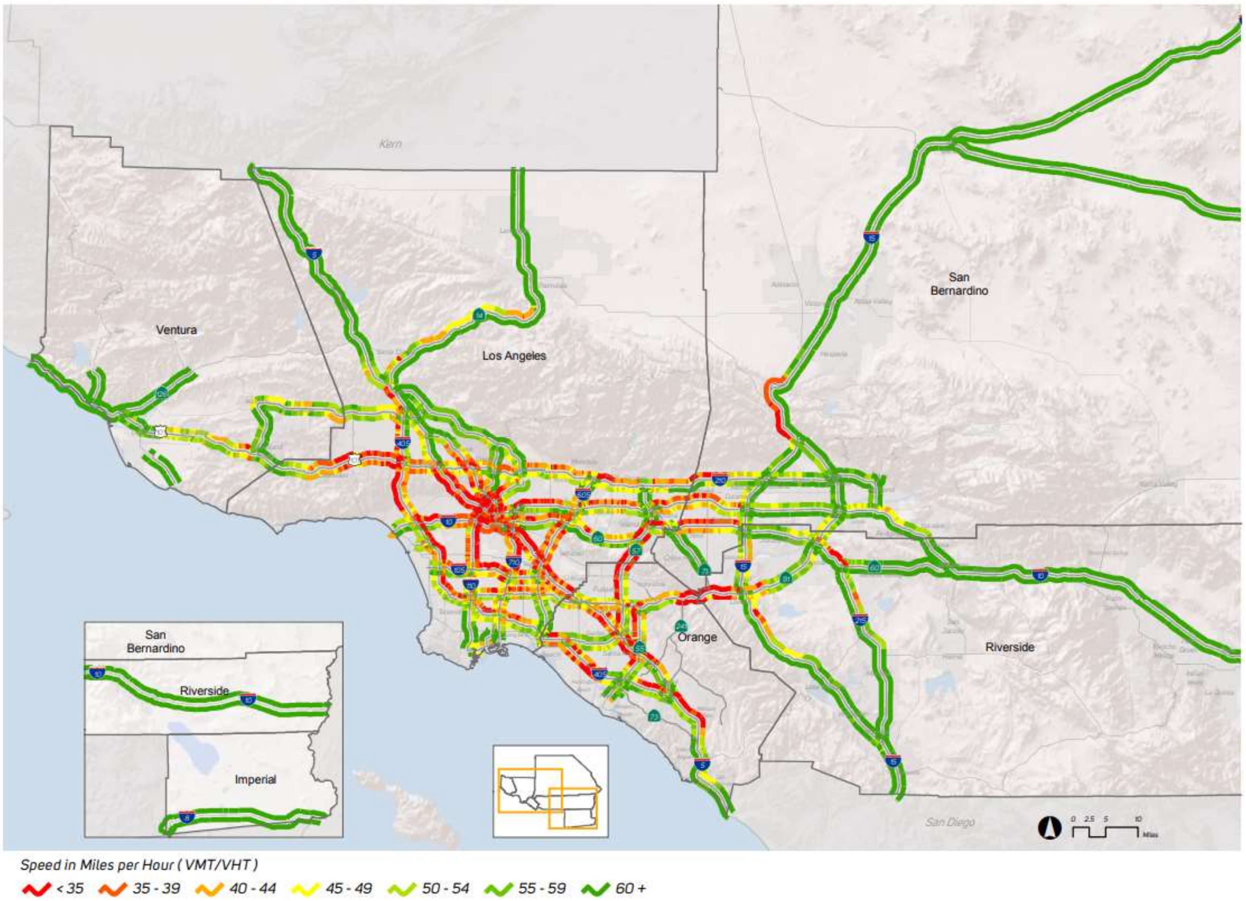


Figure 16-6: Year 2016 NPMRDS Average AM Peak Speed (Freeway)

