Federal Highway Administration

Foundational Knowledge to Support a Long-Distance Passenger Travel Demand Modeling Framework

Implementation Report

Exploratory Advanced Research Program

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<table>
<thead>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>Annual average daily traffic</td>
</tr>
<tr>
<td>AADTT</td>
<td>Average annual daily truck traffic</td>
</tr>
<tr>
<td>ACS</td>
<td>American Community Survey</td>
</tr>
<tr>
<td>BPR</td>
<td>Bureau of Public Roads</td>
</tr>
<tr>
<td>CSV</td>
<td>Comma-separated values</td>
</tr>
<tr>
<td>FAF</td>
<td>Freight Analysis Framework</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>GISDK</td>
<td>Geographic Information System Developer’s Kit</td>
</tr>
<tr>
<td>GTFS</td>
<td>General Transit Feed Specification</td>
</tr>
<tr>
<td>HBNW</td>
<td>Home-based non-work</td>
</tr>
<tr>
<td>HBW</td>
<td>Home-based work</td>
</tr>
<tr>
<td>HH</td>
<td>Household</td>
</tr>
<tr>
<td>LOS</td>
<td>Level-of-service</td>
</tr>
<tr>
<td>NAICS</td>
<td>North American Industrial Classification System</td>
</tr>
<tr>
<td>NHB</td>
<td>Non-home-based</td>
</tr>
<tr>
<td>NHPN</td>
<td>National Highway Planning Network</td>
</tr>
<tr>
<td>NHTS</td>
<td>National Household Travel Survey</td>
</tr>
<tr>
<td>NUMA</td>
<td>National Use Microdata Area</td>
</tr>
<tr>
<td>NW</td>
<td>Non-work</td>
</tr>
<tr>
<td>ODME</td>
<td>Origin-destination matrix estimation</td>
</tr>
<tr>
<td>QRM</td>
<td>Quick response methods</td>
</tr>
<tr>
<td>VisitFR</td>
<td>Visit friends and relatives purpose</td>
</tr>
</tbody>
</table>
CHAPTER 1. INTRODUCTION

Intercity travel is increasingly important in the United States. The Federal government and many states are faced with improving mobility and reducing impacts for these travelers. The Federal Highway Administration (FHWA) has invested in several studies to better understand intercity travel; this study is an extension of that interest, which began with exploratory research to develop a long-distance passenger travel demand model framework and grew to include implementation of that framework. The modeling framework is a tour-based microsimulation model of annual long-distance passenger travel for all households in the United States. The models schedule travel across one full year to capture work-related travel (employer’s business and commute) and non-work travel (visiting friends and family, personal business and shopping, and leisure). The models are multimodal (auto, rail, bus, and air) and based on national networks for each mode. This provides opportunities for evaluation of intercity transportation investments or testing national economic, environmental, and pricing policies.

This technical report documents the third phase of the DTFH61-10-R-00036 Exploratory Advanced Research program to develop Foundational Knowledge to Support a Long-Distance Passenger Travel Demand Modeling Framework. The original work included two other phases: a design phase and a research phase. The third phase is an implementation phase, focused on moving the research into practice and providing a model that can be used by state and Federal agencies interested in long-distance passenger travel.

The design and research phases concluded with the following products:

- Long-Distance Passenger Travel Demand Modeling Framework Final Report.
- Long-distance passenger travel demand model framework, with models estimated from available data.
- Recommendations for future data collection.
- Demonstration of the implementation framework.

This long-distance passenger model research did not include any new data collection, so models were estimated based on long-distance surveys collected from several states (Ohio, Colorado, Wisconsin, California, and New York). A long-distance passenger travel survey for the United States is recommended to estimate these models on a comprehensive dataset.

1.1 Objectives

The objectives of the implementation phase were the following:

- To produce a working model for the 2010 base year, including a national highway network and zone system, with multimodal travel times for rail, bus, and air modes, and a highway assignment.
- To calibrate and validate this model against available national data sources.
• To test this model and provide assurances that the calibrated and validated models produce reasonable results under a select set of policy scenarios.
• To ensure stability and reasonable performance for the application software beyond the original demonstration software in the research phase.

The national calibration was compared against recent origin-destination (O-D) trip tables developed by FHWA (with CDM Smith and RSG). The validation compared long-distance travel with traffic counts for all 50 states.

1.2 Overview of the Model System

Methods for modeling long-distance passenger movements are in their infancy in the United States. Federal and state entities have recently become interested in modeling long-distance passenger movements as part of highway infrastructure planning; similarly, agencies studying high-speed rail, or those involved in airport planning, have also expressed interest due to their dependence on long-distance travel markets. This stronger interest at the Federal and state levels has created an intersection of policy needs for long-distance passenger modeling. In practice, some states and regions have expressed interest in long-distance passenger modeling for statewide models (e.g., California, Ohio, and Arizona) and for high-speed rail ridership studies (e.g., Florida, California, and the Northeast Corridor). However, these models rely on traditional travel demand forecasting methods rather than on a robust understanding of the underlying behavior and how and why it is different from other passenger travel. This research contributes to the development of a national passenger framework.

The goal of this research was to develop a framework for a long-distance passenger travel demand model that can be used to build a national model for the United States, one based on exploring new ways to simulate behavior of long-distance passenger movements. This framework includes model specifications based on statistical analysis of available data, recommendations for data collection that facilitate the development of the national model, and a demonstration that the framework can be reasonably implemented. In addition, this national model will be estimated, calibrated, and validated on current long-distance travel data in the United States during the next phase of work. Ultimately, success will be marked by transition of the research into use for planning applications across the country. These applications include:

• Testing national policies (e.g., modal investments, pricing, economics, environmental, livability, safety, and airport/rail planning);
• Measuring system performance;
• Evaluating the impacts of private-sector decisions;
• Providing input to statewide and regional planning; and
• Assessing regional differences.

The exploratory research was conducted from 2011 to 2014 and included a long-term goal to develop long-distance passenger models not constrained by traditional methods or existing data sources, in combination with making data recommendations to support these new models. An
implementation phase was added to move the research into practice by calibrating and validating long-distance travel demand models that are practical for current use and implementing these models with software.

The long-distance passenger travel demand forecasting modeling system (Figure 1) synthesizes long-distance travel for each household in the United States (117 million households and 309 million people based on the 2010 US Census) using an annual scheduling of long-distance tours (round trips). Household and person characteristics are synthesized for the United States by Census Tract. The annual scheduling and joint mode and destination models are the centerpiece of the long-distance passenger models; these use advanced methods not previously applied in urban passenger demand travel models (e.g., activity-based models).

This long-distance passenger travel demand forecasting modeling system is implemented using software called rJourney™. For brevity, the long-distance passenger travel demand forecasting model is referenced in this report as rJourney.

1.3 Contents of the Report

This report comprises seven chapters. Chapter 1 includes the introduction and discusses the objectives of the original research and implementation phases of the work and an overview of the modeling system.

Chapter 2 discusses model calibration and reports the tour frequency, destination choice, and mode choice model calibration results. It also includes a description of the preparation of the average daily long-distance passenger travel model trip tables.

Chapter 3 describes the highway assignment parameters and the highway network. This chapter also includes a description of the background traffic estimation and the assignment application in TransCAD.

Chapter 4 describes the trip table and highway performance validation tests. There were five sensitivity tests performed (discussed in Chapter 5) in addition to the validation tests. These tests were conducted to explore the reasonableness of the models to changes in various inputs.

Chapter 6 presents details of the application software (rJourney), including the model structure and code, how to run the model, the input and output files, and the estimated model coefficients. A brief summary of the key findings for the implementation phase is presented in Chapter 7.
Figure 1: National Long-Distance Passenger Travel Demand Modeling System

Sample Household and Person Records (PUMS) → Geographic Correspondence (PUMA to Tract) → Population Synthesizer (PopGen) → Tour-Scheduling Model

- Decision to Travel
- Annual Budget

- Participation and Duration of each Activity → Numbers of Tours by Purpose → Party Size

Cross-Nested Destination and Mode Choice

- Auto Network
- Bus Network
- Rail Network
- Air Network

Household Records with Household Characteristics and Tours by Activity Type → Travel Impedance, weighted by Mode (LogSum)

Tour Records with Destination, Mode, Activity, Party Size, Nights Away, Distance, Time, Cost Details
CHAPTER 2. MODEL CALIBRATION

Model calibration is the process of applying the estimated models, comparing the results to observed values, and adjusting either the model specification or the alternative-specific constants. The various components of rJourney are vertically linked to ensure dependency between upper- and lower-level model components. As a result, calibrating one model component is likely to affect outcomes of other model components. In such cases, the general approach is to calibrate the model components in the order in which they are applied (i.e., the upper-level models are calibrated before the lower-level models). In this instance, the research team calibrated the tour generation-related model component first, followed by destination- and mode-choice models. The calibration process was applied in an iterative manner until the model, performing as a system, converged to a stable set of parameter values for all of the model components and the observed travel patterns were well represented. The following data sources were used to obtain observed target values, rates, and distributions:

1. 2007–2011 American Community Survey (ACS) 5-year estimate.
2. 2001 New York National Household Travel Survey (NHTS) add-on.
3. 2001 Wisconsin NHTS add-on.
4. 2003 Ohio Household Travel Survey.
5. 2010 Colorado Front Range Travel Survey.
6. 2012 California Household Travel Survey.

Target values and distribution from the ACS data were used for household vehicle ownership model. For other models, target distributions and rates obtained from expanded household travel survey data were used. Expansion factors were not available for 2012 California Household Travel Survey, so this survey was not used for any expanded targets. The use of these five statewide household travel surveys provided a range of target distributions and rates across the United States, but does not represent a true national household travel survey for long-distance passenger travel. As a result, calibration of these models was not intending to achieve a tight comparison between the model results and the five-state observed dataset.

Table 1 summarizes rJourney model components in the order in which they were calibrated, if required. Vehicle ownership\(^1\) is the first model in the system and did not require any calibration since the model prediction matched ACS data reasonably well (see Figure 2). And, after tour frequency model was calibrated, it was not necessary to calibrate tour scheduling, tour duration, and travel party size models (please see Figure 3, Figure 4, and Figure 5 for tour scheduling, tour duration, and travel party size models, respectively). In these figures, the five-state merged household travel survey dataset was used to represent the observed data. Calibration process of tour frequency, tour destination, and tour mode choice models is discussed in subsequent sections.

---

\(^1\) This report uses the terms “vehicle,” “auto,” and “car” interchangeably.
Table 1: Model Components that Required Calibration

<table>
<thead>
<tr>
<th>Model Components</th>
<th>Calibration Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Ownership Model</td>
<td>No</td>
</tr>
<tr>
<td>Tour Generation/Frequency Models</td>
<td>Yes</td>
</tr>
<tr>
<td>Tour Scheduling and Duration Models</td>
<td>No</td>
</tr>
<tr>
<td>Travel Party Size Models</td>
<td>No</td>
</tr>
<tr>
<td>Tour Destination-Choice Models</td>
<td>Yes</td>
</tr>
<tr>
<td>Tour Mode Choice Models</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Figure 2: Percentage of Households by Vehicle Ownership Level

Figure 3: Percentage of Tours by Season of the Year
Figure 4: Percentage of Tours by Number of Nights Away from Home

Figure 5: Percentage of Tours by Travel Party Size
2.1 Tour Frequency Models

Tour frequency models include two models applied sequentially: 1) for each tour purpose, the first model predicts whether or not a household undertakes a long-distance tour within a period of one week; and 2) the second model predicts whether or not a household undertakes more than one long-distance tour by purpose in one week. In application mode, these two models jointly predict number of tours by purpose generated by households over one year. The tour purposes are: personal business, visiting friends and relatives, leisure, commute, and employer’s business. Many variables have significant effects on the likelihood of long-distance tour generation by purpose, including household size, presence of children, age of householder, household income, household auto ownership level relative to number of adults, distance between origin and primary destination, tour duration, and month of the year.

Calibration of the tour frequency model involved the change of the alternative-specific constants to match observed tour rates by purpose with model prediction. Table 1 shows weekly tour rates by tour purpose from survey data and calibrated model prediction. Survey tour rates were calculated using data from the aforementioned five household travel surveys. In general, tour rates predicted by rJourney closely match observed data. While the frequency models do not control for tour distribution by purpose, Figure 6 shows there is significant alignment between observed and model-predicted tour distribution by purpose.

Table 2: Weekly Tour Rate by Purpose

<table>
<thead>
<tr>
<th>Tour Purpose</th>
<th>Weekly Tours per Household</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Survey</td>
<td>rJourney</td>
</tr>
<tr>
<td>Personal Business</td>
<td>0.034</td>
<td>0.031</td>
</tr>
<tr>
<td>Visiting Friends and Relatives</td>
<td>0.057</td>
<td>0.049</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.066</td>
<td>0.058</td>
</tr>
<tr>
<td>Commute</td>
<td>0.028</td>
<td>0.024</td>
</tr>
<tr>
<td>Employer’s Business</td>
<td>0.042</td>
<td>0.037</td>
</tr>
</tbody>
</table>

2 For brevity, all quantities that are derived using data from the household travel surveys will be referred to as “survey” instead of “five household travel surveys.”
2.2 Destination-Choice Models

Destination-choice models are multinomial logit models used to choose the destination zones of the long-distance tours. These zones are based on the National Use Microdata Zones (NUMAs) established and described in the Final Report for the research phase. For this set of models, all destinations that are 50+ miles away from origins were considered available. There are five destination-choice models, one for each tour purpose. The models are primarily functions of opportunities (represented by employment and/or households) and travel impedance. Opportunities that have significant effects on long-distance destination choices vary by tour purpose. In general, number of employment in accommodation, entertainment, medical, other services, retail, and wholesale industry; park areas; number of households; and college/university enrollment played a large role in determining the attractiveness of a destination. In this model, travel impedance (such as distance) was used to offset attractiveness of a destination zone. Other significant variables include logsum parameters from mode-choice models, destination type (urban/rural), and tour duration.

The model calibration process revealed that for almost all purposes, there was some under-prediction of relatively short-distance tours and some over-prediction of relatively long-distance tours. To address this discrepancy, minor adjustments were made to relevant distance-related coefficients. Figure 7 to Figure 11 compare calibrated tour-length distribution for each purpose with survey data. In general, the model’s predicted tour-length distributions are very similar to...
observed tour-length distribution. Where there are divergences between two distributions, the differences are within 4%. Table 3 presents average person-miles traveled, by purpose. While predicted average person-miles traveled for commute and employer’s business tours match survey data very well, some variations between model prediction and survey data exist for non-work-related tours. These variations may be due to rJourney over-predicting tours within 1,000 to 2,000 mile tour lengths.

**Figure 7: Round-Trip Distance-Band Distribution by Purpose—Personal business**
Figure 8: Round-Trip Distance-Band Distribution by Purpose—Visiting Friends and Relatives

Figure 9: Round-Trip Distance-Band Distribution by Purpose—Leisure
Figure 10: Round-Trip Distance-Band Distribution by Purpose—Commute

Figure 11: Round-Trip Distance-Band Distribution by Purpose—Employer’s Business
Table 3: Average Person-Miles Traveled

<table>
<thead>
<tr>
<th>Tour Purpose</th>
<th>Survey</th>
<th>rJourney</th>
<th>Difference</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Business</td>
<td>396.48</td>
<td>441.01</td>
<td>44.53</td>
<td>11.2%</td>
</tr>
<tr>
<td>Visiting Friends and Relatives</td>
<td>464.70</td>
<td>578.36</td>
<td>113.66</td>
<td>24.5%</td>
</tr>
<tr>
<td>Leisure</td>
<td>478.25</td>
<td>531.75</td>
<td>53.5</td>
<td>11.2%</td>
</tr>
<tr>
<td>Commute</td>
<td>219.25</td>
<td>219.62</td>
<td>0.37</td>
<td>0.2%</td>
</tr>
<tr>
<td>Employer's Business</td>
<td>673.02</td>
<td>641.17</td>
<td>-31.85</td>
<td>-4.7%</td>
</tr>
</tbody>
</table>

2.3 Mode-Choice Models

The tour mode choice model for each purpose is structured as a multinomial logit model with the following mode choices:

1. **Auto**: Available for all origin-destination (O-D) destination combinations that are 50+ miles apart, except:
   - From/to destinations within contiguous United States to/from destinations within Alaska and Hawaii; and
   - From/to destinations within Alaska to/from destinations within Hawaii.

2. **Bus**: Available for all O-D destination combinations that are 50+ miles apart and are connected to bus network.

3. **Rail**: Available for all O-D destination combinations that are 50+ miles apart and are connected to rail network.

4. **Air**: Available for all O-D destination combinations that are 50+ miles apart and are connected to the air network.

(The reader is referred to the Final Report for details on the development of the bus, rail, and air networks.)

Several household, person, tour-level, and destination-related attributes were found to have significant effects on tour mode choices. The calibration task was undertaken by adjusting mode-specific constants. Similar to destination-choice models, mode-choice models were calibrated for each purpose.

Figure 12 to Figure 17 present the calibrated mode-choice model results. Specifically, Figure 12 shows overall distribution of tour mode share for all purposes and Figure 13 to Figure 17 present tour mode share distribution for personal business, visiting friends and relatives, leisure, commute, and employer’s business tour purpose, respectively. Regardless of tour purposes, the calibrated mode shares match observed mode shares reasonably well with a difference within 4%. Auto is the predominant mode for long-distance tours and has an overall mode share of
88%. Personal business tours have the highest auto share (92.8%) and employer’s business tours have the lowest auto share (82.1%). The second most frequently used mode is air, with an overall share of about 8%. Air share is the highest for employer’s business (14.6%) and the lowest for commute (0.9%). Compared to auto and air, bus and rail have relatively small mode shares, in most cases ranging from less than 1% to a little over 2% (exceptions are bus and rail shares for commute tours, these shares are 3.1% and 12.0%, respectively).

