# WFRC & MAG Transportation Model Documentation

## *2007 Base Year Model*

***Version 7.0***

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WASATCH FRONT REGIONAL COUNCIL

MOUNTAINLAND Association of Governments

*Communities working together to meet the Wasatch Front's transportation needs*

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# 1.0 INTRODUCTION & BACKGROUND

## 1.1 About WFRC and MAG

The Wasatch Front Regional Council (WFRC) and Mountainland Association of Governments (MAG) are the federally mandated Metropolitan Planning Organizations (MPO) that plan, prioritize, and coordinate the use of federal transportation funds in the region. As such, the agencies are responsible for development of the six-year Transportation Improvement Program and the long-range (20 to 30-year) Regional Transportation Plan within their respective jurisdictions. As an element of transportation planning, the MPOs are also carefully reviewing growth trends and making recommendations regarding them to the member cities.

The WFRC was organized as a voluntary association of local governments in March 1969, among Davis, Salt Lake, and Weber Counties and the cities within, for the purpose of establishing a review agency to comply with requirements to obtain federal grants and loans, and to address regional issues. In June 1969, Tooele County and the municipalities within, and in 1972 Morgan County and the municipalities within joined the Regional Council. The WFRC is dedicated to fostering a cooperative effort in resolving problems, and developing policies and plans that are common to two or more counties or are regional in nature.

Mountainland Association of Governments (MAG) is a political subdivision of the State of Utah, an intergovernmental agency working for all of the cities/towns of Summit, Utah and Wasatch Counties, and the counties of Summit and Wasatch. MAG is governed by the Executive Council, with input from a series of Program Advisory Boards and other coordinating agencies.

## 1.2 The Model

The WFRC/MAG Travel Model ("the model") is a transportation model covering Weber, Davis, Salt Lake and Utah Counties. The model is a complex system of several models and various datasets used to forecast travel demand and transportation conditions along the Wasatch Front. These models estimate the travel patterns of people, based on their demographic characteristics, where they live and participate in their daily activities, as well as on the transportation facilities available to them. The models forecast where and by what mode people are likely to travel, and assign these trips onto facilities that represent the likely best route for each particular trip. Travel model output is used to evaluate transportation corridors where the future travel demand is likely to exceed the capacity of the facilities in the corridor, to assess projects that meet the travel demand, and to analyze the air quality and other ancillary impacts of the transportation system. Transportation planners can use the model to evaluate transportation and traffic impacts resulting from:

- transportation improvements
- provision of new modes of travel and/or enhancement of existing alternative modes
- changes in land use activity, and
- changes in travel behavior or policies/economic circumstances affecting behavior.

The purpose of this report is to describe

- the data sources and parameter estimation that are the foundation of the model,
- the structure and parameters of the model itself,
- the comparison of the model against observed travel data,
- the use of the model for forecasting purposes, and
- recent enhancements or changes made to the model.

This documentation provides a technical description of the procedures and parameters used by WFRC and MAG to model travel demand and transportation system performance. As such, it is written in the language of travel models with the assumption that the reader has a background in travel models. The model includes several advanced features that place it on the cutting edge of improved modeling methods required to meet the needs of pertinent Federal legislation and guidance. In addition, several features recommended by the Travel Model Improvement Program of the US Department of Transportation, the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA) and the Environmental Protection Agency (EPA) are incorporated into the model.

## 1.3 About Travel Modeling Requirements

Contrary to popular belief, there are no requirements either in Federal legislation or in the joint FHWA/FTA planning regulations that an MPO must specifically have a travel model for transportation planning. However, the regulations require that forecasts of future travel used in an area's transportation plan be based on an "analytical process". The sophistication of that analytical process is generally left to the discretion of the local planning agency.

MPOs representing urbanized areas with a population over 200,000 are designated as Transportation Management Areas (TMAs). TMAs must undergo a more formal certification review by FHWA and FTA field staff every three years. While it is theoretically possible for even a TMA to satisfy its "analytical process" without a travel model, it is not likely to have an adequate transportation planning process without one.

Beyond the Federal joint planning requirements, an MPO may need a travel model to satisfy two other Federal requirements. First, if a TMA is also an air quality non-attainment area that is serious or above for either ozone or carbon monoxide, EPA's Conformity Rule requires that forecasts of regional vehicle emissions must be based on estimates of VMT derived from a network-based model meeting certain minimal requirements. Second, FTA's New Starts criteria for major transit investment require forecasts of future transit demand that can only be derived using travel models. Lastly, the accepted practice for major transportation demand studies by any mode involves using relatively sophisticated demand models and network models. Moreover, the travel forecasting practice has evolved such that various methods can be evaluated on their relative merits. MPOs and their partnering agencies are advised to keep their models consistent with accepted practice.

# 2.0 OVERVIEW OF THE MODEL

The model is a trip-based travel model that estimates the movement of people and vehicles within the region during an average spring/fall weekday. The model represents travel by auto, transit and non-motorized modes within the 4-County (Weber, Davis, Salt Lake and Utah) urbanized area. The model is calibrated to 2007 data. The model is implemented within the CUBE modeling software package, with the application written exclusively in CUBE's native Voyager scripting.

## 2.1 Model Coverage

Until the year 2000, separate travel models were maintained for the three urbanized areas (Ogden, Salt Lake and Provo). In 2000, the three urban area models were combined into one model. The model's coverage has expanded over the years to include all of the developable area of Utah, Salt Lake, Davis and Weber counties, with the exception of the canyons and mountains to the east of the urbanized areas. In these cases, the population in the areas that are outside of the travel model coverage is small and tends to be separated from the urban area by some distance. The upper or eastern portion of Weber County represents a significant percentage of the County's land area, but its mountainous character and limited access make it unlikely that it will need to be incorporated into the modeled area in the near future.

There is significant commuting and recreation travel between the model area and Summit County (Park City), Tooele County, and increasingly Wasatch County. The combined population of these satellite counties exceeded 114,000 in 2007. The population of Summit County was approximately 38,000 in 2007, the population of Tooele County was approximately 55,000 in 2007, and the population of Wasatch County was approximately 22,000 in 2007. In each case, the population centers are separated by distances of more than 15 miles from the urban portions of Salt Lake County. It is still acceptable to treat these flows as an external flows but the issue of how to treat these growing travel flows may need to be dealt with in the future to assist in coordinated planning throughout the Greater Wasatch Front and Wasatch Back.

### 2.1.1 TAZ Structure

The model is a zone-based forecasting tool, modeling travel between aggregate Transportation Analysis Zones (TAZ). Figure 1 shows an example of the TAZ structure. TAZs are mutually exclusive (i.e. they do not overlap) and collectively exhaustive (they cover the entire model region). Figure 4 shows the TAZ numbering.

There are 2,230 internal TAZs and 20 external TAZs in the model. Land-use and socioeconomic data are summarized within this spatial framework and travel is estimated between the TAZs.