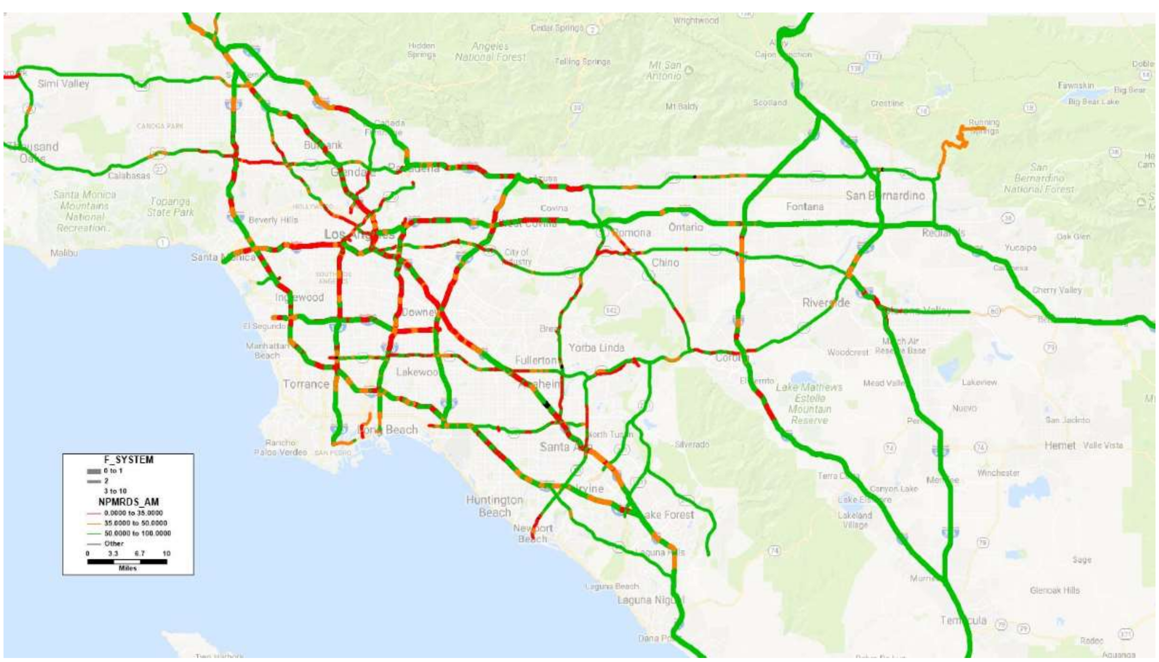


Figure 16-7: Year 2016 Model Estimated Average AM Peak Period Speed (Arterial)