**Figure 12: Overall Tour Mode Share**

![Overall Tour Mode Share](image1)

**Figure 13: Tour Mode Share by Purpose—Personal Business**

![Tour Mode Share by Purpose—Personal Business](image2)
Figure 16: Tour Mode Share by Purpose—Commute

![Bar chart showing tour mode share by purpose for commute. The chart compares survey data (blue) and rJourney data (gray). Auto mode dominates with over 80% of tours, followed by rail and bus, with air being the least used.](image16)

Figure 17: Tour Mode Share by Purpose—Employer’s Business

![Bar chart showing tour mode share by purpose for employer’s business. The chart compares survey data (blue) and rJourney data (gray). Auto mode again dominates, with over 80% of tours, followed by rail and bus, with air being the least used.](image17)
2.4 Preparation of Average Daily Long-Distance Trip Tables

The final outputs generated by rJourney include a household file (includes household-level information), a tour file (includes tour-level information), and trip matrices by mode. The trip matrices contain average daily long-distance trips and are derived from the tour file as follows:

- First, tours are converted to half-tours/trips using tour O-D zones. Information on mode, party size, distance, and expansion factors are extracted from each tour and are appended to the corresponding trip records.

- Second, expansion factors are applied to obtain an expanded trip record file. The file includes all the trips undertaken over one year. The trip records are divided by a factor of 365 to convert the annual vehicle-trip table to an average daily vehicle-trip table. Mode information is used to separate the trips into trip tables for auto, bus, rail, and air mode.

- Third, for person trip tables, the trip records are multiplied by party size to convert vehicle-trip tables to person trip tables.
CHAPTER 3. HIGHWAY ASSIGNMENT

3.1 Overview of Highway Network

Highway assignment was completed in TransCAD. The National Highway Planning Network (NHPN) was the main source of the TransCAD network. NHPN, developed by FHWA, is a geospatial database that comprises interstates, principal arterials, and rural minor arterials (over 450,000 miles of existing and planned highways in the country). The most up-to-date highway network was downloaded from the FHWA’s website. To build highway skims for the NUMA-level zonal system, centroid connecters were added to the NHPN network as additional links. Centroid connecters are not allowed to directly link to interstate facilities, since travelers have to access interstate facilities through other roads. The final highway network contains 198,634 links. TransCAD assigns long-distance and background traffic to this network to produce planning-level estimates of traffic volumes.

The key variables for building highway skims are speed and capacity. While speeds and capacities vary from facility to facility, the project team developed these based on the functional class of the highway links; this was due to a lack of facility-specific data. Table 4 and Table 5 are the look-up tables for the speed and capacity assumption.

Table 4: Urban roads’ Speed and Capacity by Functional Class

<table>
<thead>
<tr>
<th>Functional Classification</th>
<th>Urban</th>
<th>Posted Speed</th>
<th>Free-Flow Speed</th>
<th>Hourly Capacity Per Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>11</td>
<td>65</td>
<td>71.50</td>
<td>1,900</td>
</tr>
<tr>
<td>Other Freeway/Expressway</td>
<td>12</td>
<td>55</td>
<td>60.50</td>
<td>1,700</td>
</tr>
<tr>
<td>Principal Arterial</td>
<td>14</td>
<td>45</td>
<td>47.25</td>
<td>1,200</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>16</td>
<td>35</td>
<td>36.75</td>
<td>1,000</td>
</tr>
<tr>
<td>Collector</td>
<td>17</td>
<td>30</td>
<td>31.50</td>
<td>900</td>
</tr>
<tr>
<td>Local</td>
<td>19</td>
<td>25</td>
<td>26.25</td>
<td>600</td>
</tr>
</tbody>
</table>

Table 5: Rural Roads’ Speed and Capacity by Functional Class

<table>
<thead>
<tr>
<th>Functional Classification</th>
<th>Rural</th>
<th>Posted Speed</th>
<th>Free-Flow Speed</th>
<th>Hourly Capacity Per Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>1</td>
<td>70</td>
<td>73.50</td>
<td>2,000</td>
</tr>
<tr>
<td>Other Freeway/Expressway</td>
<td>2</td>
<td>60</td>
<td>63.00</td>
<td>1,800</td>
</tr>
<tr>
<td>Principal Arterial</td>
<td>6</td>
<td>50</td>
<td>52.50</td>
<td>1,400</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>7</td>
<td>45</td>
<td>47.25</td>
<td>1,200</td>
</tr>
<tr>
<td>Collector</td>
<td>8</td>
<td>40</td>
<td>42.00</td>
<td>1,000</td>
</tr>
<tr>
<td>Local</td>
<td>9</td>
<td>35</td>
<td>36.75</td>
<td>700</td>
</tr>
</tbody>
</table>
Centroid connectors also need speed and capacity constraints. Speed on centroid connectors was assumed to be the same as that for local roads. However, their capacities were set at an arbitrarily high level (999,999) to incorporate the fact that all demands have to flow through the centroid connectors.

A free-flow travel time highway skim was built for the NUMA zones. It is a 4486*4486 matrix—some NUMAs in Hawaii and Puerto Rico were not directly connected to the continental United States.

### 3.2 Estimation of Background Traffic

Long-distance trips are a small portion of the total demand on the national highway network. To obtain better assignment results, one should estimate the other trips taking up capacity on the road system so that congestion is adequately represented. These other trips include short-distance passenger trips and truck trips. At the link level, the total traffic is defined as follows:

**Equation 1: Defining Total Traffic**

\[
\text{Total Volume} = \text{Truck Volume} + \text{Long} - \text{Distance Passenger Volume} + \text{Short} - \text{distance Passenger Volume}
\]

The original NHPN, while containing annual average daily traffic (AADT) data, does not have truck AADT. The Freight Analysis Framework (FAF) network is useful for this purpose. FAF estimates commodity movements by truck and weight for truck-only, long-distance moves over specific highways. It can also be downloaded from the FHWA website. The greatest advantage of the FAF network was that it was also based on NHPN, which makes it relatively easy to correlate the average annual daily truck traffic (AADTT) with the highway links. A total of 176,231 matches were found in the FAF network. The links in Figure 18 represent those with FAF traffic counts.

To estimate the background trip table, the long-distance passenger trip table was assigned with the truck trip table using the stochastic method and subtracted from total volumes to produce an estimate of short-distance passenger volumes. These volumes were used in combination with origin-destination matrix estimation (ODME) methods to produce a short-distance passenger trip table. The short-distance passenger trips, added to the truck trips, produced a “background” trip table.

This initial estimation of background trips did not produce a reasonable estimate of total volumes, because the “seed” matrix for the ODME process was not reasonable. The seed matrix is for initial assignment purposes and could take various values—as simple as a matrix of all ones. A more theoretically sound approach, which has been applied by the project team, was generating a seed matrix using the quick response methods (QRM) for passenger travel. This method assumes trip rates (per household) for three purposes: home-based work (HBW), home-based non-work (HBNW), and non-home-based (NHB). The QRM approach uses a cross-classification table, segmented by the size of the urban area, household income, and auto
For each purpose, separated trip production and trip attraction rates were applied, and a final trip table was created by balancing both. A total QRM matrix was created by combining all three purposes.

**Figure 18: Highway Network with FAF Truck Traffic Data**

Since the background travel was focused only on short-distance travel, trips between any O-D pairs with greater than 50 miles of distance were eliminated from the QRM matrix. The final seed matrix contains 88,306 O-D pairs.

**Table 6: Statistics of the QRM Seed Matrices**

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Count</th>
<th>Mean</th>
<th>Std</th>
<th>Pct_Diag</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBW</td>
<td>19731666</td>
<td>15.6</td>
<td>1019.0</td>
<td>45.6</td>
<td>0</td>
<td>2279468</td>
</tr>
<tr>
<td>HBNW</td>
<td>19731666</td>
<td>27.9</td>
<td>1994.5</td>
<td>55.7</td>
<td>0</td>
<td>4084150</td>
</tr>
<tr>
<td>NHB</td>
<td>19731666</td>
<td>11.9</td>
<td>836.4</td>
<td>53.6</td>
<td>0</td>
<td>1740189</td>
</tr>
<tr>
<td>Total</td>
<td>19731666</td>
<td>55.4</td>
<td>3835.0</td>
<td>52.4</td>
<td>0</td>
<td>8103807</td>
</tr>
<tr>
<td>Less50</td>
<td>88306</td>
<td>12289.5</td>
<td>55998.3</td>
<td>52.8</td>
<td>1.13</td>
<td>8103808</td>
</tr>
</tbody>
</table>

QRM also produces intrazonal trips. Although these trips were never assigned to the network, a uniform 10 minutes of travel time is added to the diagonal cells of the skim to avoid invalid computational errors. The background traffic (a zonal trip matrix and link volumes) was successfully estimated using TransCAD’s ODME process to assign the QRM seed matrix onto the network.
3.3 Highway Assignment Parameters

Background trip and long-distance trip matrices produced are assigned to the NHPN. Background trips are assigned first using a biconjugate Frank-Wolfe method. The biconjugate Frank-Wolfe method is a user equilibrium assignment, which is an iterative process to achieve a convergent solution where route changes would not improve individual users’ travel times. The traditional Bureau of Public Roads (BPR) volume-delay function is used to determine the change in travel as congestion occurs (see Figure 19). This equation relates link travel times as a function of the volume/capacity ratio. The alpha and beta defined in the standard BPR function are globally assumed to be equal to their traditional values in rJourney. The background trip assignment is run with a relative gap of 0.003, with a maximum of 200 iterations.

\[ t = t_f \left[ 1 + \alpha \left( \frac{v}{c} \right)^\beta \right] \]

Where:
- \( t \) = congested link travel time
- \( t_f \) = link free-flow travel time
- \( v \) = link volume
- \( c \) = link capacity
- \( \alpha, \beta \) = 0.15, 4.0

Figure 19: Volume-Delay Curve

The resulting user equilibrium travel times from the background trips are applied to the network to provide congested travel times for long-distance trips. Due to the limited detail of the national network and the desire to utilize alternative routes, long-distance trips are assigned to the network using a stochastic assignment. A stochastic assignment distributes trips between multiple alternative paths that connect O-D pairs. The proportion of trips assigned to a path equals the choice probability for that path, which is calculated by a simple logit route choice model. Generally, a path with a lower overall travel time will have a higher choice probability. Only "reasonable" paths are considered in a stochastic assignment, so not every alternative path will be assigned. A path is determined “reasonable” if it takes the traveler farther away from the origin and/or closer to the destination. The stochastic error parameter is set at 40 and runs for 98 iterations.
3.4 Application in TransCAD

The rJourney assignment was implemented in TransCAD Version 6.0, a GIS-based travel demand modeling software, using the software’s scripting language, GISDK (Geographic Information System Developer’s Kit). TransCAD was chosen due to its ease of use and ability to handle large-scale traffic assignment algorithms within reasonable run times.

Some preprocessing is needed prior to assignment within TransCAD. While background trips were estimated in TransCAD, conversion was needed to bring the long-distance trip table into TransCAD’s matrix (.mtx) format. Long-distance tabular data was converted into a comma-separated values (CSV) file. Once processed, the CSV file was imported and converted using TransCAD import tools so that long-distance trips were in an appropriate O-D format for the national network.

A single GISDK script was created to complete the assignment approach detailed in Section 3.2. The process was broken into four parts, outlined in Figure 20. This includes the creation of the TransCAD highway network file (.net), the biconjugate Frank-Wolfe assignment of the background trips, updates to network attributes, and the stochastic assignment of long-distance trips.

Figure 20: Application in TransCAD Process

- TransCAD Highway Network File
- Background Traffic Assignment
- Update Congested Time
- Long-Distance Trip Assignment
CHAPTER 4. MODEL VALIDATION

4.1 Trip Tables by Mode

As part of model validation, the research team compared model-estimated trip tables by mode with mode-specific trip tables obtained from the following sources:

- **2008 National O-D trip tables**: These are 2008 county-to-county person trip tables for auto, bus, rail, and air. The tables include trips that are 100+ miles in length. The trip tables were developed as part of FHWA’s Traffic Analysis Framework Multimodal Interregional Passenger Travel Origin-Destination Data project. The auto and bus O-D tables were developed using the 1995 American Travel Survey as the primary source, and the 2001 and 2009 NHTS data as additional sources. The 2008 rail O-D table was created by blending data on station-to-station trips provided by Amtrak with survey data on access/egress trips to stations. The 2008 air O-D table was developed by combining Airline Origin and Destination Survey Data (DB1B) and T-100 data with data from a number of airport ground-access surveys. In addition to 2008 O-D tables, the project also developed trip tables for the year 2040. Trip tables from these two years were used to produce base year 2011 trip tables for the current research.

- **2014 Intercity bus ridership table**: This is a 2014 Core Based Statistical Area -to-Core Based Statistical Areas bus trip table for the top 200 markets. This bus trip table was developed as part of FHWA’s Developing Refined Estimates of Intercity Bus Ridership project. The table utilized data from several sources, including GTFS data for intercity bus services compiled from several sources, intercity bus schedule data from Russell’s Guide, and Northeast Corridor traveler survey. The 2014 bus ridership table was factored down to the 2011 level.

The 2008 national O-D tables and the 2014 intercity bus ridership table are not observed data and so are not used as conclusive sources for validation. The 2014 intercity bus ridership table also does not provide any information on the overall market share captured by the top 200 markets. Therefore, it is not feasible to treat these tables as benchmark values and use them for model validation. Rather, the research team compared the model-estimated trip tables with the 2011 national O-D tables and the 2011 intercity bus ridership table to obtain a general overview on the performance of the model. For this, the trip tables were summarized by nine Census Regions shown in Figure 21. The results are presented in Table 7 and Table 8. Overall, the model-estimated auto and air trip tables align relatively well with national O-D tables. The variation is more pronounced for bus and rail modes. Relative to national O-D tables, the model under-predicts total daily bus trips and over-predicts total daily rail trips by approximately 25%. When the model-predicted bus ridership values are compared with the 2011 intercity bus ridership

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3 These are preliminary research data and information the research team obtained from FHWA. At the time of this report, FHWA has not performed any quality review of the data.

4 The Census Bureau refers to these regions as Divisions, with larger aggregations of these Divisions as Regions.
table, the over-prediction rate is 60%. This divergence between rJourney values and intercity bus ridership values may be due to the fact that the spatial resolution and other information available on the definition of the top 200 markets were not detailed enough to enable a selection of the same bus markets from the model.

**Figure 21: Regions in the US Census**

Another potential data source for the current research is the long-distance component of the 2001 NHTS. Table 9 summarizes average daily long-distance trips by mode from rJourney, 2011 national O-D tables, and 2001 NHTS. The difference between the number of auto trips from rJourney and the NHTS data may be attributed to the followings:

a) To be consistent with the values in the national O-D tables, only auto trips with a length $\geq 100$ miles were selected from rJourney, while the NHTS data includes all trips with a length $\geq 50$ miles.

b) rJourney predicted values correspond to the year 2011 while NHTS data correspond to the year 2001.