### 2.1.2 Network Structure

The road network in the model includes all facilities functionally designated as collector or above by the Utah Department of Transportation (UDOT). There are approximately 27,000 road links in the base year network. Figure 2 shows a portion of the model's road network covering the Kaysville area. The transit network in the model includes all Utah Transit Authority (UTA) bus and rail routes, excluding ski routes, vanpools and commuter buses to specific employers. The transit network distinguishes local buses, express buses, bus rapid transit, light rail, and commuter rail. Future roadway and transit networks are developed for the model consistent with the regional transportation plan developed cooperatively by the MPOs and their planning partners.

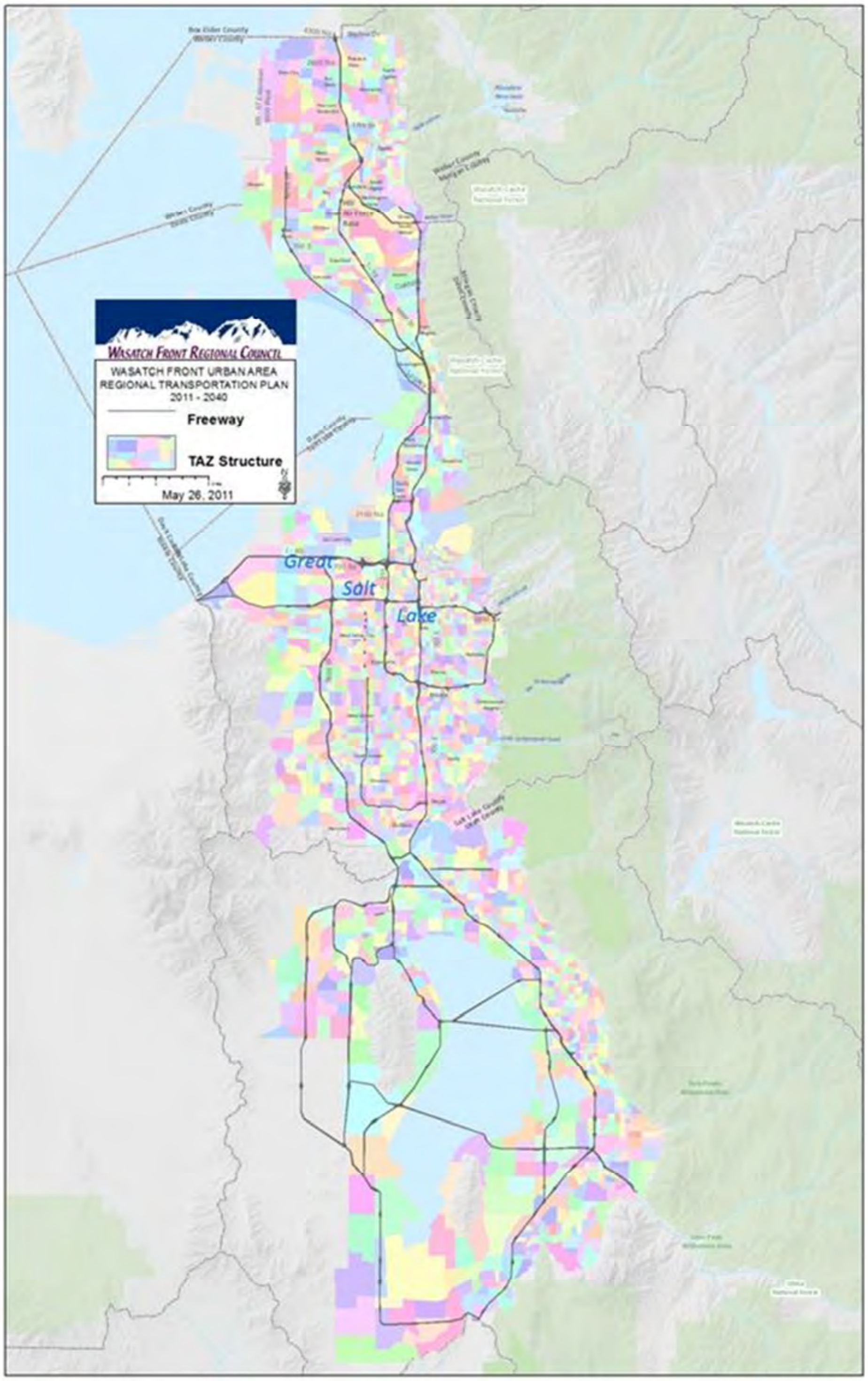



**Figure 1: Model Geography and TAZ Structure**

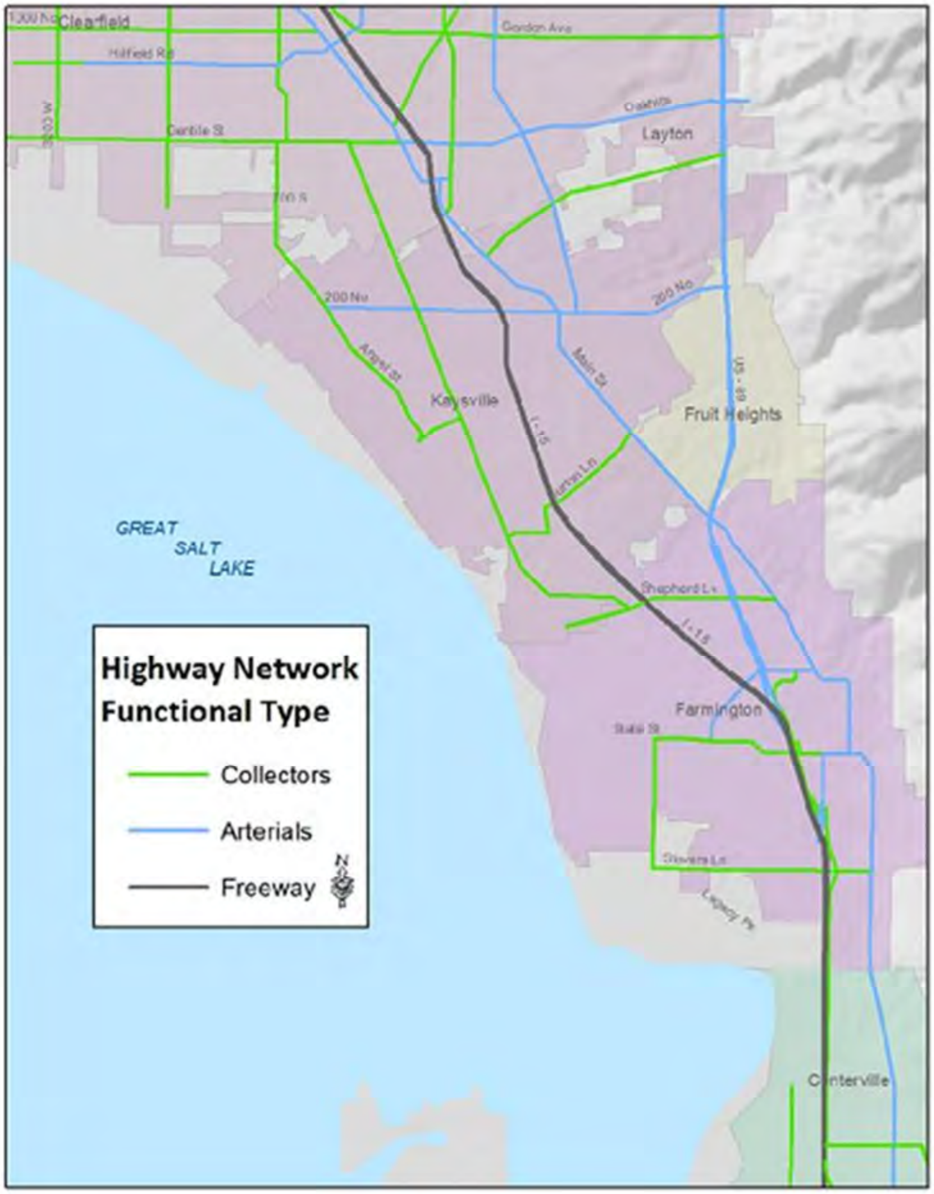



**Figure 2: Portion of 2007 Street Network**

## 2.2 Model Structure

The model is based on a common "four-step" modeling process consisting of trip generation, trip distribution, mode split, and trip assignment steps. The model incorporates these steps and adds an auto ownership step that is sensitive to urban design variables and transit accessibility.

The model has a feedback loop between trip distribution and traffic assignment, which is a process that ensures consistency between travel congestion and times that influence trip distribution patterns and that are an outcome of trip assignment. Travel time, or more generally speaking, accessibility, is calculated based on outputs from the assignment step, but also is an important determinant of trip distribution and mode split. Therefore, it is customary to iterate these steps in order to reach a convergent solution.

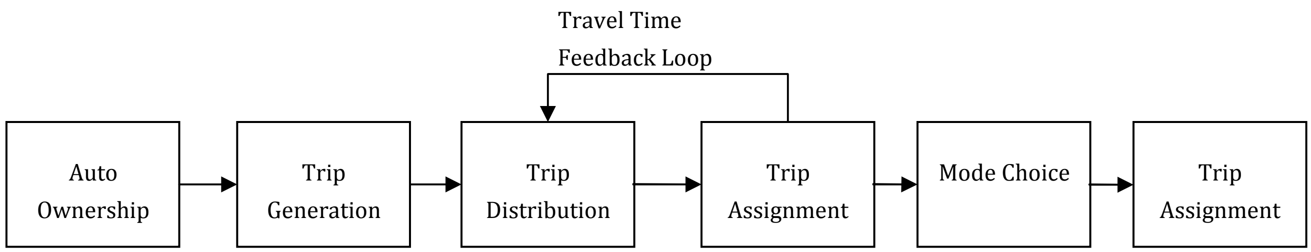



**Figure 3: Conceptual Overview of the WFRC/MAG Model**

At the start of a model run, the auto ownership model estimates household auto ownership levels. The trip generation model then estimates trip-ends by TAZ based on household and employment characteristics. These trip-ends are then paired into trips in the trip distribution model. In the mode choice model, a mode of travel is identified for each trip. Vehicle trips are assigned to the highway network in the trip assignment model, during which congestion levels on each road are estimated consistent with route choices. The travel time feedback loop in the model is run to a convergent solution prior to running mode choice. Transit trips are assigned to the transit network in the mode choice step.

### 2.2.1 Time Periods

The trip generation and trip distribution models are daily models, while the mode choice model distinguishes peak and off-peak periods, and the traffic assignment model estimates traffic flows for four periods of day:

- AM Peak: 6-9 AM
- Midday: 9 AM – 3 PM
- PM Peak: 3-6 PM
- Evening/Off-peak: 6 PM – 6 AM

The mode choice model is run separately for peak conditions and off-peak conditions so that mode choice is sensitive to different travel conditions and transit service levels by time-of-day. The work trip distribution model relies on AM peak period travel times, while the non-work models rely on midday travel times.

### 2.2.2 Trip Purposes

The model includes several trip purposes:

- **Home-Based Work Trips (HBW)**: trips made between the traveler's home and the place of work, in either direction. HBW trips first appear in the model in trip generation.
- **Home-Based College Trips (HBC)**: trips made between the traveler's home and college. HBC trips first appear in the model in trip distribution.