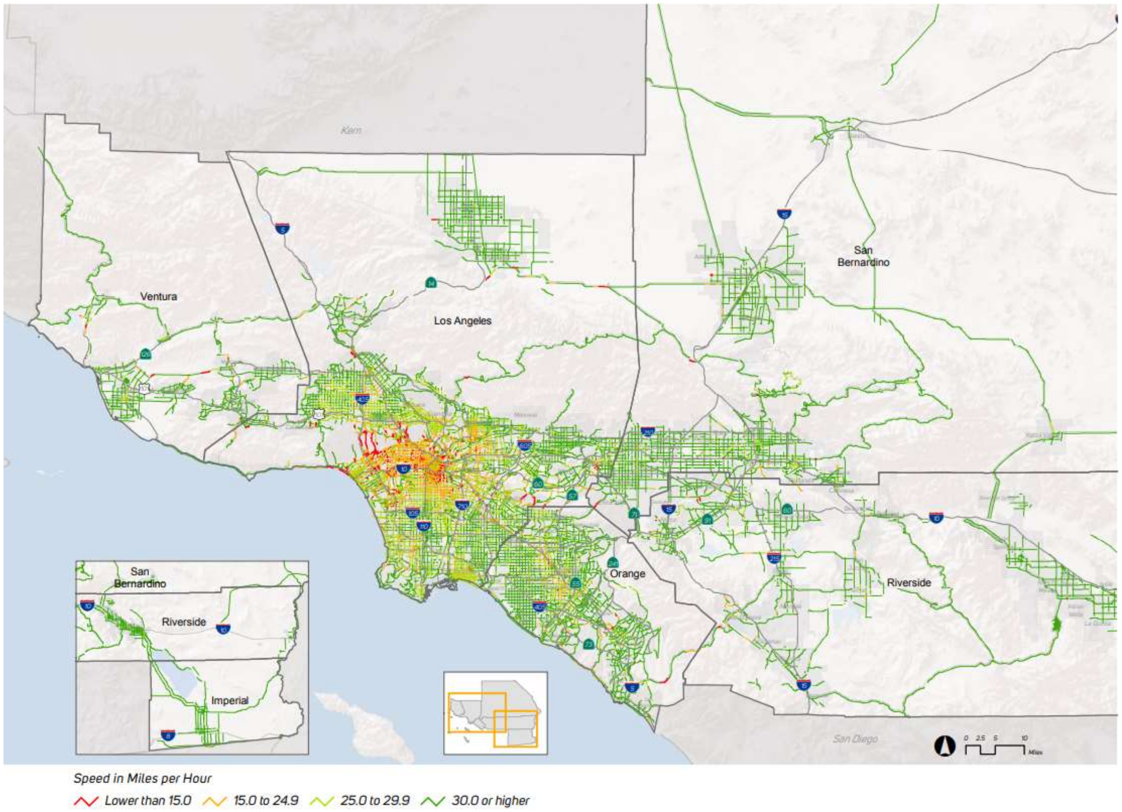


Figure 16-8: Year 2016 NPMRDS Average AM Peak Speed (Arterial)

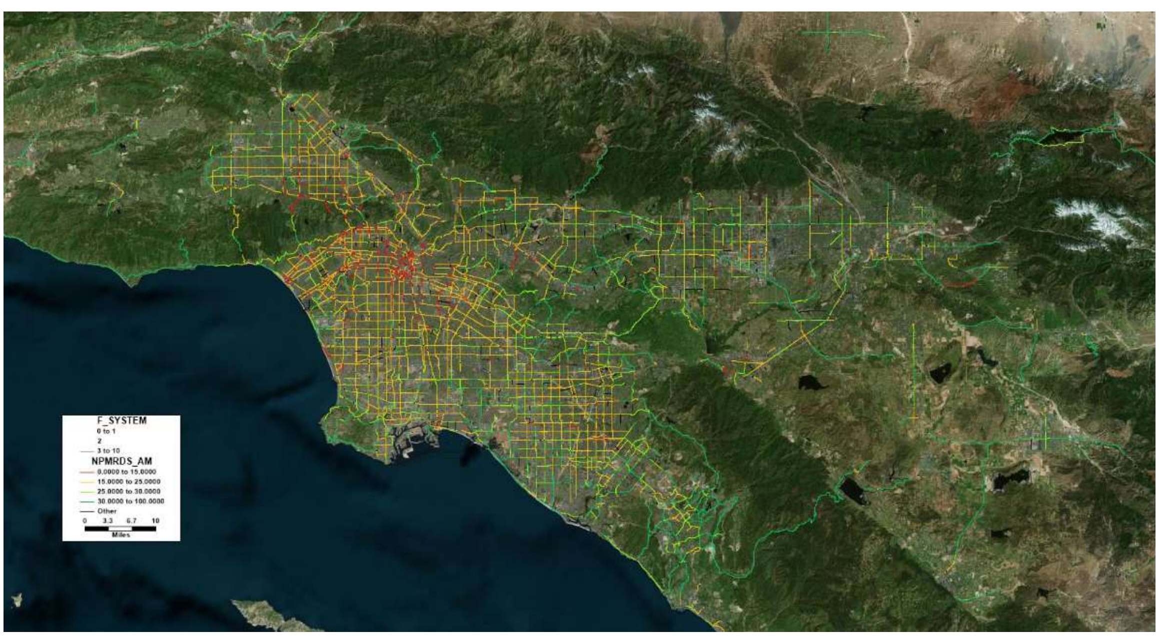


Figure 16-9: Year 2016 Model Estimated Average PM Peak Period Speed (Freeway)