Compared to NHTS data, the model over-predicts the number of air trips by more than 90%. This is not surprising since there was a significant decline in air travel in 2001 after September 11, 2001. Table 10, which shows overall mode share, also captures this decline. In contrast, mode share from rJourney and national O-D tables show similar distribution.
Table 7: Average Daily Person-Trips by Region by Mode (Trip Length ≥ 100 Miles)

<table>
<thead>
<tr>
<th>Region</th>
<th>rJourney (includes only trips with a length ≥ 100 miles)</th>
<th>National O-D table (2011)</th>
<th>The top 200 bus ridership markets (2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Auto</td>
<td>Bus</td>
<td>Rail</td>
</tr>
<tr>
<td>New England</td>
<td>307,492</td>
<td>6,920</td>
<td>10,706</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>860,904</td>
<td>22,533</td>
<td>37,781</td>
</tr>
<tr>
<td>East North Central</td>
<td>1,300,657</td>
<td>28,841</td>
<td>12,352</td>
</tr>
<tr>
<td>West North Central</td>
<td>640,750</td>
<td>10,175</td>
<td>2,282</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>1,487,693</td>
<td>30,254</td>
<td>18,221</td>
</tr>
<tr>
<td>East South Central</td>
<td>591,437</td>
<td>10,243</td>
<td>736</td>
</tr>
<tr>
<td>West South Central</td>
<td>856,572</td>
<td>16,474</td>
<td>3,899</td>
</tr>
<tr>
<td>Mountain</td>
<td>481,558</td>
<td>6,772</td>
<td>1,934</td>
</tr>
<tr>
<td>Pacific</td>
<td>694,852</td>
<td>13,053</td>
<td>13,956</td>
</tr>
<tr>
<td>Total</td>
<td>7,221,915</td>
<td>145,264</td>
<td>101,868</td>
</tr>
</tbody>
</table>

---

5 Information available on the definition of the top 200 bus ridership markets were not detailed enough to select the corresponding 200 markets from rJourney.
### Table 8: Model Estimates Over Trip Table Values Ratio

<table>
<thead>
<tr>
<th>Region</th>
<th>Ratio: rJourney/National O-D table</th>
<th></th>
<th></th>
<th></th>
<th>Ratio: rJourney/Bus ridership table</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Auto</td>
<td>Bus</td>
<td>Rail</td>
<td>Air</td>
<td>Overall Ratio</td>
</tr>
<tr>
<td>New England</td>
<td>1.13</td>
<td>0.78</td>
<td>1.32</td>
<td>0.91</td>
<td>0.59</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>1.39</td>
<td>0.80</td>
<td>1.48</td>
<td>0.95</td>
<td>0.86</td>
</tr>
<tr>
<td>East North Central</td>
<td>1.36</td>
<td>1.10</td>
<td>1.37</td>
<td>0.97</td>
<td>4.18</td>
</tr>
<tr>
<td>West North Central</td>
<td>1.03</td>
<td>0.95</td>
<td>1.42</td>
<td>0.96</td>
<td>7.38</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>1.17</td>
<td>0.81</td>
<td>1.25</td>
<td>0.71</td>
<td>2.37</td>
</tr>
<tr>
<td>East South Central</td>
<td>1.23</td>
<td>1.11</td>
<td>2.32</td>
<td>1.00</td>
<td>6.81</td>
</tr>
<tr>
<td>West South Central</td>
<td>0.81</td>
<td>0.72</td>
<td>4.18</td>
<td>0.93</td>
<td>1.78</td>
</tr>
<tr>
<td>Mountain</td>
<td>0.68</td>
<td>0.39</td>
<td>1.81</td>
<td>0.59</td>
<td>1.56</td>
</tr>
<tr>
<td>Pacific</td>
<td>0.69</td>
<td>0.38</td>
<td>0.70</td>
<td>0.71</td>
<td>1.74</td>
</tr>
<tr>
<td>Overall Ratio</td>
<td>1.03</td>
<td>0.74</td>
<td>1.25</td>
<td>0.80</td>
<td>1.62</td>
</tr>
</tbody>
</table>
### Table 9: Average Daily Long-Distance Trips by Mode

<table>
<thead>
<tr>
<th>Travel Mode</th>
<th>rJourney (includes only trips with a length ≥ 100 miles)</th>
<th>2011 National O-D tables (trip length ≥ 100 miles)</th>
<th>2001 NHTS (trip length ≥ 50 miles)</th>
<th>Ratio rJourney/National O-D table</th>
<th>Ratio rJourney/NHTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto/Personal Vehicle</td>
<td>7,221,915</td>
<td>6,985,379</td>
<td>6,400,274</td>
<td>1.03</td>
<td>1.13</td>
</tr>
<tr>
<td>Bus</td>
<td>145,264</td>
<td>195,216</td>
<td>151,781</td>
<td>0.74</td>
<td>0.96</td>
</tr>
<tr>
<td>Train</td>
<td>101,868</td>
<td>81,278</td>
<td>57,808</td>
<td>1.25</td>
<td>1.76</td>
</tr>
<tr>
<td>Air</td>
<td>1,011,855</td>
<td>1,266,582</td>
<td>529,589</td>
<td>0.80</td>
<td>1.91</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
<td>15,890</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8,480,901</td>
<td>8,528,455</td>
<td>7,155,342</td>
<td>0.99</td>
<td>1.19</td>
</tr>
</tbody>
</table>

### Table 10: Overall Mode Share

<table>
<thead>
<tr>
<th>Transportation Mode</th>
<th>rJourney (includes only trips with length ≥ 100 miles)</th>
<th>2011 National O-D tables (trip length ≥ 100 miles)</th>
<th>2001 NHTS (trip length ≥ 50 miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto/Personal Vehicle</td>
<td>85.2%</td>
<td>81.9%</td>
<td>89.4%</td>
</tr>
<tr>
<td>Bus</td>
<td>1.7%</td>
<td>2.3%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Train</td>
<td>1.2%</td>
<td>1.0%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Air</td>
<td>11.9%</td>
<td>14.9%</td>
<td>7.4%</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
<td>0.2%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

### 4.2 Highway Performance

Highway validation of passenger long-distance trips was completed by studying rural functional classes at the Census Division level. The Census Divisions are nine subdivisions of the four Census Regions (Northeast, Midwest, South, West), which provide groupings of the United States and the District of Colombia (see Figure 21).

Highway network validation is difficult at this national level for several reasons. Of necessity, the model has limited spatial resolution. Short-distance trips or background traffic are treated in an extremely simplified fashion, and limited data were available for the calibration of the long-distance demand patterns. However, an effort was made to analyze long-distance passenger trips with national data currently available. For national traffic count data, the Freight Analysis Framework Version 3 (FAF3) database was applied to the NHPN, which resulted in adding HPMS AADT for 2007 to 98% of functionally classified links within the NHPN. For rural vehicle miles traveled (VMT) data, table VM-3 from the Highway Statistics 2013 manual,

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6 2001 NHTS annual long distance trips were divided by 365 to obtain daily long-distance trips.
published by FHWA's Office of Highway Policy Information (OHPI), was aggregated from the state level into Census Divisions. Table 11 presents the long-distance rural volumes and VMT from rJourney with the percent distributions of traffic counts and VMT counts from available sources.

Table 11: Highway Model Validation Data by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>rJourney Rural Avg. Volume</th>
<th>rJourney Rural Total VMT</th>
<th>2007 AADT</th>
<th>2013 OHPI VMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific</td>
<td>3,650</td>
<td>18,472</td>
<td>19.8%</td>
<td>39.0%</td>
</tr>
<tr>
<td>Mountain</td>
<td>2,966</td>
<td>9,142</td>
<td>32.4%</td>
<td>50.5%</td>
</tr>
<tr>
<td>West South Central</td>
<td>3,928</td>
<td>12,091</td>
<td>32.5%</td>
<td>47.6%</td>
</tr>
<tr>
<td>East South Central</td>
<td>4,424</td>
<td>12,581</td>
<td>35.2%</td>
<td>46.9%</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>5,255</td>
<td>16,771</td>
<td>31.3%</td>
<td>52.7%</td>
</tr>
<tr>
<td>West North Central</td>
<td>2,454</td>
<td>6,721</td>
<td>36.5%</td>
<td>48.8%</td>
</tr>
<tr>
<td>East North Central</td>
<td>5,096</td>
<td>12,194</td>
<td>41.8%</td>
<td>68.4%</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>4,296</td>
<td>13,253</td>
<td>32.4%</td>
<td>65.2%</td>
</tr>
<tr>
<td>New England</td>
<td>3,427</td>
<td>15,352</td>
<td>22.3%</td>
<td>38.8%</td>
</tr>
</tbody>
</table>

With the exception of the Pacific and New England regions, comparing these datasets illustrates that average long-distance passenger volumes are roughly 35% of the 2007 total traffic counts and 54% of the rural VMT (see Figure 22 and Figure 23). Looking closer at the Pacific and New England regions shows a decrease in both average count and VMT comparisons. This could be attributed to the small size and relatively fewer rural roadways of these regions.
Figure 22: Highway Model Validation Volumes by Region

Census Regions

- Pacific
- Mountain
- West-South Central
- East-South Central
- South Atlantic
- West-North Central
- East North Central
- Mid-Atlantic
- New England

Volume

Avg Rural 2007 HPMS AADT
Avg Rural LD Volume
Improvement in assignment validation is possible with further investments. The network itself could be improved by addressing remaining connectivity issues, further adjusting centroid connectors and perhaps improving assumptions regarding speeds and capacities. Several improvements could be made to handling short-distance trips or background traffic, and enhancements to the long-distance trip table estimates themselves could also potentially be made by incorporating additional data, including data from traffic counts or additional O-D data if and when it becomes available.

An overall view of the assignment of journey volumes on the national highway network confirms the reasonableness of the highway assignment (Figure 24 and Figure 25). These long-distance volumes are greater around metropolitan areas due to higher population concentrations; these volumes also represent smaller populations in rural areas who travel long distances.
Figure 24: rJourney Total Volumes by Count
Figure 25: Long-Distance Journey Volumes in the United States
CHAPTER 5. SENSITIVITY TESTS

Five sensitivity tests were undertaken to assess the model’s responsiveness to changes in policy sensitive variables. The policy sensitive variables and the changes tested included:

1. **Household income**: Increase all household incomes by 10%.
2. **Auto cost**: Increase all O-D car toll and operating costs by 50%.
3. **Auto travel time**: Increase all O-D car travel times by 25%.
4. **Air fare**: Increase all O-D air fares by 50%.
5. **Rail travel time**: Decrease all O-D rail travel times by 50%.

The sensitivity tests and key findings are discussed below.

5.1 Income Test

This test involved evaluating the impacts of changes in socioeconomic conditions on long-distance travel behavior. Specifically, this sensitivity test quantified changes in long-distance travel behavior due to a 10% increase in income. Figure 25 shows that a 10% increase in income is likely to increase household vehicle ownership level by shifting 0 and 1 vehicle households toward multivehicle households (income elasticities of vehicle ownership are -.58, -.25, .14, .17, and .26 for 0, 1, 2, 3, 4+ vehicles, respectively).

![Figure 26: Percentage of Households by Vehicle Ownership Level (scenario case: income test)](image)

An increase in income is also expected to encourage more travel. The model results show a 3.2% increase in tour generation, a significant portion of which may be attributed to leisure and
employer’s business tours, as shown in Figure 26. Income elasticity of tour generation for leisure, employer’s business, and other tour purposes are presented in the last column of Table 12. The table also shows that income increase is likely to cause an almost proportional increase in air mode (overall elasticity .84).

Figure 27: Number of Tours by Purpose (scenario case: income test)

Table 12: Elasticity of Tour Mode by Purpose (scenario case: income test)

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Auto</th>
<th>Bus</th>
<th>Rail</th>
<th>Air</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Business</td>
<td>0.09</td>
<td>0.06</td>
<td>0.10</td>
<td>0.57</td>
<td>0.11</td>
</tr>
<tr>
<td>Visiting Friends and Relatives</td>
<td>0.18</td>
<td>-0.17</td>
<td>-0.02</td>
<td>0.53</td>
<td>0.20</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.39</td>
<td>-0.32</td>
<td>0.33</td>
<td>0.84</td>
<td>0.40</td>
</tr>
<tr>
<td>Commute</td>
<td>0.19</td>
<td>0.03</td>
<td>0.78</td>
<td>0.98</td>
<td>0.26</td>
</tr>
<tr>
<td>Business</td>
<td>0.49</td>
<td>0.26</td>
<td>0.35</td>
<td>1.17</td>
<td>0.58</td>
</tr>
<tr>
<td>Overall</td>
<td>0.28</td>
<td>-0.10</td>
<td>0.52</td>
<td>0.84</td>
<td>0.32</td>
</tr>
</tbody>
</table>

As expected, under this scenario, tours made by auto and rail are likely to increase as well, while tours by bus are likely to decrease. Unsurprisingly, similar proportional changes in total travel time, total travel cost, and total travel distance can be expected for each mode (Table 13). The table also shows that a 10% increase in income is likely to result in a 6.5% increase in travel expenditure. However, change in average person-miles traveled for each purpose and mode is expected to be none to minimal (Table 14 and Table 15).
Table 13: Elasticity of Total Travel Time, Cost, and Distance by Mode (scenario case: income test)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Total Travel Time</th>
<th>Total Travel Cost</th>
<th>Total Travel Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>0.28</td>
<td>0.31</td>
<td>0.28</td>
</tr>
<tr>
<td>Bus</td>
<td>-0.14</td>
<td>-0.15</td>
<td>-0.14</td>
</tr>
<tr>
<td>Rail</td>
<td>0.27</td>
<td>0.32</td>
<td>0.28</td>
</tr>
<tr>
<td>Air</td>
<td>0.79</td>
<td>0.86</td>
<td>0.79</td>
</tr>
<tr>
<td>Total</td>
<td>0.30</td>
<td>0.65</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 14: Elasticity of Average Person-Miles Traveled by Purpose (scenario case: income test)

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Average Person-Miles Traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Business</td>
<td>0.14</td>
</tr>
<tr>
<td>Visiting Friends and Relatives</td>
<td>0.11</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.15</td>
</tr>
<tr>
<td>Commute</td>
<td>0.02</td>
</tr>
<tr>
<td>Business</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 15: Elasticity of Average Person-Miles Traveled by Mode (scenario case: income test)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Average Person-Miles Traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>0.04</td>
</tr>
<tr>
<td>Bus</td>
<td>0.04</td>
</tr>
<tr>
<td>Rail</td>
<td>-0.09</td>
</tr>
<tr>
<td>Air</td>
<td>0.00</td>
</tr>
</tbody>
</table>

5.2 Pricing Test (Auto Costs)

For the Pricing Test scenario, auto costs were increased by 50% to test the effect of pricing on a household’s long-distance travel pattern. Such a change in auto costs is likely to result in an approximately 1.8% reduction in long-distance tour generation, mostly from leisure and visiting friends and relatives tour categories (Figure 27).
The test indicated that households’ long-distance travel behavior, in terms of mode choice, is fairly inelastic (Figure 27). Relative to base condition, a 50% increase in auto costs is likely to reduce auto tours by less than 2% (elasticity is -.04). This may be due to the fact that for almost 90% of long-distance tours, auto is the only viable mode option.

To offset increase in travel costs by auto, in some instances households/individuals are likely to visit destinations that are closer to home. Table 17 demonstrates that a 50% increase in auto costs is likely to reduce total distance traveled, and average person-miles traveled by auto, by a little over 5% and just under 3%, respectively. A similar reduction can be expected in total travel time by auto (Table 18). On the other hand, travel cost by auto is likely to increase by approximately 55% (Table 19). This indicates that despite a 50% increase, from a total travel cost standpoint, auto is still the preferred mode for most long-distance tours.
Table 17: Change in Distance Traveled (scenario case: auto costs test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Total Travel Distance (In Million Miles)</th>
<th>Average Person-Miles Traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Case</td>
<td>Scenario Case</td>
</tr>
<tr>
<td>Auto</td>
<td>896,814</td>
<td>850,546</td>
</tr>
<tr>
<td>Bus</td>
<td>22,114</td>
<td>22,086</td>
</tr>
<tr>
<td>Rail</td>
<td>15,305</td>
<td>15,295</td>
</tr>
<tr>
<td>Air</td>
<td>492,317</td>
<td>494,411</td>
</tr>
</tbody>
</table>

Table 18: Change in Total Travel Time (scenario case: auto costs test)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>% Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>15,485</td>
<td>14,710</td>
<td>-5.00%</td>
<td>-0.10</td>
</tr>
<tr>
<td>Bus</td>
<td>546</td>
<td>545</td>
<td>-0.14%</td>
<td>0.00</td>
</tr>
<tr>
<td>Rail</td>
<td>324</td>
<td>323</td>
<td>-0.18%</td>
<td>0.00</td>
</tr>
<tr>
<td>Air</td>
<td>1,266</td>
<td>1,272</td>
<td>0.46%</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 19: Change in Travel Cost (scenario case: auto costs test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Total Travel Cost (In Thousand $)</th>
<th>Average Travel Cost Per Mile (In $/Mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Case</td>
<td>Scenario Case</td>
</tr>
<tr>
<td>Auto</td>
<td>98,408,206</td>
<td>140,515,046</td>
</tr>
<tr>
<td>Bus</td>
<td>3,226,345</td>
<td>3,220,779</td>
</tr>
<tr>
<td>Rail</td>
<td>4,696,937</td>
<td>4,705,946</td>
</tr>
<tr>
<td>Air</td>
<td>174,259,351</td>
<td>175,282,139</td>
</tr>
</tbody>
</table>

5.3 Safety Test (Auto Times)

The Safety Test scenario indicated that long-distance travel is more sensitive to an increase in auto travel time than to an increase in auto travel cost. Under this scenario, travelers are likely to make 3.2% fewer long-distance tours—mostly fewer visiting friends and relatives and leisure tours—if auto travel time is increased by 25% (Figure 28). Such an increase in auto travel time is not expected to make any significant changes in long-distance travel mode share. Table 20 shows a 0.6% decrease in auto mode share and a 0.4% increase in air mode share under this scenario. Relative to base scenario, in some cases individuals are likely to travel to destinations closer to home by auto and to destinations that are farther afield by non-auto modes (Table 21). Despite switching destinations for some tours, total travel time by auto is likely to increase, though not proportionately (Table 22). A 10% increase in auto travel time is expected to increase total travel time by auto by approximately 5% (elasticity 0.46). However, driving to destinations closer to home may decrease total auto cost by a little less than 10% (Table 23).
Figure 29: Number of Tours by Purpose (scenario case: auto times test)

Table 20: Change in Mode Share (scenario case: auto times test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>87.88%</td>
<td>87.27%</td>
<td>-0.61%</td>
<td>-0.16</td>
</tr>
<tr>
<td>Bus</td>
<td>1.80%</td>
<td>1.88%</td>
<td>0.08%</td>
<td>0.05</td>
</tr>
<tr>
<td>Rail</td>
<td>2.66%</td>
<td>2.78%</td>
<td>0.12%</td>
<td>0.04</td>
</tr>
<tr>
<td>Air</td>
<td>7.66%</td>
<td>8.07%</td>
<td>0.41%</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Table 21: Change in Distance Traveled (scenario case: auto times test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Total Travel Distance (In Million Miles)</th>
<th>Average Person-Miles Traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Case</td>
<td>Scenario Case</td>
</tr>
<tr>
<td>Auto</td>
<td>896,814</td>
<td>796,177</td>
</tr>
<tr>
<td>Bus</td>
<td>22,114</td>
<td>22,449</td>
</tr>
<tr>
<td>Rail</td>
<td>15,305</td>
<td>15,528</td>
</tr>
<tr>
<td>Air</td>
<td>492,317</td>
<td>501,542</td>
</tr>
</tbody>
</table>

Table 22: Change in Total Travel Time (scenario case: auto times test)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>% Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>15,485</td>
<td>17,254</td>
<td>11.43%</td>
<td>0.46</td>
</tr>
<tr>
<td>Bus</td>
<td>546</td>
<td>554</td>
<td>1.54%</td>
<td>0.06</td>
</tr>
<tr>
<td>Rail</td>
<td>324</td>
<td>328</td>
<td>1.43%</td>
<td>0.06</td>
</tr>
<tr>
<td>Air</td>
<td>1,266</td>
<td>1,291</td>
<td>1.98%</td>
<td>0.08</td>
</tr>
</tbody>
</table>
Table 23: Change in Travel Cost (scenario case: auto times test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Base Case (In Thousand $)</th>
<th>Scenario Case (In Thousand $)</th>
<th>% Difference</th>
<th>Elasticity</th>
<th>Base Case ($/Mile)</th>
<th>Scenario Case ($/Mile)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>98,408,206</td>
<td>89,045,193</td>
<td>-9.51%</td>
<td>-0.38</td>
<td>0.11</td>
<td>0.11</td>
<td>0.00%</td>
</tr>
<tr>
<td>Bus</td>
<td>3,226,345</td>
<td>3,268,319</td>
<td>1.30%</td>
<td>0.05</td>
<td>0.15</td>
<td>0.15</td>
<td>0.00%</td>
</tr>
<tr>
<td>Rail</td>
<td>4,696,937</td>
<td>4,772,735</td>
<td>1.61%</td>
<td>0.06</td>
<td>0.31</td>
<td>0.31</td>
<td>0.00%</td>
</tr>
<tr>
<td>Air</td>
<td>174,259,351</td>
<td>178,276,796</td>
<td>2.31%</td>
<td>0.09</td>
<td>0.35</td>
<td>0.36</td>
<td>2.86%</td>
</tr>
</tbody>
</table>

5.4 Air Fare Test

A 50% increase in air fare is likely to suppress long-distance tours by 4%, mostly leisure tours, followed by visiting friends and relatives and employer’s business tours (Figure 29). This scenario indicates a modal shift primarily from air to auto (1.6%, see Table 24).