- **Home Based Other Trips (HBO)**: trips made between the traveler's home and all other non-work, non-college locations, e.g., shopping or recreational trips. HBO trips first appear in the model in trip generation.
- **Non-Based Work Trips (NHB)**: trips that do not begin or end at the traveler's home. NHB trips most often occur as part of trip chains or tours and as a result tend to be more difficult to represent accurately. NHB trips first appear in the model in trip generation.

- **Commercial Vehicle Trips**: Commercial vehicle trips encompass in one trip purpose a broad range of trip purposes and vehicle types, including freight trucks, the mail man, and contractor vehicles.
- **Internal-External Trips (IXXI)**: trips with a trip-end outside the model area. These trips include truck/freight trips as well as passenger trips, and can either be in the internal-external direction or the external-internal direction.
- **External through Trips (XX)**: trips that pass through the model region with both trip-ends outside the model region. Like IXXI trips, these trips include passengers and freight.

The trip generation model includes the most detail in terms of the number of trip purposes and produces trips for four HBO sub-categories and two NHB sub-categories. These sub-categories are then combined into the HBO and NHB trip purposes for subsequent model steps. The trip generation HBO and NHB sub-categories are as follows:

- Home-Based School (HBSC)
- Home-Based Shop (HBSH)
- Home-Based Personal Business (HBPB)
- Home-Based Other (HBO)
- Non-Home-Based Work (NHBW)
- Non-Home-Based Non-Work (NHBN)

### 2.2.3 Model Components

Although considered a "four-step" process and conceptualized in a simplistic way above, the model is actually comprised of several additional steps and each step is scripted and can be run separately. These steps include:

- **Household classification model** stratifies households jointly by income, number of workers and household size. This process applies statistical distributions derived from Census data to TAZ information such as the total households, average household size, and average zonal income, to estimate the total number of households in combinations of these categories: into six HH size categories (1 person to 6+ person), four worker categories (0 to 3+), and four income quartile categories.
- **Auto ownership model** estimates the likelihood of each household in the region owning 0, 1, 2, 3+ autos. The auto ownership model is a logit model and is a function of characteristics of the households and the TAZ characteristics. Auto ownership and availability is a strong predictor of trip making and mode choice behavior.
- **Trip generation model** calculates the number of person trips generated within each TAZ. The trip generation model parameters are developed from travel surveys collected in 1993 (local diary) and rates were validated using 2001 NHTS data. The trip-ends at home locations are estimated using cross-classification models, while trip attractions at non-home locations are estimated using regression models built from Institute of Transportation Engineers (ITE) data.
- **Trip distribution model** pairs the productions and attractions for each zone by trip purpose. The result of this is a person trip matrix for each trip type. Trip distribution links trip-ends based primarily on the spatial separation of different land-uses and observed sensitivities to trip length. The HBW trip distribution is estimated using a destination choice model, while the HBO, NHB and IX/XI trip distributions are estimated using gravity models. The XX distribution is estimated outside the model, and the HBC and Airport distributions are derived from linear regression equations for each destination.