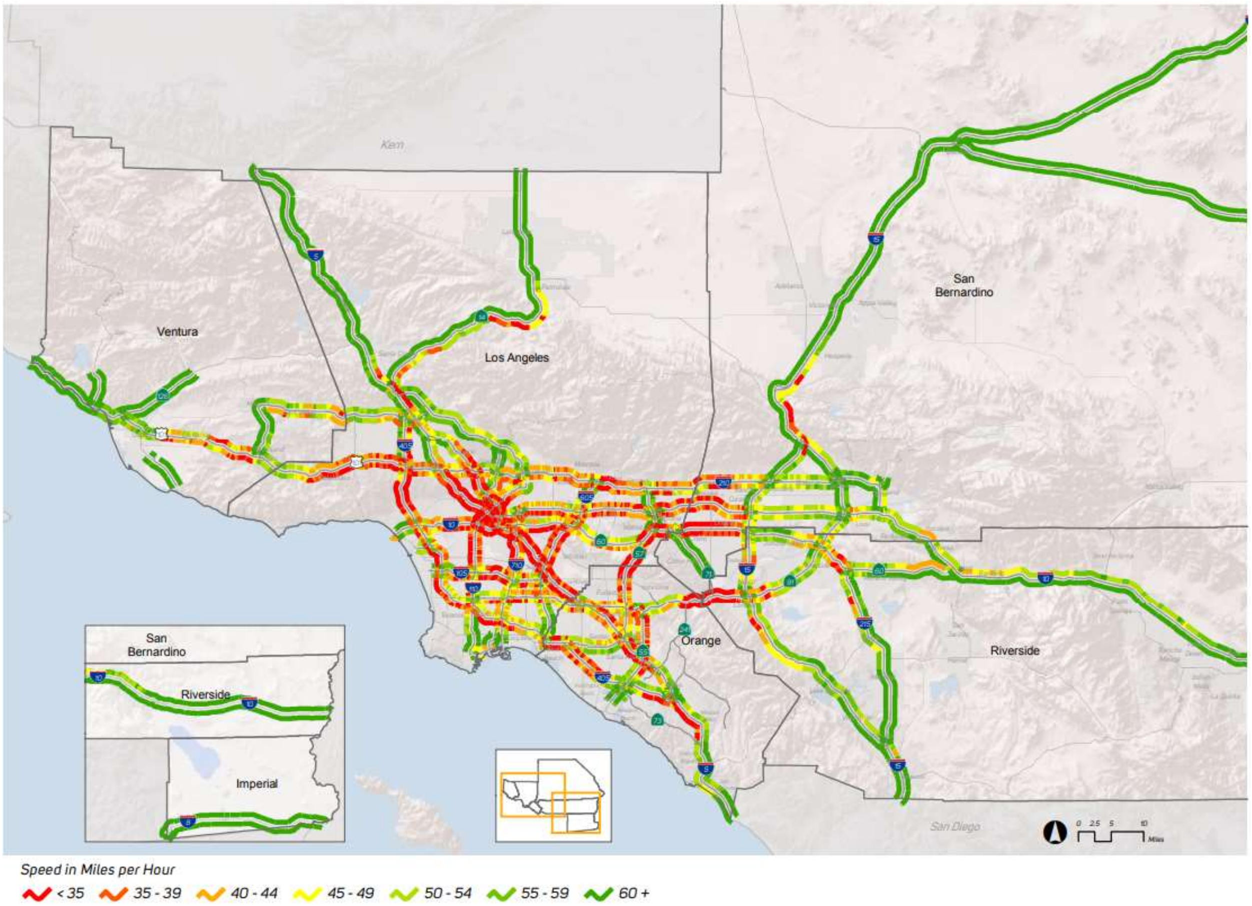


Figure 16-10: Year 2016 NPMRDS Average PM Peak Speed (Freeway)

Figure 16-11: Year 2016 Model Estimated Average PM Peak Period Speed (Arterial)