Figure 30: Number of Tours by Purpose (scenario case: air fare test)

Table 24: Change in Mode Share (scenario case: air fare test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>87.88%</td>
<td>89.48%</td>
<td>1.60%</td>
<td>-0.04</td>
</tr>
<tr>
<td>Bus</td>
<td>1.80%</td>
<td>1.82%</td>
<td>0.02%</td>
<td>-0.05</td>
</tr>
<tr>
<td>Rail</td>
<td>2.66%</td>
<td>2.75%</td>
<td>0.09%</td>
<td>-0.01</td>
</tr>
<tr>
<td>Air</td>
<td>7.66%</td>
<td>5.95%</td>
<td>-1.72%</td>
<td>-0.51</td>
</tr>
</tbody>
</table>

As a result, total distance traveled by air is likely to drop by almost 30%, though expected reduction in average person-miles traveled by air is more modest, approximately 1.9% (Table 25). In line with total travel distance, total travel time by air is also likely to decrease significantly (Table 26). In addition, the results indicate that, far from being proportionate, a 10%
increase in air fare is going to increase air expenditure by only 1.5% (elasticity of air travel cost with respect to air fare is .15, Table 27). This finding, together with other summary tables for this scenario, points to changes in long-distance travel patterns that are a combination of tour suppression, modal shift, and changes in destination choice.

Table 25: Change in Distance Traveled (scenario case: air fare test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Total Travel Distance (In Million Miles)</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>% Difference</th>
<th>Elasticity</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>896,814</td>
<td>875,697</td>
<td>-2.35%</td>
<td>-0.05</td>
<td>365</td>
<td>367</td>
<td>0.65%</td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>22,114</td>
<td>21,425</td>
<td>-3.12%</td>
<td>-0.06</td>
<td>487</td>
<td>493</td>
<td>1.16%</td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>15,305</td>
<td>15,161</td>
<td>-0.95%</td>
<td>-0.02</td>
<td>300</td>
<td>302</td>
<td>0.64%</td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>492,317</td>
<td>349,727</td>
<td>-28.96%</td>
<td>-0.58</td>
<td>2,642</td>
<td>2,591</td>
<td>-1.92%</td>
<td></td>
</tr>
</tbody>
</table>

Table 26: Change in Total Travel Time (scenario case: air fare test)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>% Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>15,485</td>
<td>15,116</td>
<td>-2.38%</td>
<td>-0.05</td>
</tr>
<tr>
<td>Bus</td>
<td>546</td>
<td>529</td>
<td>-3.08%</td>
<td>-0.06</td>
</tr>
<tr>
<td>Rail</td>
<td>324</td>
<td>321</td>
<td>-0.88%</td>
<td>-0.02</td>
</tr>
<tr>
<td>Air</td>
<td>1,266</td>
<td>898</td>
<td>-29.07%</td>
<td>-0.58</td>
</tr>
</tbody>
</table>

Table 27: Change in Travel Cost (scenario case: air fare test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Total Travel Cost (In Thousand $)</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>% Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>98,408,206</td>
<td>96,545,001</td>
<td>-1.89%</td>
<td>-0.04</td>
<td>0.11</td>
</tr>
<tr>
<td>Bus</td>
<td>3,226,345</td>
<td>3,114,353</td>
<td>-3.47%</td>
<td>-0.07</td>
<td>0.15</td>
</tr>
<tr>
<td>Rail</td>
<td>4,696,937</td>
<td>4,649,209</td>
<td>-1.02%</td>
<td>-0.02</td>
<td>0.31</td>
</tr>
<tr>
<td>Air</td>
<td>174,259,351</td>
<td>187,384,824</td>
<td>7.53%</td>
<td>0.15</td>
<td>0.35</td>
</tr>
</tbody>
</table>

5.5 Rail Time Test

The rail time test scenario measures the effect of a 50% reduction in rail travel time on long-distance travel. The results indicated that this scenario is likely to generate approximately 2.5 million more tours, mostly visiting friends and relatives, leisure, and employer’s business tours (Figure 30). The results also indicate that a 50% faster rail system is likely to have no to a negligible effect on long-distance travel mode share (Table 30).
Figure 31: Number of Tours by Purpose (scenario case: rail time test)

![Graph showing number of tours by purpose (personal business, visiting friends and relatives, leisure, commute, employer's business) for both base case and scenario case.]

Table 28: Change in Mode Share (scenario case: rail time test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>87.88%</td>
<td>87.70%</td>
<td>-0.18%</td>
<td>0.00</td>
</tr>
<tr>
<td>Bus</td>
<td>1.80%</td>
<td>1.79%</td>
<td>-0.01%</td>
<td>0.01</td>
</tr>
<tr>
<td>Rail</td>
<td>2.66%</td>
<td>2.88%</td>
<td>0.22%</td>
<td>-0.17</td>
</tr>
<tr>
<td>Air</td>
<td>7.66%</td>
<td>7.64%</td>
<td>-0.03%</td>
<td>0.00</td>
</tr>
</tbody>
</table>

This scenario is likely to encourage individuals to travel farther by rail, however. Table 29 shows that total distance traveled by rail is highly sensitive to rail travel time (elasticity -1.04). As a result, average person-miles traveled by rail can be expected to increase by almost 40%. Because of this significant increase in total travel distance, total travel time can be expected to result in a over 16% decrease (Table 30). Longer rail tours are also likely to contribute to higher travel costs (Table 31).

Table 29: Change in Distance Traveled (scenario case: rail time test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Total Travel Distance (In Million Miles)</th>
<th>Average Person-Miles Traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Case</td>
<td>Scenario Case</td>
</tr>
<tr>
<td>Auto</td>
<td>896,814</td>
<td>896,730</td>
</tr>
<tr>
<td>Bus</td>
<td>22,114</td>
<td>21,979</td>
</tr>
<tr>
<td>Rail</td>
<td>15,305</td>
<td>23,297</td>
</tr>
<tr>
<td>Air</td>
<td>492,317</td>
<td>491,230</td>
</tr>
</tbody>
</table>
Table 30: Change in Total Travel Time (scenario case: rail time test)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Base Case</th>
<th>Scenario Case</th>
<th>% Difference</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>15,485</td>
<td>15,484</td>
<td>-0.01%</td>
<td>0.00</td>
</tr>
<tr>
<td>Bus</td>
<td>546</td>
<td>543</td>
<td>-0.60%</td>
<td>0.01</td>
</tr>
<tr>
<td>Rail</td>
<td>324</td>
<td>271</td>
<td>-16.35%</td>
<td>0.33</td>
</tr>
<tr>
<td>Air</td>
<td>1,266</td>
<td>1,263</td>
<td>-0.21%</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 31: Change in Travel Cost (scenario case: rail time test)

<table>
<thead>
<tr>
<th>Tour Mode</th>
<th>Total Travel Cost (In Thousand $)</th>
<th>Average Travel Cost Per Mile (In $/Mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Case</td>
<td>Scenario Case</td>
</tr>
<tr>
<td>Auto</td>
<td>98,408,206</td>
<td>98,351,951</td>
</tr>
<tr>
<td>Bus</td>
<td>3,226,345</td>
<td>3,208,206</td>
</tr>
<tr>
<td>Rail</td>
<td>4,696,937</td>
<td>6,059,240</td>
</tr>
<tr>
<td>Air</td>
<td>174,259,351</td>
<td>173,982,734</td>
</tr>
</tbody>
</table>

5.6 Summary

A summary of the sensitivity test results is provided in Table 32. The test results indicate that:

- Higher incomes generate more tours, with some shift to longer distances and more expensive modes, mainly air;
- For auto, sensitivity to time changes is higher than sensitivity to cost changes—this may be due to the fact that current auto costs are low;
- For auto trips, changing destinations is much more likely than changing mode or changing number of tours—this is because, for shorter distances, there is often no reasonable alternative to auto;
- The air fare elasticity is higher than car cost elasticity, with the largest mode shift effect; and
- The rail time elasticity is higher than the car time elasticity, with substantial shifts in both mode and destination.
Table 32: Sensitivity Test Results Summary

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Income</th>
<th>Car Time</th>
<th>Rail Time</th>
<th>Car Cost</th>
<th>Air Fare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Up 10%</td>
<td>Up 25%</td>
<td>Down 50%</td>
<td>Up 50%</td>
<td>Up 50%</td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modes Included In Numbers Below</td>
<td>All</td>
<td>Car</td>
<td>Rail</td>
<td>Car</td>
<td>Air</td>
</tr>
<tr>
<td>Change in Total Tours Made</td>
<td>3.2%</td>
<td>-3.2%</td>
<td>0.2%</td>
<td>-1.8%</td>
<td>-4.0%</td>
</tr>
<tr>
<td>Change in Mode Share as a Percentage of Base Case Mode Share</td>
<td>n/a</td>
<td>-0.7%</td>
<td>8.2%</td>
<td>-0.3%</td>
<td>-22.4%</td>
</tr>
<tr>
<td>Change in Average Travel Distance per Tour</td>
<td>1.3%</td>
<td>-7.6%</td>
<td>40.4%</td>
<td>-3.2%</td>
<td>-4.7%</td>
</tr>
<tr>
<td>Change in Total Travel Distance in Mode(s)</td>
<td>4.5%</td>
<td>-11.2%</td>
<td>52.2%</td>
<td>-5.2%</td>
<td>-29.0%</td>
</tr>
<tr>
<td>Change in Average Travel Time per Tour</td>
<td>-0.2%</td>
<td>15.9%</td>
<td>-22.8%</td>
<td>-3.0%</td>
<td>-4.8%</td>
</tr>
<tr>
<td>Change in Total Travel Time in Mode(s)</td>
<td>3.0%</td>
<td>11.4%</td>
<td>-16.3%</td>
<td>-5.0%</td>
<td>-29.1%</td>
</tr>
<tr>
<td>Change in Average Travel Cost per Tour</td>
<td>3.2%</td>
<td>-5.8%</td>
<td>19.0%</td>
<td>45.9%</td>
<td>44.3%</td>
</tr>
<tr>
<td>Change in Total Travel Cost in Mode(s)</td>
<td>6.5%</td>
<td>-9.5%</td>
<td>29.0%</td>
<td>42.8%</td>
<td>7.5%</td>
</tr>
<tr>
<td>Elasticity of Travel Distance in Mode(s)</td>
<td>0.45</td>
<td>-0.45</td>
<td>-1.04</td>
<td>-0.10</td>
<td>-0.58</td>
</tr>
<tr>
<td>Elasticity of Travel Time Expenditure in Mode(s)</td>
<td>0.30</td>
<td>0.46</td>
<td>0.32</td>
<td>-0.10</td>
<td>-0.58</td>
</tr>
<tr>
<td>Elasticity of Travel Cost Expenditure in Mode(s)</td>
<td>0.65</td>
<td>-0.38</td>
<td>-0.58</td>
<td>0.86</td>
<td>0.15</td>
</tr>
<tr>
<td>Elasticity of travel distance by purpose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal business</td>
<td>0.23</td>
<td>-0.25</td>
<td>-1.11</td>
<td>-0.06</td>
<td>-0.53</td>
</tr>
<tr>
<td>Visit friends or relatives</td>
<td>0.31</td>
<td>-0.49</td>
<td>-1.72</td>
<td>-0.13</td>
<td>-0.66</td>
</tr>
<tr>
<td>Leisure / vacation</td>
<td>0.54</td>
<td>-0.58</td>
<td>-1.15</td>
<td>-0.13</td>
<td>-0.75</td>
</tr>
<tr>
<td>Commuting</td>
<td>0.13</td>
<td>-0.13</td>
<td>-0.21</td>
<td>-0.05</td>
<td>-0.43</td>
</tr>
<tr>
<td>Employer's business</td>
<td>0.75</td>
<td>-0.31</td>
<td>-1.06</td>
<td>-0.03</td>
<td>-0.26</td>
</tr>
</tbody>
</table>
CHAPTER 6. APPLICATION SOFTWARE

6.1 Model Structure and Code

Model Structure

The structure of the long-distance tour-based microsimulation model system used for the initial application is depicted in Figure 31. The main inputs are the following:

- Synthesized population representing every household in the United States and all members of those households.
- Land-use file containing estimates of population, employment, and other key variables at the zone (NUMA) level.
- Zone-to-zone matrices containing travel times, costs, and other key O-D variables for auto, bus, rail and air.
- Files with estimated/calibrated coefficients for each choice model.

These input files are documented in Section 6.3.

The choice models include models of auto ownership, long-distance tour generation, tour duration of stay, tour party size, tour destination choice, and tour mode choice. The estimated models are documented in Section 6.4. Output records are written at both the household level and the tour level. Trip matrices can also be output, based on either mode/destination probabilities or stochastically simulated tours. The output file contents and formats are documented in Section 6.4.

A key aspect of the model structure is that the mode and destination probabilities and logsums are precalculated for all relevant combinations of income, auto availability, tour purpose, tour duration of stay, and tour party size. The probabilities are stored in memory and used to predict the outcome for each simulated tour, which eliminates the need to apply the mode and destination-choice models separately for each tour. This structure reduces the model run time by at least an order of magnitude, and makes it practical to predict long-distance travel over the period of one year for the entire US population.

The model is currently coded in Delphi (Pascal), which was selected for its fast run times. The Delphi language is similar to C++. The program code is fairly compact, with only 1,750 lines of Delphi code.
Hardware Requirements

The program can run on a machine running any recent version of Windows with at least 4 GB of RAM and 10 GB of free disk space. The program runs on a single processor, so there is no need for multiple cores. The major requirement is free disk space for the output file generated, particularly if the user wishes to output individual tour records for several different scenarios.

Code Procedures

Below are listed the main procedures (classes) in the code, and their order of execution and iteration:

- **GetConfigurationSettings**: Reads in the user configuration file.
- **InitializeSummaryOutput**: Empties all counters for summary output tables.
- **LoadZoneLandUseData**: Loads data from the zonal land-use file into memory.
• **LoadRoadLOSMatrices**: Loads data from the auto and bus level-of-service file into memory.

• **LoadRailLOSMatrices**: Loads data from the rail level-of-service file into memory.

• **LoadAirLOSMatrices**: Loads data from the auto and bus level-of-service file into memory.

• **OpenHouseholdInputFile**: Opens the synthetic population file for sequential input.

• **OpenHouseholdOutputFile**: If specified by user, opens a new household-level file for output.

• **OpenTourOutputFile**: If specified by user, opens a new tour-level file for output.

• **OpenTripMatrixOutputFile**: If specified by user, opens a new trip matrix file output.

• **Loop on households in synthetic population**:
  
  o **LoadNextHouseholdRecord**: Reads the next household record into memory.

  o **Check if current household is from a new residence zone, if so**...

    ▪ **CalculateModeDestinationProbabilities**: Applies the tour mode and destination-choice models to calculate all probabilities and logsums from (and back to) the new residence zone.

  o **Check if current household is to be simulated, according to user settings. If so**...

    ▪ **ApplyAutoOwnershipModel**: Applies the auto ownership model and simulates a single choice.

    ▪ **ApplyTourGenerationModel**: Applies the tour generation models and simulates how many tours are made for each tour purpose on each simulated month and day.

    ▪ **For each generated tour (if any)**...

      • **SimulateNewTour**: Sets some variables and runs tour-level models.

      • **ApplyTourNightsAwayModel**: Applies the tour duration model and simulates a single choice.

      • **ApplyTourPartySizeModel**: Applies the tour party size model and simulates a single choice.

      • **ApplyTourModeDestinationModel**: Uses the mode/destination-choice probabilities for the relevant income, car ownership, purpose, duration, and party size segments to simulate a single mode and destination and/or add the probabilities to the predicted trip matrices, depending on user settings.

      • **WriteTourRecord**: If specified by user, writes a new tour record to output file.
- **WriteHouseholdRecord**: If specified by user, writes a new household record to output file.