- **Time-of-Day model** segments the daily travel demand by time period and direction of travel. The time-of-day split for person trips varies by trip purpose and is estimated from home interview survey data and NHTS survey data, and then further adjusted to better match vehicle counts and transit boarding counts.
- **Highway/transit skim builder** finds the best available travel path via each of the travel modes. The modes modeled include auto, transit modes (local bus, bus rapid transit, light rail, commuter rail) and non-motorized modes. "Skims" are approximations of the travel time and cost between all pairs of TAZs, and skims are described for each travel mode. The path-finding algorithms are calibrated based on observed travel paths and observed relationships between volumes and congested speeds. Shortest paths are identified using a function of travel time, distance and travel cost, all converted to equivalent minutes. For transit path-finding, out-of-vehicle travel time and transfers are also considered.
- **Mode choice model** calculates which mode the person trips are likely to take based on availability and mode-specific parameters (e.g. time, cost, transit frequency). The mode choice model is a nested logit model that provides a breakdown of person trips by mode both for captive riders (people without automobiles) and for the total population. The mode split model is developed based on observed data on mode preferences and what those preferences imply about sensitivities to mode attributes.
- **Vehicle assignment model** locates the "best" routes between each origin/destination pair and assigns the vehicle trips to the highway network consistent with network equilibrium principles. Important outputs of this step include the number of vehicles on each roadway segment by time period and turning movements at intersections. Several other pieces of data can be extracted, including operating speeds, travel times, VMT, VHT, and V/C on links and at intersections. In addition, one can configure the vehicle assignment to save all the vehicle trips that use a particular link (select link analysis) or all the vehicle trips that originate or are destined for a zone (select zone analysis).
- **Transit assignment model** uses the transit trip table output from mode choice and assigns person trips using transit to the appropriate transit routes by time-of-day. This provides a means of viewing transit ridership graphically and understanding the relative effectiveness of different segments of the transit network.
- **Model output** is summarized automatically by the model, including regional statistics (e.g. VMT, VHT, transit shares and trip lengths), corridor and segment performance statistics (e.g. delay, volume, and ridership), district and county-level trip flows, and calibration statistics. There are many automated reports and custom indicators that are produced when the model is run.

## 2.3 Calibration and Validation of the Model

The model is calibrated to represent 2007 "base year" travel conditions and patterns by adjusting model input data, assumptions and parameters so that intermediate and final outputs more closely match observed data. Model output is checked or "validated" against real-world data. Trip rates, transit ridership and highway volumes are examples of type of model outputs that are validated. For future forecast years, the model output is reviewed for "reasonableness" to validate model results and model sensitivities can be assessed.

Some of the most useful model outputs that are important to validate include Origin-Destination flows, roadway vehicle volumes, vehicular travel times and speeds, and transit ridership.

# 3.0 Traffic Analysis Zones

| **Zone Ranges and Purposes, Model version 7.0** | | | **July 1, 2010** |
|---|---|---|---|
| | | | |
| **1-2250** | Used zones in V7 | **Zone Numbering Method** | |
| **2251-3400** | Unused range (available for subregional modeling) | For WFRC, TAZs are sequentially numbered | |
| **3401 - ?** | WFRC nodes available for use in typical roadways | by small, then medium, then large district. | |
| **?** | MAG nodes available for use in typical roadways | Example: Zones 1-6 = DistSml 1; Zones 1-18 = | |
| **20000 - 20999** | Rail nodes | DistSml 1-3 AND DistMed 1; etc. for DistLrg. | |
| **21000 - 21999** | HOV and Managed Lanes | MAG is not numbered this way yet. | |
| | Other ranges? | | |
| | | **Colleges** | |
| **1-283** | **Weber County TAZs (283 total, 5 external)** | 241 | Weber State University |
| 174-193 | Internal, unused | 921, 922 | U of U main campus, Medical |
| 279 | Major External: I-15 North @ Box Elder Line | 996 | Westminster College |
| 280 | Minor External: US 89 @ Box Elder Line | 744 | SLCC-Redwood |
| 281 | Minor External: North Ogden Pass | 1338 | SLCC-Jordan |
| 282 | Minor External: Ogden Canyon | 1924, 1925 | UVU Main, West |
| 283 | Major External: I-84 East to Morgan | 1959 | BYU, entire campus |
| | | 796 | LDS Business College, Triad |
| **284-502** | **Davis County TAZs (218 total, 0 external)** | | |
| | | | |
| **503-1632** | **SL County TAZs (1129 total, 7 external)** | **Zones with Major Retail (not comprehensive)** | |
| 1626 | Major External: I-80 West to Tooele | | Ogden DT Mall area |
| 1627 | Major External: SR-201 West to Tooele | | Riverdale Rd, Newgate Mall |
| 1628 | Minor External: Emigration Canyon | | Layton Mall, Walmart |
| 1629 | Major External: I-80 East to Park City | | Jordan Landing |
| 1630 | Minor External: Millcreek Canyon | | Gateway Mall |
| 1631 | Minor External: Big Cottonwood Canyon | | Trolly Square |
| 1632 | Minor External: Little Cottonwood Canyon | | Sugarhouse retail |
| | | | Valley Fair Mall |
| **1633-2250** | **Utah County TAZs (617 total, 8 external)** | | Cottonwood Mall |
| 2243 | Minor External: American Fork Canyon | | Redwood/I-215 retail |
| 2244 | Major External: US-189, Provo Canyon to Heber | | Fashion Place Mall |
| 2245 | Minor External: Hobble Creek Canyon | | Fort Union Area |
| 2246 | Major External: US-6, SF Canyon to Price/Moab | | South Town Mall |
| 2247 | Minor External: Payson Canyon | | American Fork mega-retail area |
| 2248 | Major External: I-15 South @ Juab County Line | | University Mall |
| 2249 | Minor External: US 6 West to Delta | | Provo Towne Center |
| 2250 | Minor External: SR 73 West to Tooele | | |
| | | | |
| | | **Other Zones of Interest** | |
| **County Codes (Used in various spots)** | | | HAFB range |
| 1 | Weber | | Freeport N, Freeport S |
| 2 | Davis | 411 | Lagoon |
| 3 | Salt Lake | 589 | Airport |
| 4 | Utah | 812 | Temple Square, LDS Offices |
| 5 | Box Elder (2 externals) | | Ogden Intermodal Center |
| 6 | Morgan (1 external, I-84) | | SL Intermodal Center |
| 7 | Summit (1 external, I-80) | | |
| 8 | Wasatch (1 external, Provo Canyon) | | |
| 9 | Juab (1-external, I-15) | | |
| 10 | Millard (1-external, US-6 to Delta) | | |
| 11 | Tooele (3 externals, SR-72, SR-201, I-80) | | |