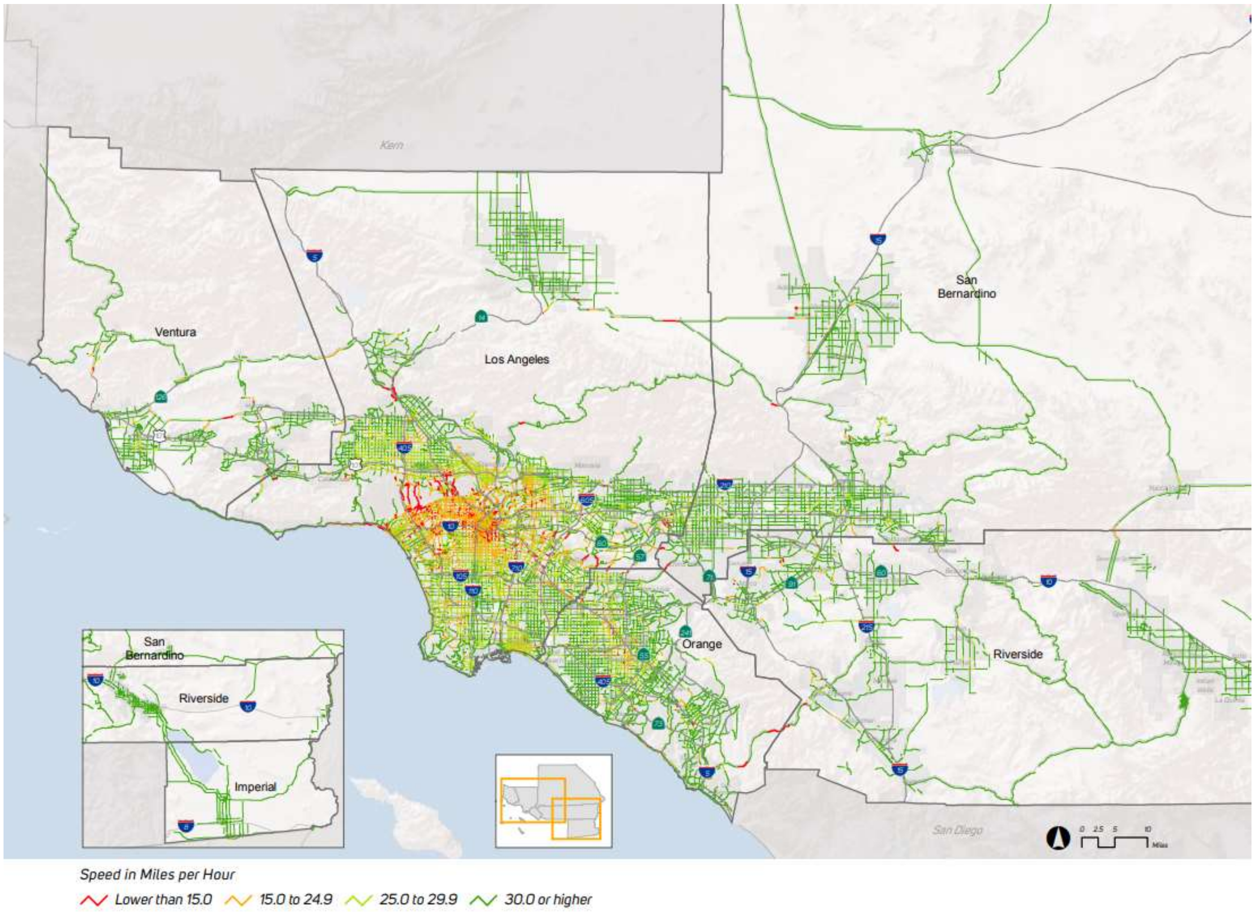
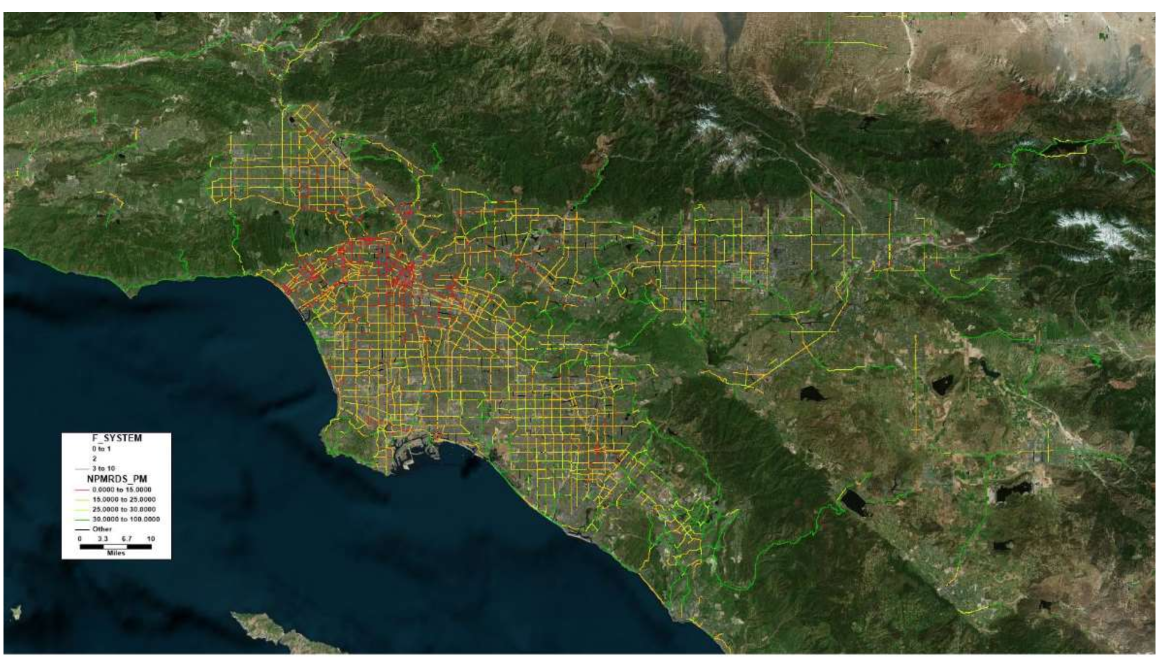