- **End of loop on households**
- **CloseHouseholdInputFile**
- **CloseHouseholdOutputFile**
- **CloseTourOutputFile**
- **WriteTripMatrixOutputFile**: if specified by user, write the output trip matrix file
- **WriteSummaryOutput**: Writes summary prediction tables to the log print file

### 6.2 Running the Model

The software is a simple console application that can be run by double-clicking on the `rJourney_1_1.EXE` file in Windows Explorer. Windows will then open a console command window and ask the user to input the name of the relevant user configuration file. The user can also set up a batch file giving the name of the configuration file as a command argument and double-click on that. For example, the batch file `rJourney.BAT` could be created with the single line:

```
rJourney_1.1.exe inputs\scenario5_1_config.txt
```

Double-clicking on that batch file would run the program and use the specified configuration file as input.

### Configuration File Options

Table 33 is a list of all of the user configuration options currently recognized by the software. Each option is specified by a specific text label that is given in the first column of the table. (The labels are not case-sensitive—any upper- and lower-case combination can be used.) If the user provides a configuration label that does not match one of these valid options in the table, the invalid input line is flagged for the user on the screen and also written to the log print file. Each configuration variable also has a default value that is used if the specific configuration label is not found in the configuration file (meaning that it is not necessary to include a line for a specific option if one wishes to use the default value).

A sample configuration text file containing all the possible labels with the default values is provided along with the software, and the user can edit this file to create new configurations.
Table 33: Configuration File Options

<table>
<thead>
<tr>
<th>Configuration File Label</th>
<th>Default Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RunTitle</td>
<td>National_Long_Distance_Model</td>
<td>A text label identifying the run in the log print file - contains no spaces</td>
</tr>
<tr>
<td>RoadLOSFileName</td>
<td>inputs\zoneRoadLOS.dat</td>
<td>The path and filename of the input zonal auto and bus level-of-service data</td>
</tr>
<tr>
<td>RailLOSFileName</td>
<td>inputs\zoneRailLOS.dat</td>
<td>The path and filename of the input zonal rail level-of-service data</td>
</tr>
<tr>
<td>AirLOSFileName</td>
<td>inputs\zoneAirLOS.dat</td>
<td>The path and filename of the input zonal air level-of-service data</td>
</tr>
<tr>
<td>ZoneLandUseFileName</td>
<td>inputs\numa_2010_landuse.dat</td>
<td>The path and filename of the input zonal land-use data</td>
</tr>
<tr>
<td>HouseholdFileName</td>
<td>inputs\us_synpop_hh3_sorted.dat</td>
<td>The path and filename of the input synthetic population household file</td>
</tr>
<tr>
<td>DestChoiceCoefficientFile_1</td>
<td>inputs\pbusdest6_bxc.F12</td>
<td>The path and filename of the pers. business tour destination-choice coefficients</td>
</tr>
<tr>
<td>DestChoiceCoefficientFile_2</td>
<td>inputs\vfardest6_bxc.F12</td>
<td>The path and filename of the visit f &amp; r tour destination-choice coefficients</td>
</tr>
<tr>
<td>DestChoiceCoefficientFile_3</td>
<td>inputs\leisdest6_bxc.F12</td>
<td>The path and filename of the leisure tour destination-choice coefficients</td>
</tr>
<tr>
<td>DestChoiceCoefficientFile_4</td>
<td>inputs\commdest6_bxc.F12</td>
<td>The path and filename of the commute tour destination-choice coefficients</td>
</tr>
<tr>
<td>DestChoiceCoefficientFile_5</td>
<td>inputs\ebusdest6_bxc.F12</td>
<td>The path and filename of the empl.business tour destination-choice coefficients</td>
</tr>
<tr>
<td>ModeChoiceCoefficientFile_1</td>
<td>inputs\pbusmode13_est.F12</td>
<td>The path and filename of the pers. business tour mode choice coefficients</td>
</tr>
<tr>
<td>ModeChoiceCoefficientFile_2</td>
<td>inputs\vfarmode13_est.F12</td>
<td>The path and filename of the visit f &amp; r tour mode choice coefficients</td>
</tr>
<tr>
<td>Configuration File Label</td>
<td>Default Value</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------</td>
<td>-------------</td>
</tr>
<tr>
<td>ModeChoiceCoefficientFile_3</td>
<td>inputs\leismode13_est.F12</td>
<td>The path and filename of the leisure tour mode choice coefficients</td>
</tr>
<tr>
<td>ModeChoiceCoefficientFile_4</td>
<td>inputs\commmode13_est.F12</td>
<td>The path and filename of the commute tour mode choice coefficients</td>
</tr>
<tr>
<td>ModeChoiceCoefficientFile_5</td>
<td>inputs\ebusmode13_est.F12</td>
<td>The path and filename of the empl.business tour mode choice coefficients</td>
</tr>
<tr>
<td>PartySizeCoefficientFile_1</td>
<td>inputs\pbus_psize3.F12</td>
<td>The path and filename of the pers. business tour party size choice coefficients</td>
</tr>
<tr>
<td>PartySizeCoefficientFile_2</td>
<td>inputs\vfar_psize3.F12</td>
<td>The path and filename of the visit f &amp; r tour party size choice coefficients</td>
</tr>
<tr>
<td>PartySizeCoefficientFile_3</td>
<td>inputs\leis_psize3.F12</td>
<td>The path and filename of the leisure tour party size choice coefficients</td>
</tr>
<tr>
<td>PartySizeCoefficientFile_4</td>
<td>inputs\comm_psize3.F12</td>
<td>The path and filename of the commute tour party size choice coefficients</td>
</tr>
<tr>
<td>PartySizeCoefficientFile_5</td>
<td>inputs\ebus_psize3.F12</td>
<td>The path and filename of the empl.business tour party size choice coefficients</td>
</tr>
<tr>
<td>NightsAwayCoefficientFile_1</td>
<td>inputs\pbus_dur3.F12</td>
<td>The path and filename of the pers. business tour duration of stay choice coefficients</td>
</tr>
<tr>
<td>NightsAwayCoefficientFile_2</td>
<td>inputs\vfar_dur3.F12</td>
<td>The path and filename of the visit f &amp; r tour duration of stay choice coefficients</td>
</tr>
<tr>
<td>NightsAwayCoefficientFile_3</td>
<td>inputs\leis_dur3.F12</td>
<td>The path and filename of the leisure tour duration of stay choice coefficients</td>
</tr>
<tr>
<td>NightsAwayCoefficientFile_4</td>
<td>inputs\comm_dur3.F12</td>
<td>The path and filename of the commute tour duration of stay choice coefficients</td>
</tr>
<tr>
<td>NightsAwayCoefficientFile_5</td>
<td>inputs\ebus_dur3.F12</td>
<td>The path and filename of the empl.business tour duration of stay choice coefficients</td>
</tr>
<tr>
<td>TourFreqCoefficientsFile_1</td>
<td>inputs\freqest3b.f12</td>
<td>The path and filename of the primary tour generation coefficients</td>
</tr>
<tr>
<td>Configuration File Label</td>
<td>Default Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>TourFreqCoefficientsFile_2</td>
<td>inputs\fsecest3b.f12</td>
<td>The path and filename of the secondary tour generation coefficients</td>
</tr>
<tr>
<td>AutoOwnCoefficientsFile</td>
<td>inputs\carown3.f12</td>
<td>The path and filename of the household car ownership coefficients</td>
</tr>
<tr>
<td>HouseholdOutputFileName</td>
<td>outputs\household_out_1.dat</td>
<td>The path and filename of the output household records</td>
</tr>
<tr>
<td>TourOutputFileName</td>
<td>outputs\tour_out_1.dat</td>
<td>The path and filename of the output tour records</td>
</tr>
<tr>
<td>TripMatrixOutputFileName</td>
<td>outputs\trip_out_1.dat</td>
<td>The path and filename of the output trip matrix records</td>
</tr>
<tr>
<td>OutputFileDelimeter</td>
<td>32</td>
<td>The delimiter character used in the output files (32=space, 9=tab, 44=comma)</td>
</tr>
<tr>
<td>MonthOfYear</td>
<td>0</td>
<td>The month of the year to simulate (0=all months, 1=Jan, 2=Feb, …, 12=Dec)</td>
</tr>
<tr>
<td>EachDayOfTheMonth</td>
<td>FALSE</td>
<td>True/False switch to simulate each day of each month separately</td>
</tr>
<tr>
<td>RandomSeed</td>
<td>12345</td>
<td>Initial seed value to use for random number generator</td>
</tr>
<tr>
<td>Sample1inX</td>
<td>1</td>
<td>Subsampling factor (e.g. 100 selects every 100th household for simulation)</td>
</tr>
<tr>
<td>SampleOffset</td>
<td>0</td>
<td>Subsampling offset (e.g. in above example, 3 selects the 3rd out of every 100 HH)</td>
</tr>
<tr>
<td>WriteHouseholdRecords</td>
<td>TRUE</td>
<td>Whether or not to write out household-level records</td>
</tr>
<tr>
<td>WriteTourRecords</td>
<td>TRUE</td>
<td>Whether or not to write out tour-level records</td>
</tr>
<tr>
<td>WriteCarTripMatrix</td>
<td>TRUE</td>
<td>Whether or not to write out zone-to-zone trip matrix for car trips</td>
</tr>
<tr>
<td>WriteBusTripMatrix</td>
<td>FALSE</td>
<td>Whether or not to write out zone-to-zone trip matrix for bus trips</td>
</tr>
<tr>
<td>WriteRailTripMatrix</td>
<td>FALSE</td>
<td>Whether or not to write out zone-to-zone trip matrix for rail trips</td>
</tr>
<tr>
<td>Configuration File Label</td>
<td>Default Value</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>---------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>WriteAirTripMatrix</td>
<td>FALSE</td>
<td>Whether or not to write out zone-to-zone trip matrix for air trips</td>
</tr>
<tr>
<td>UseProbabilitiesInMatrices</td>
<td>FALSE</td>
<td>If true, uses mode/destination probabilities rather than single choices for matrices</td>
</tr>
<tr>
<td>UseADTUnitsInMatrices</td>
<td>FALSE</td>
<td>If true, writes out trip matrices as daily trips rather than total trips</td>
</tr>
<tr>
<td>PersonTripsInMatrices</td>
<td>FALSE</td>
<td>If true, writes out person-trips in matrices rather than party/vehicle-trips</td>
</tr>
<tr>
<td>TripMatrixMinimumDistance</td>
<td>50</td>
<td>The minimum one-way trip distance to include in the trip matrices</td>
</tr>
<tr>
<td>ScenarioPercentIncomeChange</td>
<td>0</td>
<td>For scenario tests - changes all household incomes by specified percentage</td>
</tr>
<tr>
<td>ScenarioPercentAutoCostChange</td>
<td>0</td>
<td>For scenario tests - changes auto toll and operating costs by specified percentage</td>
</tr>
<tr>
<td>ScenarioPercentAutoTimeChange</td>
<td>0</td>
<td>For scenario tests - changes all auto travel times by specified percentage</td>
</tr>
<tr>
<td>ScenarioPercentAirFareChange</td>
<td>0</td>
<td>For scenario tests - changes all air fares by specified percentage</td>
</tr>
<tr>
<td>ScenarioPercentRailTimeChange</td>
<td>0</td>
<td>For scenario tests - changes all rail travel times by specified percentage</td>
</tr>
</tbody>
</table>
The configuration options permit several methods for running the simulation, with some of the main options described below.

**Subsampling on Households**

One way to limit run time in the simulation is to not simulate travel for every household in the synthetic population, but only for a random subsample. The configuration settings `Sample1inX` and `SampleOffSet` facilitate subsampling. For example, if the values 20 and 7 are used, respectively, it would simulate only the seventh household out of every 20 households in the synthetic population file. The fraction sampled would then be equal to $\frac{1}{Sample1inX}$, (a 5% sample in the example above). The household expansion factor for output is set equal to `Sample1inX`.

**Subsampling on Months and/or Days**

Another way to influence run time and target the forecast to a particular month or season is to use `MonthOfYear` and `EachDayOfTheMonth`. By default, an entire year of travel is simulated by setting `MonthOfYear` to 0 to simulate all 12 months for each household. By default, only one representative travel day is simulated for each month by setting `EachDayOfTheMonth` to False. This means that the tour generation and subsequent models are only applied once for the month, and the expansion factor for each generated tour in the month is multiplied by the number of days in the month (31 for January, 28 for February, etc.). If `EachDayOfTheMonth` is set to true, every day of the month will be simulated separately, which will increase the number of tours simulated and tour records written by a factor of 30 or so, but this will not increase the expanded number of tours. The reason to simulate each day separately may be to add more variability (and thus less random simulation error) in the output. However, since each day of the month is simulated using identical probabilities (there is no conditionality from one day of the month to the next, so no intrahousehold-level consistency of travel scheduling), this does not add any true behavioral variability. In general, it is advisable to save run time by setting `EachDayOfTheMonth` to False rather than by subsampling households, since each household record is different. As a result, using more households in the simulation does add some true behavioral variability.

**Options for Generating Trip Matrices**

The models, being a simplification of reality based on the limited data available, assume that all long-distance tours consist of exactly two trips: one trip from the residence zone to the destination zone and a second trip back to the residence zone. (In reality, a small percentage of long-distance tours contain three or more long-distance trips connecting multiple destinations, other than simply stopping for gas or a meal. But simulating such complex tours would not be possible with this model structure, and would require a structure taking many times longer to run.)

In principle, one could simply post-process the tour file to generate trip matrices, accumulating one O-D and one D-O trip for each tour. To avoid the need for such post-processing, the software will accumulate and write out trip matrices for any specified modes. There are also a number user options provided for accumulating the trip matrices:
• **UseProbabilitiesinMatrices**: This is the most important option because it changes the ways that the mode/destination probabilities are used for the trip matrices. Instead of stochastically choosing a single mode and a single destination for each tour—which is done for the output tour records—this option adds the probability (times the expansion factor) to the matrix for every possible mode/destination alternative (four modes times approximately 4,500 zones, or 18,000 alternatives). This is analogous to the way that 4-step models work. Rather than resulting in integer numbers of trips in each cell of the matrix, there are fractions of trips—often tiny fractions. The advantage of this approach to generating matrices is that it adds variability—particularly spatial variability—and reduces random stochastic simulation error. The tradeoff is that it increases run times somewhat, and the trip outputs will not exactly match the tour outputs in terms of mode and spatial distribution.

• **PersonTripsInMatrices**: In most cases, it makes sense to set this to true, since passenger counts for air rail and bus are in units of person-trips. The exception is when one wishes to generate vehicle-trip matrices for the auto mode, in which case this can be left as False (and in which case it makes sense to write out trip matrices only for the auto mode, which is the default setting.)

• **UseADTUnitsInMatrices**: If this is true, the matrices are simply scaled to units of average daily trips instead of annual or monthly trips.

• **TripMatrixMinimumDistance**: Although the models use a (somewhat arbitrary) threshold of 50 miles one way to define a long-distance trip, it may be desirable to generate outputs that are comparable to other data sources that use a different threshold. For example, by setting this to 100, only trips between zones that are 100 or more miles apart (based on network auto distance) are counted in the matrices.

**The Log Print File**

Each time the software runs, it generates a log print file that is named automatically so as not to overwrite previous log files. For example, if `inputs\test1_config.txt` is the name of the configuration settings file, then the print file the first time it is run will be named `inputs\test1_config_01.log`. If the same configuration file is used again, the print file will automatically be named `inputs\test1_config_02.log`, and so on.

The contents of the log file are the same as what appears on the screen during the run. The date and time the run starts and finishes are shown, along with an echo of all the configuration settings used for the run. In addition, a series of summary output tables are provided as a quick check on the results. An example of a log print file is provided in Section 0.

**Comparison of Run Times and Output Characteristics**

Table 34 provides an idea of the model run times and file sizes using different combinations of configuration settings. The runs were done on an HP workstation with 16 GB of RAM and four processors. (The software itself uses only 2 GB of RAM and a single processor, since it is not yet written to use multithreading on multiple processors.)
Run 1 uses $Sample1inX = 100$ to run only a 1% sample of households, so the expansion factors are 100. It simulates every month of the year and each day of the month separately and uses stochastic choices rather than mode/destination probabilities for the trip matrices. The run time is approximately 55 minutes. Out of a possible 20 million or so O-D pairs in the trip matrices, there is a positive number of auto trips for 3.64 million, or 18% of possible O-D pairs. There are 1.1 million household records in the output HH file, which is a size of 60 MB, and 17.5 million tour records, for a file size of just under 1 GB.

Run 2 uses $Sample1inX = 1$ to simulate every household, but uses $EachDayOfTheMonth = False$ to simulate only a single representative day per month. In this case, the expansion factors range from 28 to 31 depending on the month. Compared to Run 1, the run time increases slightly to 65 minutes, but the spatial coverage in the auto trip matrix increases by a factor of nearly two, with positive trips for 31% of possible OD zone pairs. Of course, the size of the output household file increases by a factor of 100 to 114.6 million records and almost 6 GB, while the size of the tour file increases by a factor of three or so., to 55.1 million tour records and a 3.1 GB. (After expansion, the total numbers of households, tours, and trips are virtually identical in all runs. These are just different ways of generating them.)