**Figure 4: TAZ Numbering**

## 3.1 Version 7 Districts

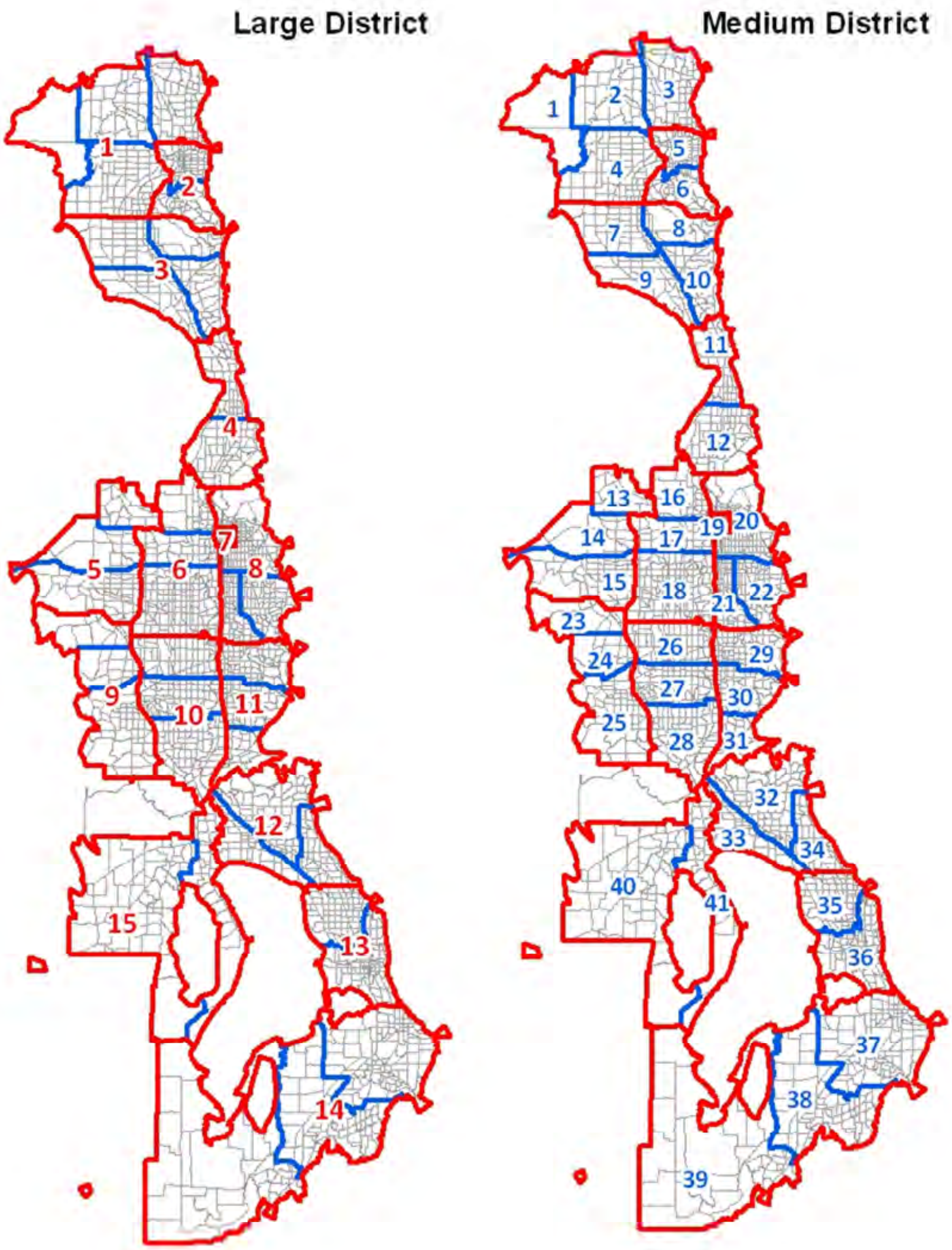



**Figure 5: District Geographies**

# 4.0 LAND-USE DATA

Travel models describe the movement of people and goods within an urban area. Knowledge of the number of people, the number of jobs, the locations of activities and the characteristics of the people is crucial to understanding travel demand. Consequently, one of the initial steps in travel modeling is to gather current conditions and forecast how socioeconomic characteristics and locations are expected to change over time.

## 4.1 Base Year Land-use Data

The WFRC/MAG travel model is calibrated to 2007 conditions. Land-use and socio-economic data for the base year model comes from the following sources:

- 2000 Census and Census Transportation Planning Package (CTPP)
    - housing units and vacancy
    - household size & auto ownership
    - median income
- Annual buildings permits by TAZ (since the Census)
- 2007 parcel data for each county
- 2007 county-level population and household totals and average household size (Governor's Office of Planning and Budget (GOPB))
- 2007 county-level employment estimates by sector (GOPB)
- 2007 establishment-level employment categorized by employment sector (Department of Workforce Services (DWS))

### 4.1.1 Base Year Households

The 2007 base year household estimates by TAZ starts with the 2000 Census. The Census reports the number of households and population at the block level, along with average household size and vacancy rates. These block-level totals are aggregated to the TAZ level, which are made up of one or more blocks. TAZ growth is then estimated from the number of building permits issued in each TAZ. Building permits are geocoded from the address specified on the permit and checked with parcel data and aerial photography. It is assumed that each housing unit built represents a household. The total households in each county are then summed and compared to the 2007 county control total from GOPB. The TAZ total households are then factored to match the county control total from GOPB.

Base year population is estimated by multiplying the 2007 TAZ households by the TAZ-level average household size from the Census (using Block Group data). The TAZ population are then summed by county and compared with the GOPB 2007 county population control total, and then factored to match the GOPB total. The average household size in each TAZ is then recalculated. Household and population are then aggregated to medium and large districts and to the city level for quality control and to check for accuracy.

The total population control totals used in the model represent household population and exclude group quarter population, i.e. populations in prisons, nursing homes, dormitories and military barracks. It is assumed, however, that the population includes people who are temporarily away on business or vacation, as well as those attending school in the region and living off-campus, but not those away at school or on LDS missions.

In Utah County and Weber County, a small percentage of the county households, population, and employment totals reside outside the modeled geographic area. These totals are subtracted from the GOPB county control totals prior to factoring.

A total of 650,000 households and nearly 2.0 million people were within the model region in 2007.

**Table 1: Base Year Households & Populations in each County**

| County | Population | Households | Avg. HH Size |
|---|---|---|---|
| Weber | 217,471 | 75,119 | 2.90 |
| Davis | 291,678 | 92,240 | 3.16 |
| Salt Lake | 1,002,883 | 343,988 | 2.92 |
| Utah | 486,353 | 137,528 | 3.54 |

### 4.1.2 Base Year Employment

WFRC and MAG obtain annual establishment-level employment data from the Department of Workforce Services (DWS). Since the DWS employment has a privacy agreement and use restrictions users of the employment data must agree to follow the terms upon which the data have been released. The employment data contains information such as the name of the employer, the address of the employer, the number of employees, and the employer's industry code (NAICS classification).

Employer locations are geocoded using GIS and the employer's address to obtain a discrete point representing a number of employees as of July 1. Each business is assigned to the TAZ in which the point resides. The points are then factored by the total employment for each NAICS classification to account for the employment addressed that could not be successfully geocoded.