Figure 16-12: Year 2016 NPMRDS Average PM Peak Speed (Arterial)



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 origin-destination format, and for five time periods, AM, MD, PM, EVE, NT.

Transit trips estimated by the trip mode choice model on the final feedback loop are aggregated across trip purposes to create unlinked transit trips for two mode groups, conventional and premium, resulting in five transit trip tables.

The resulting loaded transit network files are aggregated to create total daily loaded trips.

TRANSIT ASSIGNMENT VALIDATION AND SUMMARY

The 2016 transit assignment loaded 2,074,697 unlinked passenger trips (boardings) on the transit network. Table 16-9 compares the model estimated daily transit boardings for the four predominant transit modes, to actual transit boarding statistics for 2016.

Table 16-9: Year 2016 Daily Transit Boardings - Model vs. Actual Counts

Transit Mode	Model Estimated Boardings	Actual Boardings 2016	Ratio
Commuter Rail	48,446	44,407	1.09
Urban Rail	371,903	348,505	1.07
MTA Bus *	932,256	957,891	0.97
Other Transit **	722,091	645,893	1.12
Total Boardings	2,074,697	1,996,696	1.04

* 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

Appendix A1: 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
- 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

Truck Prohibition Flag
- Null – Truck Not Prohibited
- 1 – Trucks Prohibited

Appendix A2: 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" non-fuel costs. Other costs include repairs, maintenance, tires, and accessories.

The table below summarizes the Year 2016 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. Fuel efficiency data from CARB's Auto Operating Cost Calculator Tool was used as base information by SCAG staff to calculate the average miles per gallon. Fuel price data includes gasoline, diesel (both data from California Energy Commission), and electric and hydrogen (both from CARB). The average fuel price is calculated as weighted average by VMT with each type of fuel (estimated by CARB). Thus, the fuel cost in terms of cents/mile can be derived from dividing fuel cost (252.46 cents/gallon) by average fuel efficiency (23.34 miles/gallon). As a result, the 10.82 cents-per-mile fuel cost (in 2011 cents) was estimated and used for the 2016 model validation.

2016 Auto Operating Cost ($2011)		
Item	**Value**	**Units**
Fuel economy	23.34	Miles per gallon
Fuel price	252.46	Cents per gallon
Fuel cost	10.82	Cents per mile
Non-fuel cost (maintenance and tires)	5.89	Cents per mile
Total auto operating cost	16.70	Cents per mile

The Year 2016 Model Validation uses the value of 5.89 cents per mile (in 2011 dollars) for non-fuel cost, including maintenance and tires. The data is based on "Your Driving Costs" issued by the American Automobile Association. Adding 5.89 cents per mile for non-fuel costs to the fuel costs per mile (10.91 cents/mile), yields a total auto operating cost of 16.70 cents per mile for 2016 in 2011 dollars.

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
CARB	California Air Resource Board
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
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

Acronym	Definition
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
IVT	In-Vehicle Time
KNR	Kiss-and-Ride
KSF	Thousand Square Feet
LA Metro	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
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
SBCTA	San Bernardino County Transportation Authority
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

Acronym	Definition
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
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