*The settings for Run 2 are recommended for users who mainly want to analyze the output at the level of individual tour records, rather than using the trip matrix file generated by the software.*

**Table 34: Comparison of Run Times and Output Characteristics under Different Settings**

<table>
<thead>
<tr>
<th>Run</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH Sampling Rate</td>
<td>1%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Months Simulated</td>
<td>All</td>
<td>All</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td>Each Day of Month Separately?</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Use Probabilities in Trip Matrix?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Expansion Factors</td>
<td>100</td>
<td>28-31*</td>
<td>28-31*</td>
<td>1</td>
</tr>
<tr>
<td>Run Time</td>
<td>55 min</td>
<td>65 min</td>
<td>240 min</td>
<td>105 min</td>
</tr>
<tr>
<td>O-Ds In Car Trip Matrix (Million)</td>
<td>3.64</td>
<td>6.31</td>
<td>19.65</td>
<td>16.27</td>
</tr>
<tr>
<td>% Of Possible ODs In Matrix</td>
<td>18%</td>
<td>31%</td>
<td>98%</td>
<td>81%</td>
</tr>
<tr>
<td>HH Records (Million)</td>
<td>1.1</td>
<td>114.6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>HH File Size (MB)</td>
<td>60</td>
<td>5,780</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Tour Records (Million)</td>
<td>17.5</td>
<td>55.1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Tour File Size (MB)</td>
<td>992</td>
<td>3,128</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

* Days In The Month
Run 3 is identical to Run 2, but the trip matrices use the mode/destination probabilities rather than stochastic trips. This extra computation of the matrices does increase run time by a factor of nearly four—to 240 minutes—but the spatial coverage of the car trip matrices has also increased by a factor of more than three, up to 98% of all O-D pairs. (The only zone pairs without car trips in this case are intrazonals and trips to or from Hawaii and Alaska, which are not connected by car to the other 48 states in the networks). If household and/or tour files were written in this run, they would be identical to Run 2, since only the method of calculating trips matrices was changed.

Finally, Run 4 shows an alternative way of increasing spatial coverage of the trip matrices while reducing run time. Unlike Run 3, this method uses simulated integer trips instead of mode/destination probabilities to accumulate the trip matrices, but it also simulates each day of each month separately. This run is effectively the same as Run 1, but using a 100% household sample instead of a 1% sample. The resulting run time is about twice as long as Run 1, but less than half as long as Run 3. The car matrix O-D coverage is 81%, which is nearly as high as Run 3, and may be just as useful for assignment, considering the matrices for Run 4 have at least one trip in each cell (all integer numbers), while the matrices from Run 3 have many cells with small fractions of trips. If a tour file had been generated from Run 4, it would be 100 times the size of the tour file from Run 1, with roughly 1.75 billion tour records and a file size of nearly 100 GB. Thus, the settings for Run 4 are good for generating trip matrices, but not practical for generating and analyzing detailed tour records.

The settings for Run 4 are recommended for users who mainly want to use the trip matrix file generated by the software (e.g., for highway assignment), but do not wish to write out or analyze individual tour records.

Adapting the Software for Different Zone Systems and/or Networks

The software could be used to run on data for other synthetic populations, networks, and/or zone systems, provided that all data input files keep the same formats and variable order as the current input files. In practice, this would mean generating new land-use and network skim files matching the new zone system. If the zone system is an aggregation of Census tracts, then data preparation could be made easier in two ways:

1. Provided with the software is a land-use file at the Census tract level, which could be aggregated up to a different zone system.

2. The synthetic population was controlled at the tract level, and the Census tract ID is included on each record; as a result, the zone ID field on the synthetic population records could be recoded to match a different tract-to-zone correspondence.

Note: Due to current Delphi memory limitations, the number of zones is limited to a maximum of 4,700. This is a limitation that may be improved in future versions of the code.
6.3 Input File Documentation

NUMA_2010_landuse.dat

Based on 2010 to 2012 Census tract-level population and employment data, aggregated to NUMA zones. Employment categories are mutually exclusive, broken down by NAICS code. The file is space-delimited text, with a header record:

1. ZoneID: NUMA ID
2. NTracts: The number of Census tracts in the zone
3. LandSqm: The land area in the zone (square miles)
4. NUMALat: The latitude of the NUMA centroid (degrees)
5. NUMALong: The longitude of the NUMA centroid (degrees)
6. StateFIP: The state FIPS code
7. ParkSqm: The land area in public parks (square miles)
8. TotHH: The number of households living in the zone
9. UnivEnr: The number of university students enrolled in the zone
10. TotalEmp: The total number of jobs in the zone
11. AgricEmp: The number of agricultural jobs in the zone
12. MininEmp: The number of mining jobs in the zone
13. UtiliEmp: The number of utility jobs in the zone
14. ConstEmp: The number of construction jobs in the zone
15. ManufEmp: The number of manufacturing jobs in the zone
16. WholeEmp: The number of wholesale trade jobs in the zone
17. RetailEmp: The number of retail trade jobs in the zone
18. TransEmp: The number of transportation services jobs in the zone
19. InforEmp: The number of information services jobs in the zone
20. FinanEmp: The number of financial services jobs in the zone
21. RealeEmp: The number of real estate service jobs in the zone
22. ProfeEmp: The number of professional services jobs in the zone
23. ManagEmp: The number of managerial jobs in the zone
24. AdminEmp: The number of administrative jobs in the zone
25. EducaEmp: The number of education jobs in the zone
26. MedicEmp: The number of medical jobs in the zone
27. EnterEmp: The number of entertainment jobs in the zone
28. AccomEmp: The number of accommodation jobs in the zone
29. OServEmp: The number of other service category jobs in the zone
30. PubAdEmp: The number of public administration jobs in the zone
31. StateEmp: The number of state government jobs in the zone
32. FederEmp: The number of Federal government jobs in the zone
33. BusStats: The number of bus stations within 40 miles of the zone centroid
34. RailStats: The number of rail stations within 50 miles of the zone centroid
MinStDist: Distance from the zone centroid to the nearest rail station (miles)
Airports: The number of airports within 100 miles of the zone centroid
MinAPDist: Distance from the zone centroid to the nearest airport (miles)

zoneRoadLOS.dat

Based on the NHPN, with connectors added to NUMA zones, airports, and rail stations. The file is space-delimited text, with no header record:

1. OZoneID: Origin zone (NUMA ID)
2. DZoneID: Destination zone (NUMA ID)
3. CarTime: Car time (minutes, 0 indicates no road connection)
4. CarDist: Car distance (miles)
5. CarToll: Car toll (cents)
6. BusTime: Bus time (minutes, based on factoring car time)
7. BusFare: Bus fare (dollars, from equation based on car distance)

zoneRailLOS.dat

Based on Amtrak schedules and fares, and road access network, The least-generalized-cost station-pair is used for each zone pair. The file is space-delimited text, with no header record:

1. OZoneID: Origin zone (NUMA ID)
2. DZoneID: Destination zone (NUMA ID)
3. RailTime: Rail journey time, including stops (minutes, 0 indicates no rail connection)
4. RailXfers: Rail transfers * 100
5. RailFreq: Rail frequency (departures per week)
6. RailEconFare: Rail economy fare (dollars, from equation based on distance)
7. RailBusiFare: Rail business fare (dollars, from equation based on distance)
8. RailAccDist: Rail access distance (miles from NUMA to station, maximum is 50)
9. RailEgrDist: Rail egress distance (miles from station to NUMA, maximum is 50)
10. RailOStationID: Rail origin station ID #
11. RailDStationID: Rail destination station ID #
12. RailOStationCode: Rail origin station 3-letter code
13. RailDStationCode: Rail destination station 3-letter code

zoneAirLOS.dat

Based on DB1B ticket database and on-time database, the least-generalized-cost airport pair is used for each zone pair. The file is space-delimited text, with no header record:

1. OZoneID: Origin zone (NUMA ID)
2. DZoneID: Destination zone (NUMA ID)
3. AirTime: Airport pair in-flight time (minutes, 0 indicates no air connection)
4. AXfers: Airport pair average transfers * 100
5. AirFreqDirect: Airport pair frequency of direct flights (departures per week)
6. AirFreq1Stop: Airport pair frequency of routes with one stop (departures per week)
7. AirFreq2Stop: Airport pair frequency of routes with two stops (departures per week)
8. AirPctOnTime: Airport pair percent of flights within 30 minutes of scheduled arrival time
9. AirEconFare: Airport pair average economy fare paid (dollars)
10. AirBusiFare: Airport pair average business fare paid (dollars, from equation based on distance)
11. AirAccDist: Air access distance (miles from NUMA to airport, maximum is 100)
12. AirEgrDist: Air egress distance (miles from airport to NUMA, maximum is 50)
13. AirOAirportID: Air origin airport ID #
14. AirDAirportID: Air destination airport ID #
15. AirOAirportCode: Air origin airport 3-letter code
16. AirDAirportCode: Air destination airport 3-letter code

US_SynPop_HH2_sorted.dat

The synthetic population file with roughly 115 million household records, sampled using the PopGen software with 2010 Census tract-level controls, and then sorted by residence zone ID. The file is space-delimited text, with a header record:

1. HHId: Household identification number
2. HHTract: 2010 residence Census tract FIPS code
3. HHZone: Residence zone # (NUMA ID)
4. HHSize: The number of persons in the household
5. HHWokers: The number of employed persons in the household (full or part time)
6. HHNonWkrs: The number of non-employed adults (age 18+) in the household
7. HHHasKids: Whether or not the household has kids under age 18 (1=yes, 2=no)
8. HHHeadAge: The age of the head of the household, in years
9. HHIncome: The previous year total gross income, in dollars
10. HHExpFactor: The household expansion factor (always equals one on input)

Various Model Coefficient Files

These are kept in the .F12 text file format output by the ALogit model estimation software in order to minimize editing errors. For each variable, only the coefficient numbers and values are used by model code (not the labels or standard errors).

6.4 Output File Documentation

The Household File

A record written for each simulated household, if specified by the user.
1. HHId: Household identification number
2. HHZone: Residence zone # (NUMA ID)
3. HHState: Residence state (FIP code)
4. HHSIZE: The number of persons in the household
5. HHWorkers: The number of employed persons in the household (full or part time)
6. HHNonWkrs: The number of non-employed adults (age 18+) in the household
7. HHhHasKids: Whether or not the household has kids under age 18 (1=yes, 2=no)
8. HHHeadAge: The age of the head of the household, in years
9. HHIncome: The previous year total gross income, in dollars
10. HHVehicles: The number of vehicles predicted by the auto ownership model (4 = 4 or more)
11. HHPersBusTours: The number of personal business tours simulated for the household
12. HHVisitTours: The number of visit friends/relatives tours simulated for the household
13. HHLLeisureTours: The number of leisure tours simulated for the household
14. HHCommuteTours: The number of commute tours simulated for the household
15. HHEmplBusTours: The number of employer’s business tours simulated for the household
16. hhExpOut: The household expansion factor for output (depends on subsampling)

The Tour File

A record written for each simulated household, if specified by the user.

1. HHId: Household identification number
2. trNo: The tour sequence number for the household (1,2,3, etc.)
3. trMonth: The month the tour was generated (1=Jan, …, 12=Dec)
4. trPurpose: The main tour purpose (1=Pers.Bus, 2=Visit, 3=Leisure, 4=Commute, 5=Emp.Business)
5. trPartySize: The tour travel party size (1=1, 2=2, 3=3, 4=4 or more)
6. trNightsCategory: The tour duration (1=day trip, 2=1-2 nights, 3=3-6 nights, 4=7 or more nights)
7. trMode: The main tour mode (1=Car, 2=Bus, 3=Rail, 4=Air)
8. trOSTate: The tour origin state (FIP code)
9. trDState: The tour destination state (FIP code)
10. trOZone: The tour origin zone (NUMA ID)
11. trDZone: The tour destination zone (NUMA ID)
12. trAutoDistance: The tour round-trip distance if it were made on the auto network (miles)
13. trTravelTime: The tour round-trip travel time by the chosen main mode (minutes)
14. trTravelCost: The tour round-trip travel cost by the chosen mode (dollars, per person for non-auto)
15. trExpFactor: The tour expansion factor
16. trOrigStation: The tour origin rail station or airport ID #
17. trDestStation: The tour destination rail station or airport ID #

The Trip Matrix File

A record written for each zone pair with a non-zero number of trips, if specified by the user for a given mode

1. OrigZone: The trip origin zone (NUMA ID)
2. DestZone: The trip destination zone (NUMA ID)
3. Mode: The main trip mode (1=Car, 2=Bus, 3=Rail, 4=Air)
4. Trips: The number of trips predicted for the origin/destination/mode

6.5 Estimated Model Coefficients

Estimated model coefficients are provided in Table 35 through Table 40 for auto ownership, tour generation, tour party size, duration of stay, destination choice, and mode choice, respectively. All models indicate the coefficient number (as shown in the F12 coefficient input files and used in the model code) and the alternative name, the variable description, the estimated coefficient value, and the computed t-statistic. Some variables indicated by * were used in model estimation to allow for missing data or adjust for retrospective survey bias, and are not needed for model application.
Table 35: Auto Ownership Model

<table>
<thead>
<tr>
<th>Coeff. #</th>
<th>Altern.</th>
<th>Variable</th>
<th>Coefficient</th>
<th>T-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0 cars</td>
<td>Constant</td>
<td>-2.98</td>
<td>-20.9</td>
</tr>
<tr>
<td>11</td>
<td>0 cars</td>
<td>1 adult HH</td>
<td>2.45</td>
<td>44</td>
</tr>
<tr>
<td>12</td>
<td>0 cars</td>
<td>3 adult HH</td>
<td>0.813</td>
<td>9.3</td>
</tr>
<tr>
<td>13</td>
<td>0 cars</td>
<td>4+ adult HH</td>
<td>1.14</td>
<td>8.1</td>
</tr>
<tr>
<td>14</td>
<td>0 cars</td>
<td>HH workers/adults</td>
<td>-0.442</td>
<td>-7</td>
</tr>
<tr>
<td>14</td>
<td>0 cars</td>
<td>HH has children</td>
<td>-0.877</td>
<td>-15.3</td>
</tr>
<tr>
<td>16</td>
<td>0 cars</td>
<td>Head of HH age 65+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>0 cars</td>
<td>Head of HH under 35</td>
<td>0.269</td>
<td>4.4</td>
</tr>
<tr>
<td>18</td>
<td>0 cars</td>
<td>Log of HH+job density</td>
<td>0.767</td>
<td>57.6</td>
</tr>
<tr>
<td>19</td>
<td>0 cars</td>
<td>Log of (HH income/1000)</td>
<td>-1.52</td>
<td>-50</td>
</tr>
<tr>
<td>61</td>
<td>0 cars</td>
<td>Missing HH income data*</td>
<td>-6.22</td>
<td>-41.8</td>
</tr>
<tr>
<td>20</td>
<td>1 car</td>
<td>Constant</td>
<td>0.726</td>
<td>10.9</td>
</tr>
<tr>
<td>21</td>
<td>1 car</td>
<td>1 adult HH</td>
<td>2.42</td>
<td>111.6</td>
</tr>
<tr>
<td>22</td>
<td>1 car</td>
<td>3 adult HH</td>
<td>-0.189</td>
<td>-4.5</td>
</tr>
<tr>
<td>23</td>
<td>1 car</td>
<td>4+ adult HH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1 car</td>
<td>HH workers/adults</td>
<td>-0.224</td>
<td>-7.8</td>
</tr>
<tr>
<td>25</td>
<td>1 car</td>
<td>HH has children</td>
<td>-1</td>
<td>-44</td>
</tr>
<tr>
<td>26</td>
<td>1 car</td>
<td>Head of HH age 65+</td>
<td>0.184</td>
<td>6.6</td>
</tr>
<tr>
<td>27</td>
<td>1 car</td>
<td>Head of HH under 35</td>
<td>0.112</td>
<td>4.1</td>
</tr>
<tr>
<td>28</td>
<td>1 car</td>
<td>Log of HH+job density</td>
<td>0.243</td>
<td>43.9</td>
</tr>
<tr>
<td>29</td>
<td>1 car</td>
<td>Log of (HH income/1000)</td>
<td>-0.87</td>
<td>-55.4</td>
</tr>
<tr>
<td>62</td>
<td>1 car</td>
<td>Missing HH income data*</td>
<td>-3.65</td>
<td>-50.1</td>
</tr>
<tr>
<td>30</td>
<td>2 cars</td>
<td>Constant</td>
<td>0</td>
<td>base alt.</td>
</tr>
<tr>
<td>40</td>
<td>3 cars</td>
<td>Constant</td>
<td>-1.4</td>
<td>-21.6</td>
</tr>
<tr>
<td>41</td>
<td>3 cars</td>
<td>1 adult HH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>3 cars</td>
<td>3 adult HH</td>
<td>1.61</td>
<td>77.6</td>
</tr>
<tr>
<td>43</td>
<td>3 cars</td>
<td>4+ adult HH</td>
<td>1.95</td>
<td>47.9</td>
</tr>
<tr>
<td>44</td>
<td>3 cars</td>
<td>HH workers/adults</td>
<td>0.464</td>
<td>16.9</td>
</tr>
<tr>
<td>45</td>
<td>3 cars</td>
<td>HH has children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>3 cars</td>
<td>Head of HH age 65+</td>
<td>-0.218</td>
<td>-7.6</td>
</tr>
<tr>
<td>47</td>
<td>3 cars</td>
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**Model Fit Statistics**

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Table 36: Tour-Generation Models

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**Model Fit Statistics**

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Table 37: Tour-Size-Party Models