The DWS data is then converted to GOPB employment definitions using the crosswalk table identified below and scaled to match the GOPB employment sector totals by county. A percentage of the employment representing home-based jobs are then skimmed off the top by sector and added to a new, home-based job classification. The 2000 Census (percentage of work at home jobs by county) is used to match or validate the number of home-based jobs by county.

Table 2 shows the base year employment across employment type in each county. Table 3 shows the sector definition and equivalency table across multiple employment datasets.

**Table 2: Base Year Employment by Sector in each County**

| County | Retail | Industrial | Other | Total | Jobs/HH |
|---|---|---|---|---|---|
| Weber | 23,838 | 19,485 | 68,877 | 112,195 | 1.49 |
| Davis | 29,008 | 22,928 | 79,179 | 131,130 | 1.42 |
| Salt Lake | 129,959 | 109,373 | 432,678 | 671,978 | 1.95 |
| Utah | 45,146 | 26,867 | 145,744 | 217,754 | 1.58 |

**Table 3: Employment Sector Equivalency Table**

| GOPB ID | Industry Description | DWS NAICS & Ownership ID | Travel Model Sector | % Home-Based Jobs |
|---|---|---|---|---|
| 0 | Forestry, Fishing | 113,114 and 111421, 111422 | removed | 0% |
| 1 | Mining | 21 | removed | 0% |
| 2 | Utilities | 22 | Industrial | 1% |
| 3 | Construction | 23 | removed | 1% |
| 4 | Manufacturing | 31-33 | Industrial | 1% |
| 5 | Wholesale Trade | 42 | Industrial | 1% |
| 6 | Retail Trade | 44-45 | Retail | 3% |
| 7 | Trans/Warehousing | 48-49 | Industrial | 1% |
| 8 | Information | 51 | Other | 8% |
| 9 | Finance, Insurance | 52 | Other | 3% |
| 10 | Real Estate/Leasing | 53 | Other | 3% |
| 11 | Prof/Tech Services | 54 | Other | 8% |
| 12 | Mgt. of Co., Entertain. | 55 | Other | 8% |
| 13 | Admin, Waste Services | 56 | Other | 8% |
| 14 | Educational Services | 61 | Other | 8% |
| 15 | Health Care, Social Assist. | 62 | Other | 8% |
| 16 | Arts, Entertainment, Rec. | 71 | Other | 8% |
| 17 | Accom., Food Services | 72 | Other | 3% |
| 18 | Other Services (excl. govt) | 81 | Other | 8% |
| 19-21 | State & Local Gov, Fed & Civilian Military | 92, and ownership code 10, 20, or 30 from all sectors | Other | 3% |
| 22 | Farm | 111-112,115 (excluding 111421,111422) | removed | 20% |

## 4.2 Future Year Land-use Data

The socioeconomic forecasting process involves analytical models and local negotiation/review. The primary model used to allocate future demographic data differed for each MPO. Regardless of the analytical methods used to initially allocate population and job growth, the final projections are revised and agreeable to local governments. The socioeconomic forecasting process for each MPO essentially follows the following process:

1. The Utah GOPB provides county-level population and employment totals.
2. Estimate TAZ-level population, households and employment:
    a. MAG uses historical growth factors based on zonal density
    b. WFRC uses UrbanSim
    c. WFRC/MAG forecasts are guided by developable land and zoning densities
3. If necessary, the modeling process is iterative, considering the relative reasonableness of the different estimates.
4. Adjustments are made to the forecasts based on the judgment of MPO planners
5. Cities and planners review results, and their comments are implemented as applicable.

**Table 4: Future Population by County**

| County | 2007 Population | 2020 Population | 2030 Population | 2040 Population |
|---|---|---|---|---|
| Weber | 217,471 | 273,916 | 315,243 | 363,671 |
| Davis | 291,678 | 364,050 | 383,204 | 398,719 |
| Salt Lake | 1,002,883 | 1,251,774 | 1,441,026 | 1,637,359 |
| Utah | 486,353 | 707,524 | 881,558 | 1,060,034 |

**Table 5: Future Households by County**

| County | 2007 Households | 2020 Households | 2030 Households | 2040 Households |
|---|---|---|---|---|
| Weber | 75,119 | 99,428 | 119,489 | 140,478 |
| Davis | 92,240 | 122,029 | 135,759 | 146,646 |
| Salt Lake | 343,988 | 453,993 | 544,378 | 629,950 |
| Utah | 137,528 | 203,166 | 256,615 | 312,791 |

**Table 6: Future Employment by County**

| County | 2007 Employment | 2020 Employment | 2030 Employment | 2040 Employment |
|---|---|---|---|---|
| Weber | 112,195 | 145,347 | 168,198 | 194,364 |
| Davis | 131,130 | 176,966 | 187,647 | 193,442 |
| Salt Lake | 671,978 | 796,848 | 883,261 | 986,193 |
| Utah | 217,754 | 323,620 | 400,754 | 487,026 |

## 4.3 Household Disaggregation Process

Households are classified by market segment so that relevant characteristics of households can be used to forecast travel behavior. The 2000 Census was used to classify households by size (# people in the household), income quartile, and workers per household. A household disaggregation model relates statistical distributions of these characteristics to basic zonal information such as the total households, average household size, and average zonal income, to estimate the total number of households in combinations of these categories: into six HH size categories (1 person to 6+ person), four worker categories (0 to 3+), and four income quartile categories. This data is the input to Auto Ownership, Trip Generation, and Mode Choice, allowing for market segmentation to be used throughout the modeling process.

1990 and 2000 Census data were used to estimate/calibrate models to forecast three marginal distributions: (1) households by size (based on zonal average household size); (2) households by income quartile (based on the ratio of zonal average income to regional average income); and (3) households by workers (using a logit model with HH size and income as independent variables). A 3-dimensional matrix balancing routine is used to produce joint distributions, conserving the marginal distributions of each household characteristic.

The segmentation process begins by projecting a household size distribution for each TAZ, based on zonal average household size. The HH size distribution lookup table was developed using 2000 Census data and was smoothed and calibrated to reproduce the marginal distribution at the region level. The lookup table is charted in Figure 6.

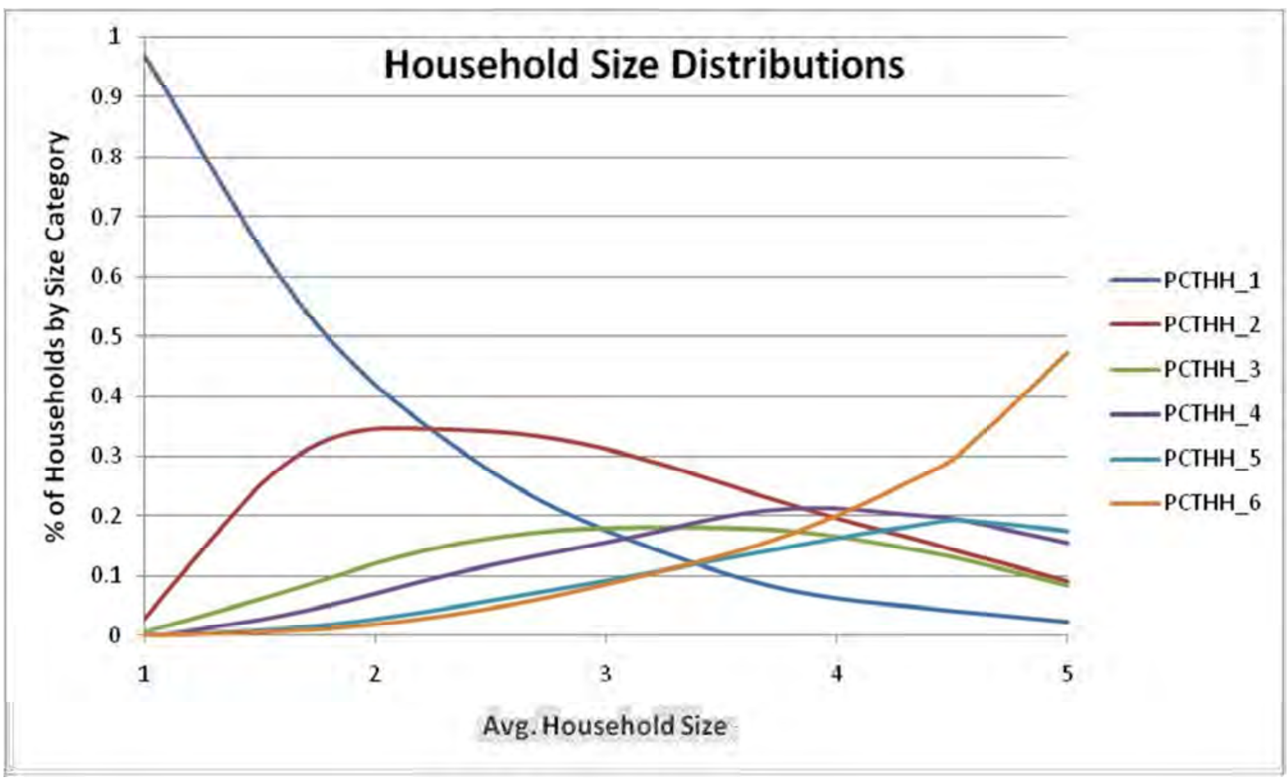



**Figure 6: HH Size Distribution Curves**

The second step in the segmentation process is to forecast the marginal distribution of households by income quartile. Given an average zonal income, relative to the regional income, a distribution of households by quartile is estimated. The lookup table was developed using 2000 Census data and was smoothed and calibrated to reproduce the marginal distribution at the region level. The lookup table is charted in Figure 7.

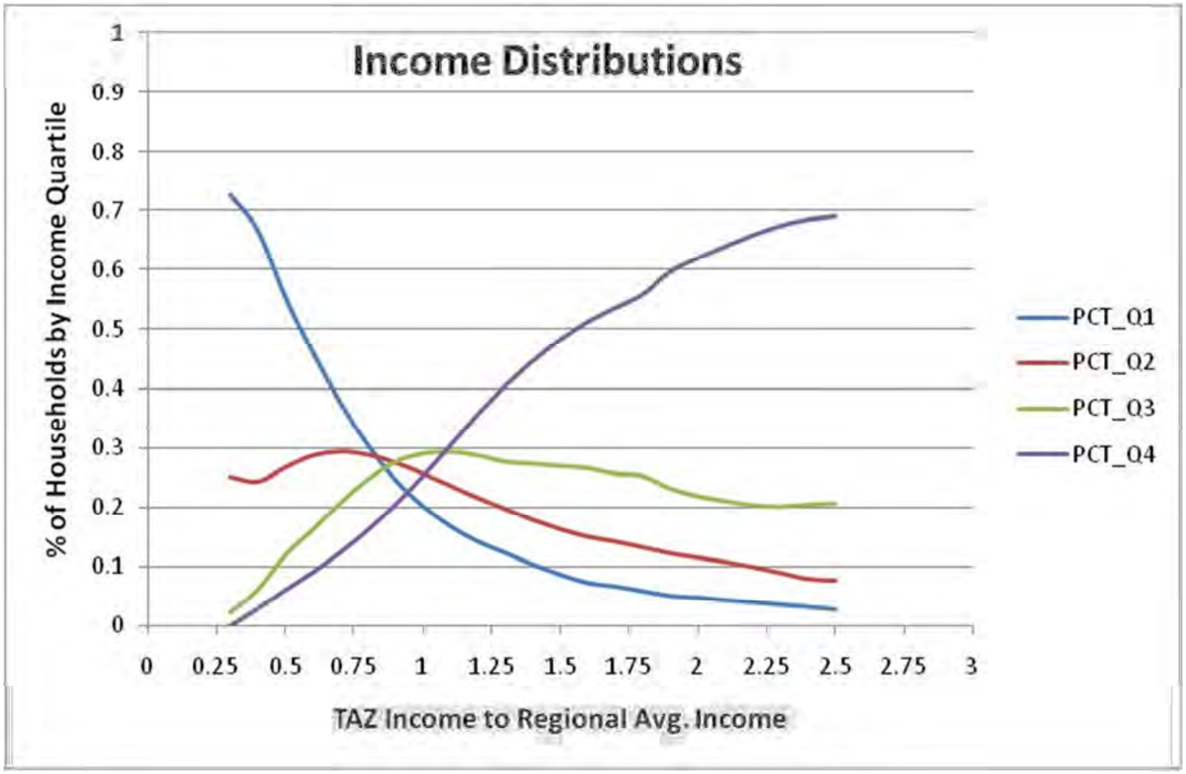



**Figure 7: Income Distribution Curves**

Once the household size and income marginal distributions have been estimated, a 2-dimensional matrix balancing routine is used to simultaneously conserve marginal distributions and produce a joint distribution be size and income quartile.

The fourth step in the segmentation process is a logit model that estimates the share of households within each size/income category that have 0, 1, 2, 3+ workers in them. The logit model was estimated using PUMS data and includes parameters for each household size category, each income quartile, and for combinations of size and income where statistically meaningful. The resulting shares for each size/income category are presented in Table 7.