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101       | 1 person | Constant | 0 | | 0 | | base alt | | 0 | | base alt | | 0 | | base alt | | 0 | | base alt |
<p>| 201      | 2 people | Constant | 0.355 | | 4.7 | | -0.089 | | -0.9 | | 0.81 | | 9.7 | | 0.0226 | | 0.1 | | 0.203 | | 1.4 |
| 202      | 2 people | HH workers/Adults | -0.187 | | -3.8 | | -0.266 | | -5.5 | | -0.113 | | -2.8 | | -0.501 | | -8 |
| 203      | 2 people | Log of (HH income/1000) | 0.0502 | | 2.3 | | 0.0818 | | 4.2 | | -0.424 | | -7.6 | | -0.151 | | -5 |
| 204      | 2 people | Missing HH income data* | 0.0759 | | 0.7 | | 0.386 | | 4.1 | | -1.7 | | -6.4 | | -0.739 | | -4.9 |
| 205      | 2 people | HH has 0 vehicles | -0.467 | | -3.9 | | 0.216 | | 1.8 | | -0.616 | | -2.5 | | 0.78 | | 4.6 |
| 206      | 2 people | HH has car competition | 0.428 | | 7.9 | | 0.37 | | 7.6 | | 0.29 | | 4.7 | | |
| 207      | 2 people | 0 nights away from home | 0.259 | | 4 | | 0.526 | | 10 | | | | | | | -0.419 | | -8.5 |
| 208      | 2 people | 1-2 nights away from home | 0.284 | | 3.6 | | 0.286 | | 5.5 | | 0.132 | | 4.2 | | |
| 209      | 2 people | 7+ nights away from home | 0.118 | | 2.2 | | | | | | | | | | |
| 210      | 2 people | Missing nights away data* | -0.264 | | -3.5 | | -0.24 | | -4.6 | | -0.0538 | | -1.6 | | -0.6 | | -13.4 |
| 211      | 2 people | Month is June-August | 0.118 | | 2.2 | | | | | | | | | | | |
| 212      | 2 people | Month is Jan-March | -0.122 | | -2.5 | | -0.121 | | -2.8 | | | | 0.38 | | 3.5 |
| 213      | 2 people | Month is Nov-December | 0.129 | | 2.7 | | -0.121 | | -3.2 | | | | | | | |
| 214      | 2 people | Missing month data* | -0.287 | | -4.5 | | 0.0125 | | 0.2 | | -0.136 | | -2.2 | | -0.054 | | -0.7 |</p>
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69
| Coeff. # | Altern. | Variable | Personal Business | | | | Visit F&R | | | | Leisure | | | | Commute | | | | Employer Business | | | |
| 316 | 3 people | Head of hh age 65+ | -0.193 | -2.6 | -0.109 | -1.7 | -0.232 | -4.6 | -0.987 | -2.6 |
| 401 | 4+ people | Constant | -0.0688 | -0.5 | -0.845 | -11.8 | 0.637 | 14.3 | 1.54 | 3.4 | 0.894 | 4.1 |
| 402 | 4+ people | HH workers/Adults | | | -0.261 | -4.5 | -0.179 | -3.9 | 0.898 | 3.1 | -0.315 | -2.9 |
| 403 | 4+ people | Log of (HH income/1000) | -0.0933 | -3.3 | | | -1.5 | -16.6 | -0.594 | -12.4 |
| 404 | 4+ people | Missing HH income data* | -0.623 | -4.2 | | | -6.22 | -12.8 | -3.04 | -11.7 |
| 405 | 4+ people | HH has 0 vehicles | | | | | 0.519 | 3.8 | | | 2.39 | 13 |
| 406 | 4+ people | HH has car competition | 0.254 | 4 | 0.346 | 6.4 | 0.361 | 5.7 | 1.48 | 9.5 |
| 407 | 4+ people | 0 nights away from home | | | 0.746 | 12.4 | | | | -0.716 | -8.9 |
| 408 | 4+ people | 1-2 nights away from home | 0.291 | 4.8 | 0.349 | 5.8 | | | | | |
| 409 | 4+ people | 7+ nights away from home | | | | | | | | | |
| 410 | 4+ people | Missing nights away data* | -0.776 | -11.7 | -0.292 | -4.5 | | | -0.636 | -7.3 |
| 411 | 4+ people | Month is June-August | 0.557 | 9.3 | 0.261 | 5.7 | 0.44 | 13.7 | 0.294 | 3.9 |
| 412 | 4+ people | Month is Jan-March | | | | | -0.139 | -2.6 | 0.0795 | 2.2 | -1.44 | -3.9 |
| 413 | 4+ people | Month is Nov-December | 0.113 | 1.7 | 0.545 | 9.9 | | | 0.863 | 3.2 |
| 414 | 4+ people | Missing month data* | -0.0725 | -0.9 | 0.191 | 2.6 | -0.597 | -9.6 | -0.491 | -2.7 | -0.941 | -8.3 |
| 415 | 4+ people | Head of hh under age 35 | 0.325 | 5.9 | 0.36 | 9.2 | 0.287 | 8 | 0.575 | 4.2 |
| 416 | 4+ people | Head of hh age 65+ | -0.194 | -2.7 | -0.425 | -6.2 | -0.315 | -6.8 | -0.755 | -2.1 |
### Models by Tour Purpose

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<td>-0.0592</td>
<td>-5.1</td>
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<td>22</td>
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<td>Missing HH income data*</td>
<td>0.631</td>
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<td>0.18</td>
<td>1.6</td>
<td>1.09</td>
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<tr>
<td>23</td>
<td>1-2</td>
<td>Log of (HH income/1000)</td>
<td>0.155</td>
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<td>0.0445</td>
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<td>0.275</td>
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<tr>
<td>24</td>
<td>1-2</td>
<td>Head of HH age 65+</td>
<td>-0.288</td>
<td>-4.3</td>
<td>-0.358</td>
<td>-7.7</td>
<td>-0.354</td>
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<tr>
<td>25</td>
<td>1-2</td>
<td>Head of HH under age 35</td>
<td>0.419</td>
<td>6.7</td>
<td>0.361</td>
<td>9.3</td>
<td>0.141</td>
</tr>
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<td>26</td>
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<td>Log zone HH+job density</td>
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<td>0.0873</td>
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<td>27</td>
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<td>Month is June-August</td>
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<td>28</td>
<td>1-2</td>
<td>Month is Jan-March</td>
<td>-0.348</td>
<td>-5.4</td>
<td>-0.102</td>
<td>-2.7</td>
<td>-0.105</td>
</tr>
</tbody>
</table>

#### Model Fit Statistics

- Observations: 18833, 31634, 35998, 9012, 18626
- Final log-likelihood: -22552, -33315.9, -39526.2, -5533.6, -16982.7
- Rho-squared vs. 0: 0.136, 0.24, 0.208, 0.557, 0.342
- Rho-squared vs. constants: 0.095, 0.212, 0.131, 0.084, 0.04

### Table 38: Tour Duration of Stay Models
| Coef. # | Altern. | Variable | Personal Business | | | Visit F&R | | | Leisure | | | Commute | | | Employer Business | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 1-2 nights | Month is Nov-December | -0.263 | -3.6 | | -0.224 | -5.1 | | | | | | | | |
| 30 | 3-6 nights | Constant | -3.48 | -14.7 | | -1.51 | -10.6 | | -3.93 | -27.5 | | -3.88 | -5.4 | | -3.37 | -14 |
| 31 | 3-6 nights | HH size | | | | -0.142 | -8.9 | | -0.0517 | -3.9 | | | | -0.0794 | -3.3 |
| 32 | 3-6 nights | Missing HH income data* | 0.875 | 3.5 | | 0.383 | 2.6 | | 1.88 | 12.3 | | 2.31 | 3 | | 2.2 | 8.3 |
| 33 | 3-6 nights | Log of (HH income/1000) | 0.167 | 3.2 | | 0.099 | 3.3 | | 0.433 | 13.6 | | 0.391 | 2.4 | | 0.437 | 8.2 |
| 34 | 3-6 nights | Head of HH age 65+ | 0.239 | 2.8 | | 0.141 | 2.6 | | | | | | | | |
| 35 | 3-6 nights | Head of HH under age 35 | 0.217 | 2.2 | | 0.15 | 2.8 | | | | | | | | |
| 36 | 3-6 nights | Log zone HH+job density | 0.134 | 7.2 | | 0.0678 | 6.4 | | 0.172 | 15.6 | | | | 0.058 | 3.7 |
| 37 | 3-6 nights | Month is June-August | | | | 0.273 | 5.6 | | 0.565 | 13.7 | | | | | |
| 38 | 3-6 nights | Month is Jan-March | -0.458 | -4.9 | | -0.152 | -2.7 | | -0.151 | -2.7 | | -0.4 | -2.1 | | | |
| 39 | 3-6 nights | Month is Nov-December | -0.357 | -3.3 | | 0.389 | 7.8 | | -0.178 | -2.9 | | | | | |
| 40 | 7+ nights | Constant | -4.7 | -12.7 | | -2.25 | -16.6 | | -5.13 | -25.9 | | -3.5 | -8.9 | | -4.85 | -11.4 |
| 41 | 7+ nights | HH size | | | | -0.218 | -8.5 | | | | | -0.165 | -1.4 | | | |
| 42 | 7+ nights | Missing HH income data* | 1.65 | 4 | | 2.29 | 11 | | | | | | | | 1.59 | 3.4 |
| 43 | 7+ nights | Log of (HH income/1000) | 0.361 | 4.2 | | 0.524 | 12 | | | | | | | | 0.263 | 2.7 |
| 44 | 7+ nights | Head of HH age 65+ | 0.313 | 2.4 | | 0.32 | 4.3 | | 0.334 | 5.2 | | | | | |
| 45 | 7+ nights | Head of HH under age 35 | | | | | -0.275 | -3.1 | | | | | | | | |
| 46 | 7+ nights | Log zone HH+job density | 0.111 | 6.9 | | 0.137 | 9.3 | | | | | | | | 0.125 | 4.3 |
Table 39: Destination-Choice Models

<table>
<thead>
<tr>
<th>Coeff. #</th>
<th>Altern.</th>
<th>Variable</th>
<th>Personal Business</th>
<th>Visit F&amp;R</th>
<th>Leisure</th>
<th>Commute</th>
<th>Employer Business</th>
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<tbody>
<tr>
<td>47</td>
<td>7+ nights</td>
<td>Month is June-August</td>
<td>0.173</td>
<td>0.482</td>
<td>0.629</td>
<td>1.19</td>
<td>0.504</td>
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<tr>
<td>48</td>
<td>7+ nights</td>
<td>Month is Jan-March</td>
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<td>4.2</td>
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<td>0.298</td>
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<td>49</td>
<td>7+ nights</td>
<td>Month is Nov-December</td>
<td>0.348</td>
<td>4.6</td>
<td>-0.373</td>
<td>-4</td>
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Model Fit Statistics

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<tr>
<th></th>
<th>Observations</th>
<th>Final log-likelihood</th>
<th>Rho-squared vs. 0</th>
<th>Rho-squared vs. constants</th>
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<td>11932</td>
<td>-10710.8</td>
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<td>-25730.6</td>
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<td>-30052.8</td>
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<td>1967</td>
<td>-1387.3</td>
<td>0.491</td>
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<td>9689</td>
<td>-10355</td>
<td>0.229</td>
<td>0.010</td>
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Table 39: Destination-Choice Models

<table>
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<th>Coeff. #</th>
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<th>Visit F&amp;R</th>
<th>Leisure</th>
<th>Commute</th>
<th>Employer Business</th>
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<tr>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>0.211</td>
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<tr>
<td>2</td>
<td>All</td>
<td>Log (one-way distance)</td>
<td>-1.9</td>
<td>-1.09</td>
<td>-3.13</td>
<td>-3.58</td>
<td>-46.7</td>
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<tr>
<td>3</td>
<td>All</td>
<td>One-way distance squared</td>
<td>0.006</td>
<td>0.0033</td>
<td>0.0045</td>
<td>0.0238</td>
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<td>-0.023</td>
<td>-0.0269</td>
<td>-0.0032</td>
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<td>1-2 nights*1-way dist squared</td>
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<td>-0.0104</td>
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<td>-0.0018</td>
<td>-0.0021</td>
<td>-0.0123</td>
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<td>All</td>
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<td>-0.784</td>
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<td>All</td>
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<td>One-way dist 250-500 miles</td>
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<td>Variable</td>
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<td>Visit F&amp;R</td>
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<td>Commute</td>
<td>Employer Business</td>
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<td>T-stat</td>
<td>Coefficient</td>
<td>T-stat</td>
<td>Coefficient</td>
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<td>One-way dist 500-1000 miles</td>
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<td>0.229</td>
<td>2.7</td>
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<td>All</td>
<td>One-way dist 1000-1500 miles</td>
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<td>One-way dist over 2000 miles</td>
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<td>Desti zone has rural density</td>
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<td>O and D zones have urban density</td>
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<td>66.3</td>
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<td>constr</td>
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<td>Size variable 1 (log of coef)</td>
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<td>Size variable 2 (log of coef)</td>
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<td>Size variable 3 (log of coef)</td>
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<td>Size variable 4 (log of coef)</td>
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Model Fit Statistics

<table>
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<tr>
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<th>Observations</th>
<th>Final log-likelihood</th>
<th>Rho-squared vs. 0</th>
<th>Rho-squared vs. constants</th>
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Table 40: Mode Choice Models

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<th>Variable</th>
<th>Models by Tour Purpose…</th>
<th>Personal Business</th>
<th>Visit F&amp;R</th>
<th>Leisure</th>
<th>Commute</th>
<th>Employer Business</th>
</tr>
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<td>T-stat</td>
<td>Coefficient</td>
<td>T-stat</td>
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<td>-14.7</td>
<td>-1.22</td>
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<td>Party size = 3 or more</td>
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<td>-3.06</td>
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<td>Bus</td>
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<td>Bus</td>
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<td>0.284</td>
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<td>3.6</td>
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<td>Rail</td>
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<td>Air</td>
<td>Log of (HH income/1000)</td>
<td>0.197</td>
<td>2</td>
<td>0.0917</td>
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<td>T-stat</td>
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<tr>
<td>409</td>
<td>Air</td>
<td>Log of origin zone density</td>
<td>0.153</td>
<td>4.6</td>
<td>0.151</td>
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<td>0 nights away from home</td>
<td>-2.26</td>
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<td>One-way dist 50-150 miles</td>
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<td>-7</td>
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**Model Fit Statistics**

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<th></th>
<th>Personal Business</th>
<th>Visit F&amp;R</th>
<th>Leisure</th>
<th>Commute</th>
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<td>6076</td>
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<td>-4614.8</td>
<td>-6478.3</td>
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<td>-3940.5</td>
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<td>Rho-squared vs. 0</td>
<td>0.852</td>
<td>0.863</td>
<td>0.816</td>
<td>0.783</td>
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**Generalized Cost Coefficients**

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<th>Coefficient</th>
<th>T-stat</th>
<th>Coefficient</th>
<th>T-stat</th>
<th>Coefficient</th>
<th>T-stat</th>
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<th>T-stat</th>
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<td>Rail</td>
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<tr>
<td>35</td>
<td>Rail</td>
<td>Acc+egr distance/car distance</td>
<td>-1.16</td>
<td></td>
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<td>-0.15</td>
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<td>-0.3</td>
<td></td>
<td>-0.5</td>
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<tr>
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<td>Frequency/week</td>
<td>0.06</td>
<td></td>
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<td>-0.005</td>
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<td>-0.006</td>
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<td>45</td>
<td>Air</td>
<td>Acc+egr distance/car distance</td>
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<td>-3.3</td>
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<td>-0.46</td>
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<td>-1.86</td>
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<td>Variable</td>
<td>Coefficient</td>
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<td>Coefficient</td>
<td>T-stat</td>
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<td>Coefficient</td>
<td>T-stat</td>
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<tr>
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</tr>
<tr>
<td>46</td>
<td>Air</td>
<td>On-time percentage</td>
<td>0.015</td>
<td>0.03</td>
<td>0.015</td>
<td>0.03</td>
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<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
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</tbody>
</table>
6.6 Sample Log Print File

Reading configuration file inputs\test3_config.txt
RunTitle        FHWA_Long_Distance_Model_Test_Run
RoadLOSFileName inputs\zoneRoadLOS.dat
RailLOSFileName inputs\zoneRailLos.dat
AirLOSFileName inputs\zoneAirLOS.dat
ZoneLandUseFileName inputs\numa_2010_landuse.dat
HouseholdFileName inputs\us_synpop_hh3_sorted.dat
DestChoiceCoefficientFile_1 inputs\pbusdest6_bxc.F12
DestChoiceCoefficientFile_2 inputs\vfardest6_bxc.F12
DestChoiceCoefficientFile_3 inputs\leisdest6_bxc.F12
DestChoiceCoefficientFile_4 inputs\commdest6_bxc.F12
DestChoiceCoefficientFile_5 inputs\ebusdest6_bxc.F12
ModeChoiceCoefficientFile_1 inputs\pbusmode13_est.F12
ModeChoiceCoefficientFile_2 inputs\vfarmode13_est.F12
ModeChoiceCoefficientFile_3 inputs\leismode13_est.F12
ModeChoiceCoefficientFile_4 inputs\commmode13_est.F12
ModeChoiceCoefficientFile_5 inputs\ebusmode13_est.F12
PartySizeCoefficientFile_1 inputs\pbus_psize3.F12
PartySizeCoefficientFile_2 inputs\vfar_psize3.F12
PartySizeCoefficientFile_3 inputs\leis_psize3.F12
PartySizeCoefficientFile_4 inputs\comm_psize3.F12
PartySizeCoefficientFile_5 inputs\ebus_psize3.F12
NightsAwayCoefficientFile_1 inputs\pbus_dur3.F12
NightsAwayCoefficientFile_2 inputs\vfar_dur3.F12
NightsAwayCoefficientFile_3 inputs\leis_dur3.F12
NightsAwayCoefficientFile_4 inputs\comm_dur3.F12
NightsAwayCoefficientFile_5 inputs\ebus_dur3.F12
TourFreqCoefficientsFile_1 inputs\freqest3b.f12
TourFreqCoefficientsFile_2 inputs\fsecest3b.f12
AutoOwnCoefficientsFile inputs\carown3.f12
HouseholdOutputFileName outputs\household_out_21.dat
TourOutputFileName outputs\tour_out_21.dat
TripMatrixOutputFileName outputs\trip_out_21.dat
OutputFileDelimeter 32
MonthOfYear  0
EachDayOfTheMonth F
RandomSeed  12345
SampleinX  1
SampleOffset  0
WriteHouseholdRecords  T
WriteTourRecords  T
WriteCarTripMatrix  F
WriteBusTripMatrix  F
WriteRailTripMatrix  F
WriteAirTripMatrix  F
UseProbabilitiesInMatrices F
UseADTUnitsInMatrices T
PersonTripsInMatrices T
TripMatrixMinimumDistance 100
ScenarioPercentIncomeChange  0
ScenarioPercentAutoCostChange  0
ScenarioPercentAutoTimeChange  0
ScenarioPercentAirFareChange  0
ScenarioPercentRailTimeChange  0
Run started at 11/15/2016 11:29:26 AM
Loading Zone Land Use Data from inputs\numa_2010_landuse.dat
Loading Road LOS Matrices from inputs\zoneRoadLOS.dat
Loading Rail LOS Matrices from inputs\zoneRailLos.dat
Loading Air LOS Matrices from inputs\zoneAirLOS.dat

Total expanded households simulated = 114736858

Household car ownership distribution by income group

<table>
<thead>
<tr>
<th>Income</th>
<th>Total</th>
<th>0-35 $k</th>
<th>35-65$k</th>
<th>65-100k</th>
<th>100-150</th>
<th>Over150</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 cars</td>
<td>5.16%</td>
<td>11.71%</td>
<td>2.98%</td>
<td>1.14%</td>
<td>0.85%</td>
<td>0.55%</td>
</tr>
<tr>
<td>1 car</td>
<td>29.80%</td>
<td>51.49%</td>
<td>28.56%</td>
<td>16.33%</td>
<td>10.51%</td>
<td>7.62%</td>
</tr>
<tr>
<td>2 cars</td>
<td>40.90%</td>
<td>25.98%</td>
<td>44.43%</td>
<td>49.78%</td>
<td>51.08%</td>
<td>53.60%</td>
</tr>
<tr>
<td>3 cars</td>
<td>15.51%</td>
<td>7.70%</td>
<td>15.95%</td>
<td>20.34%</td>
<td>22.69%</td>
<td>23.17%</td>
</tr>
</tbody>
</table>
### Household tour rates by purpose and income group (for simulated period)

<table>
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<tr>
<th>Income Group</th>
<th>PersBus</th>
<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-35 $k</td>
<td>68.49%</td>
<td>40.09%</td>
<td>46.27%</td>
<td>78.10%</td>
<td>54.73%</td>
</tr>
<tr>
<td>35-65$k</td>
<td>2.6339</td>
<td>2.4413</td>
<td>2.6931</td>
<td>2.7640</td>
<td>2.7427</td>
</tr>
<tr>
<td>65-100k</td>
<td>2.5640</td>
<td>3.0832</td>
<td>3.8963</td>
<td>4.2143</td>
<td>4.4568</td>
</tr>
<tr>
<td>100-150</td>
<td>2.5640</td>
<td>3.0832</td>
<td>3.8963</td>
<td>4.2143</td>
<td>4.4568</td>
</tr>
<tr>
<td>Over150</td>
<td>2.5640</td>
<td>3.0832</td>
<td>3.8963</td>
<td>4.2143</td>
<td>4.4568</td>
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</tbody>
</table>

### Total expanded tours simulated = 1627477184

### Tour nights away distribution by purpose

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Total</th>
<th>PersBus</th>
<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
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</thead>
<tbody>
<tr>
<td>Daytrip</td>
<td>53.10%</td>
<td>68.49%</td>
<td>40.09%</td>
<td>46.27%</td>
<td>78.10%</td>
<td>54.73%</td>
</tr>
<tr>
<td>1-2 nts</td>
<td>26.84%</td>
<td>20.46%</td>
<td>35.89%</td>
<td>27.91%</td>
<td>11.52%</td>
<td>25.68%</td>
</tr>
<tr>
<td>3-6 nts</td>
<td>14.51%</td>
<td>8.02%</td>
<td>17.29%</td>
<td>17.44%</td>
<td>8.19%</td>
<td>15.68%</td>
</tr>
<tr>
<td>7+ nts</td>
<td>5.55%</td>
<td>3.03%</td>
<td>6.72%</td>
<td>8.38%</td>
<td>2.19%</td>
<td>3.90%</td>
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### Tour party size distribution by purpose

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<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 pers</td>
<td>33.03%</td>
<td>21.85%</td>
<td>26.21%</td>
<td>12.52%</td>
<td>79.78%</td>
<td>61.45%</td>
</tr>
<tr>
<td>2 pers</td>
<td>34.74%</td>
<td>39.73%</td>
<td>38.44%</td>
<td>41.13%</td>
<td>13.98%</td>
<td>25.01%</td>
</tr>
<tr>
<td>3 pers</td>
<td>13.21%</td>
<td>17.57%</td>
<td>15.28%</td>
<td>15.95%</td>
<td>3.43%</td>
<td>6.54%</td>
</tr>
<tr>
<td>4+ pers</td>
<td>19.02%</td>
<td>20.85%</td>
<td>20.07%</td>
<td>30.40%</td>
<td>2.81%</td>
<td>7.00%</td>
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</table>

### Tour distance band distribution by purpose

<table>
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<tr>
<th>Mode</th>
<th>50-99 m</th>
<th>100-149</th>
<th>150-249</th>
<th>250-499</th>
<th>500-999</th>
<th>-1999 m</th>
<th>2000+ m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>43.78%</td>
<td>46.32%</td>
<td>34.42%</td>
<td>41.85%</td>
<td>80.38%</td>
<td>48.06%</td>
<td>40.80%</td>
</tr>
<tr>
<td>Bus</td>
<td>13.66%</td>
<td>19.34%</td>
<td>19.83%</td>
<td>15.56%</td>
<td>7.35%</td>
<td>15.30%</td>
<td>13.62%</td>
</tr>
<tr>
<td>Rail</td>
<td>6.83%</td>
<td>6.13%</td>
<td>7.83%</td>
<td>7.03%</td>
<td>0.85%</td>
<td>8.57%</td>
<td>8.57%</td>
</tr>
</tbody>
</table>

### Tour mode choice distribution by purpose

<table>
<thead>
<tr>
<th>Mode</th>
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<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>87.92%</td>
<td>92.60%</td>
<td>87.56%</td>
<td>90.64%</td>
<td>84.01%</td>
</tr>
<tr>
<td>Bus</td>
<td>1.75%</td>
<td>1.95%</td>
<td>1.23%</td>
<td>2.29%</td>
<td>3.11%</td>
</tr>
<tr>
<td>Rail</td>
<td>2.30%</td>
<td>2.00%</td>
<td>2.14%</td>
<td>2.29%</td>
<td>3.11%</td>
</tr>
<tr>
<td>Air</td>
<td>8.03%</td>
<td>8.04%</td>
<td>8.04%</td>
<td>8.04%</td>
<td>8.04%</td>
</tr>
</tbody>
</table>

### Tour distance band distribution by mode and purpose

#### Mode = Car

<table>
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<tr>
<th>Purpose</th>
<th>Total</th>
<th>PersBus</th>
<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-99 m</td>
<td>47.21%</td>
<td>48.52%</td>
<td>30.01%</td>
<td>44.67%</td>
<td>80.38%</td>
<td>48.06%</td>
</tr>
<tr>
<td>100-149</td>
<td>20.18%</td>
<td>22.13%</td>
<td>21.75%</td>
<td>19.69%</td>
<td>11.28%</td>
<td>20.64%</td>
</tr>
<tr>
<td>150-249</td>
<td>15.32%</td>
<td>14.41%</td>
<td>18.54%</td>
<td>17.20%</td>
<td>4.43%</td>
<td>13.62%</td>
</tr>
<tr>
<td>250-499</td>
<td>10.85%</td>
<td>8.49%</td>
<td>14.74%</td>
<td>10.97%</td>
<td>2.22%</td>
<td>11.42%</td>
</tr>
<tr>
<td>-1999 m</td>
<td>3.75%</td>
<td>2.69%</td>
<td>4.43%</td>
<td>3.42%</td>
<td>1.30%</td>
<td>5.46%</td>
</tr>
<tr>
<td>2000+ m</td>
<td>1.92%</td>
<td>1.24%</td>
<td>2.48%</td>
<td>1.83%</td>
<td>0.01%</td>
<td>2.82%</td>
</tr>
</tbody>
</table>

#### Mode = Bus

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Total</th>
<th>PersBus</th>
<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-99 m</td>
<td>40.91%</td>
<td>45.09%</td>
<td>36.42%</td>
<td>35.97%</td>
<td>55.50%</td>
<td>35.06%</td>
</tr>
<tr>
<td>100-149</td>
<td>15.09%</td>
<td>18.06%</td>
<td>18.49%</td>
<td>15.36%</td>
<td>7.35%</td>
<td>13.43%</td>
</tr>
<tr>
<td>150-249</td>
<td>17.61%</td>
<td>14.15%</td>
<td>15.03%</td>
<td>19.75%</td>
<td>20.70%</td>
<td>17.38%</td>
</tr>
<tr>
<td>250-499</td>
<td>10.72%</td>
<td>7.66%</td>
<td>10.76%</td>
<td>12.21%</td>
<td>9.75%</td>
<td>13.45%</td>
</tr>
<tr>
<td>-1999 m</td>
<td>1.45%</td>
<td>1.37%</td>
<td>1.45%</td>
<td>1.61%</td>
<td>0.94%</td>
<td>1.52%</td>
</tr>
<tr>
<td>2000+ m</td>
<td>0.12%</td>
<td>0.11%</td>
<td>0.12%</td>
<td>0.16%</td>
<td>0.00%</td>
<td>0.15%</td>
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</tbody>
</table>

#### Mode = Rail

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<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-99 m</td>
<td>47.21%</td>
<td>48.52%</td>
<td>30.01%</td>
<td>44.67%</td>
<td>80.38%</td>
<td>48.06%</td>
</tr>
<tr>
<td>100-149</td>
<td>20.18%</td>
<td>22.13%</td>
<td>21.75%</td>
<td>19.69%</td>
<td>11.28%</td>
<td>20.64%</td>
</tr>
<tr>
<td>150-249</td>
<td>15.32%</td>
<td>14.41%</td>
<td>18.54%</td>
<td>17.20%</td>
<td>4.43%</td>
<td>13.62%</td>
</tr>
<tr>
<td>250-499</td>
<td>10.85%</td>
<td>8.49%</td>
<td>14.74%</td>
<td>10.97%</td>
<td>2.22%</td>
<td>11.42%</td>
</tr>
<tr>
<td>-1999 m</td>
<td>3.75%</td>
<td>2.69%</td>
<td>4.43%</td>
<td>3.42%</td>
<td>1.30%</td>
<td>5.46%</td>
</tr>
<tr>
<td>2000+ m</td>
<td>1.92%</td>
<td>1.24%</td>
<td>2.48%</td>
<td>1.83%</td>
<td>0.01%</td>
<td>2.82%</td>
</tr>
</tbody>
</table>
## Daily tours by mode and O-D Census divisions (thousands)

### Mode = Air

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Total</th>
<th>PersBus</th>
<th>VisitFR</th>
<th>Leisure</th>
<th>Commute</th>
<th>EmplBus</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-99 m</td>
<td>0.84%</td>
<td>0.84%</td>
<td>0.36%</td>
<td>2.14%</td>
<td>2.51%</td>
<td>0.48%</td>
</tr>
<tr>
<td>100-149</td>
<td>0.54%</td>
<td>0.53%</td>
<td>0.35%</td>
<td>1.10%</td>
<td>0.49%</td>
<td>0.39%</td>
</tr>
<tr>
<td>150-249</td>
<td>8.47%</td>
<td>9.30%</td>
<td>6.22%</td>
<td>7.53%</td>
<td>27.56%</td>
<td>10.35%</td>
</tr>
<tr>
<td>250-499</td>
<td>9.91%</td>
<td>8.30%</td>
<td>8.38%</td>
<td>7.64%</td>
<td>18.87%</td>
<td>12.93%</td>
</tr>
<tr>
<td>500-999</td>
<td>28.01%</td>
<td>27.46%</td>
<td>28.79%</td>
<td>24.15%</td>
<td>10.15%</td>
<td>30.25%</td>
</tr>
<tr>
<td>-1999 m</td>
<td>29.78%</td>
<td>29.07%</td>
<td>30.43%</td>
<td>39.73%</td>
<td>27.61%</td>
<td></td>
</tr>
<tr>
<td>2000+ m</td>
<td>22.45%</td>
<td>24.51%</td>
<td>24.31%</td>
<td>27.01%</td>
<td>17.98%</td>
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</tr>
</tbody>
</table>

### Mode = Car

<table>
<thead>
<tr>
<th>O / D</th>
<th>New Eng</th>
<th>Mid Atl</th>
<th>NE Cent</th>
<th>NW Cent</th>
<th>Sou Atl</th>
<th>SE Cent</th>
<th>SW Cent</th>
<th>Mountn</th>
<th>Pacific</th>
<th>AK &amp; HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Eng</td>
<td>47985.9</td>
<td>23041.5</td>
<td>834.5</td>
<td>214.2</td>
<td>2105.5</td>
<td>254.4</td>
<td>163.9</td>
<td>69.0</td>
<td>56.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Mid Atl</td>
<td>22093.1</td>
<td>128206.2</td>
<td>11102.5</td>
<td>876.8</td>
<td>27893.9</td>
<td>1352.7</td>
<td>631.5</td>
<td>218.3</td>
<td>128.2</td>
<td>0.0</td>
</tr>
<tr>
<td>NE Cent</td>
<td>669.0</td>
<td>10328.5</td>
<td>190200.8</td>
<td>19015.8</td>
<td>8816.1</td>
<td>12967.1</td>
<td>2735.8</td>
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</tr>
<tr>
<td>NW Cent</td>
<td>142.7</td>
<td>592.0</td>
<td>15561.0</td>
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<td>1434.2</td>
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<td>2972.9</td>
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</tr>
<tr>
<td>Sou Atl</td>
<td>1755.4</td>
<td>23123.4</td>
<td>8775.8</td>
<td>1627.5</td>
<td>230913.4</td>
<td>19944.1</td>
<td>3086.7</td>
<td>421.9</td>
<td>206.6</td>
<td>0.0</td>
</tr>
<tr>
<td>SE Cent</td>
<td>191.7</td>
<td>1024.7</td>
<td>11743.9</td>
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<td>18944.4</td>
<td>52178.2</td>
<td>8632.8</td>
<td>359.6</td>
<td>88.7</td>
<td>0.0</td>
</tr>
<tr>
<td>SW Cent</td>
<td>97.0</td>
<td>365.8</td>
<td>1814.4</td>
<td>6883.6</td>
<td>2545.9</td>
<td>7502.8</td>
<td>129573.2</td>
<td>3543.6</td>
<td>379.2</td>
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</tr>
<tr>
<td>Mountn</td>
<td>39.5</td>
<td>116.3</td>
<td>521.8</td>
<td>2219.2</td>
<td>295.2</td>
<td>221.3</td>
<td>3463.4</td>
<td>74705.8</td>
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</tr>
<tr>
<td>Pacific</td>
<td>45.7</td>
<td>98.2</td>
<td>202.0</td>
<td>403.1</td>
<td>213.2</td>
<td>107.3</td>
<td>658.4</td>
<td>12252.4</td>
<td>166863.8</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Run finished at 11/15/2016 12:43:10 PM with 114736859 households processed**
CHAPTER 7. Summary

The implementation phase of the long-distance passenger travel demand modeling system moved the exploratory research of the modeling framework into a practical application that can be used by FHWA and adapted for use by state and regional agencies across the United States. This modeling system (rJourney) is multimodal and may be useful to other Federal agencies (e.g., Federal Railroad Administration, Federal Aviation Administration, or Federal Transit Administration).

The calibration and validation of rJourney was completed at a national scale using available data sources. These available data sources were somewhat restricted in scope or detail, which limited comparisons of model outputs to these observed data sources. The household travel surveys for long-distance travel represent 5 of the 50 states in the United States where a national long-distance survey would have provided a more representative sample for model calibration. The traffic counts on the highway system include a large amount of short-distance passenger travel and truck travel. As a result, comparisons of long-distance traffic volumes with counts were compared for reasonableness rather than a more traditional model validation of the results. Recognizing these limitations, the models perform well compared to these available calibration and validation data sources.

rJourney is currently useful for testing national policies, based on the outcomes of the sensitivity testing conducted in the implementation phase. These sensitivity tests included changes to cost, time, and household income, and produced intuitively reasonable results. Additional sensitivity tests may be useful prior to evaluating national policies that may engage other aspects of the modeling system.

The implementation phase required additional effort to build multimodal national networks, with travel time and cost details, and a zone system, with land-use and demographic data, which may prove useful in other national planning activities. These data may also be useful to statewide or regional planning agencies that must look beyond their borders, with additional attention to areas surrounding the region or state of interest.

rJourney will also be useful to regional and state agencies that want to represent long-distance passenger travel that cross their borders and test transportation investments that may affect these travelers. rJourney was designed with this objective in mind, but will require more detailed evaluation of the input data and a more detailed model validation surrounding the region or state of interest before these model outputs are ready to use.