**Table 7: Workers per Household Model**

| HH SIZE | INCOME QRT | PCTWKR0 | PCTWKR1 | PCTWKR2 | PCTWKR3 |
|---|---|---|---|---|---|
| 1 | 1 | 0.43118 | 0.56882 | 0.00000 | 0.00000 |
| 1 | 2 | 0.18079 | 0.81921 | 0.00000 | 0.00000 |
| 1 | 3 | 0.10470 | 0.89530 | 0.00000 | 0.00000 |
| 1 | 4 | 0.06111 | 0.93889 | 0.00000 | 0.00000 |
| 2 | 1 | 0.30723 | 0.31783 | 0.37494 | 0.00000 |
| 2 | 2 | 0.21747 | 0.30039 | 0.48214 | 0.00000 |
| 2 | 3 | 0.11634 | 0.30326 | 0.58040 | 0.00000 |
| 2 | 4 | 0.04627 | 0.21670 | 0.73703 | 0.00000 |
| 3 | 1 | 0.00433 | 0.36048 | 0.42169 | 0.21349 |
| 3 | 2 | 0.00318 | 0.22096 | 0.56162 | 0.21425 |
| 3 | 3 | 0.00130 | 0.17052 | 0.51681 | 0.31137 |
| 3 | 4 | 0.00030 | 0.07125 | 0.38374 | 0.54472 |
| 4 | 1 | 0.00433 | 0.36048 | 0.42169 | 0.21349 |
| 4 | 2 | 0.00197 | 0.13722 | 0.72777 | 0.13305 |
| 4 | 3 | 0.00066 | 0.08713 | 0.75311 | 0.15910 |
| 4 | 4 | 0.00019 | 0.04403 | 0.61916 | 0.33663 |
| 5 | 1 | 0.00192 | 0.08084 | 0.90595 | 0.01129 |
| 5 | 2 | 0.00140 | 0.09759 | 0.80639 | 0.09462 |
| 5 | 3 | 0.00090 | 0.11826 | 0.66489 | 0.21595 |
| 5 | 4 | 0.00030 | 0.07125 | 0.38374 | 0.54472 |
| 6 | 1 | 0.00596 | 0.12065 | 0.57984 | 0.29355 |
| 6 | 2 | 0.00318 | 0.22096 | 0.56162 | 0.21425 |
| 6 | 3 | 0.00130 | 0.17052 | 0.51681 | 0.31137 |
| 6 | 4 | 0.00030 | 0.07125 | 0.38374 | 0.54472 |

# 5.0 ROADWAY NETWORK

The transportation system is represented in the travel model by abstract networks that represent the roadway and transit systems. While the networks will always be an abstraction of the actual system, they attempt to represent the system in a manner that is as realistic as possible. This section covers the road network and the next section covers the transit network.

The highway network is a series of links and nodes depicting all freeways, principal arterials, minor arterials and collectors in the region. TAZs are connected into the highway network by centroid connectors, which are artificial locations where traffic loads to/from the network. The data that distinguishes each highway link includes the following basic information:

- A and B nodes
- Distance
- Functional type (FT)
- Number of lanes
- One-way or two-way traffic
- Area type

The MPOs use functional type, number of lanes and area type to assign free-flow speeds and capacity values to highway links. Area type is estimated by the model based on TAZ data, but lanes and functional type are user-specified along with the basic structure and connectivity.

## 5.1 "Master" Roadway Network

The "master" roadway network is a multi-year, multi-scenario database that contains the link-specific attributes for multiple years from the base year to future years (including anticipated projects). The master network has separate lanes and FT fields for the various years/scenarios and a Voyager script is used to extract the correct network features for the scenario that is to be modeled. This process has resulted in a single network with all the input data associated with multiple years, which improves network coding efficiency and consistency.

## 5.2 Roadway Link Attributes

| Field | Example names | Field description | Populated By |
|---|---|---|---|
| Lanes | LN07, LN_2040 | The number of lanes per direction in a given scenario. In these examples, 2007 is the base year network and 2040 is the current RTP. | User |
| Facility Type | FT_2007, FT_2040 | The functional classification of a link. In these examples, 2007 is the base year network and 2040 is the current RTP. | User |
| Traffic Zone | TAZID | The TAZ that the link is within. This field is populated using GIS. | GIS, User |
| Observed Count | AWDT07 | Observed Average Weekday Traffic for 2007 | GIS, User |
| Distance | Distance | Distance of the link | Cube |
| Street name | Street Name | Street Name | User |

## 5.3 Roadway Node Attributes

| Field | Example names | Field description | Populated By |
|---|---|---|---|
| Park and Ride Lot | PNR_2007, PNR_2040 | The location of transit park and ride lots, by mode accessing the lot. | User |
| Traffic Zone | TAZID | The TAZ that the node is within. This field is populated using GIS. | GIS, User |
| District | DistLRG, DistMED, DistSML | Large District, Medium District, Small District | GIS |

## 5.4 Estimation of Roadway Free-flow Speeds

Free-flow speeds are attributed to a link based on functional type using a lookup table. The current default values for capacity and FF speed are shown in Figure 8 and Figure 10, respectively.

Methodologies in NCHRP 357 and HCM 2001 were used to estimate FF speeds. Speeds are estimated first by assuming an unsignalized speed (stratified by functional type and area type), then factoring speeds down based on an average number of stops/mile and the delay/stop for the functional type and area type. Speeds are further adjusted based on whether the link is part of a high priority or low priority corridor. Higher priority corridors are more likely to have higher green times, better signal coordination, and less on-street parking, thus higher free-flow speeds. Free flow speeds were compared against GPS speed data to adjust NCHRP 387 default values. GPS speed data was used to validate both these free flow speeds and congested speeds.

### Free Flow Speed

| | | Speed by Area Type | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| **FT** | **Functional Type** | **Rural** | **Transition** | **Suburban** | **Urban** | **CBD-Like** |
| 1 | Centroid Connector / Local | 30.0 | 23.2 | 20.2 | 17.0 | 13.5 |
| 2 | Principle Arterial | 55.0 | 44.7 | 39.6 | 32.8 | 23.4 |
| 3 | Minor Arterial | 50.0 | 39.1 | 35.3 | 30.1 | 20.4 |
| 4 | Major Collector | 43.0 | 31.7 | 28.8 | 25.7 | 18.4 |
| 5 | Minor Collector | 40.0 | 28.7 | 25.8 | 22.7 | 15.4 |

**Free Flow Speed Calulation**

SFF = 1 / ((1 / unsignalized speed) + (Num stops per mile * Uncongested delay per V / 3600))

**Unsignalized Speed**

| | Rural | Transition | Suburban | Urban | CBD-Like |
|---|---|---|---|---|---|
| **Centroid Connector / Local** | 30 | 30 | 28 | 27 | 26 |
| **Principle Arterial** | 55 | 55 | 50 | 45 | 35 |
| **Minor Arterial** | 50 | 50 | 48 | 44 | 33 |
| **Collectors** | 43 | 43 | 40 | 37 | 34 |
| **Multilane Hwy** | 50 | | | | |
| **Rural Hwy** | 51 | | | | |

**Required stops/mile due to signals or stop signs**

| | Rural | Transition | Suburban | Urban | CBD-Like |
|---|---|---|---|---|---|
| **Centroid Connector / Local** | 0.0 | 3.5 | 5.0 | 6.0 | 8.5 |
| **Principle Arterial** | 0.0 | 1.5 | 1.9 | 2.3 | 3.4 |
| **Minor Arterial** | 0.0 | 2.0 | 2.7 | 2.9 | 4.5 |
| **Collectors** | 0.0 | 3.0 | 3.5 | 3.3 | 6.0 |
| **Multilane Hwy** | 1.5 | | | | |
| **Rural Hwy** | 1.0 | | | | |

**Uncongested delay per stop - all types (Sec/veh between LOS B-C)**

| | Rural | Transition | Suburban | Urban | CBD-Like |
|---|---|---|---|---|---|
| **All types** | 0 | 10 | 10 | 13 | 15 |
| **Multilane Hwy** | 10 | | | | |
| **Rural Hwy** | 10 | | | | |

**Figure 8: Free-Flow Speed Estimation for FT 1 to FT 5**

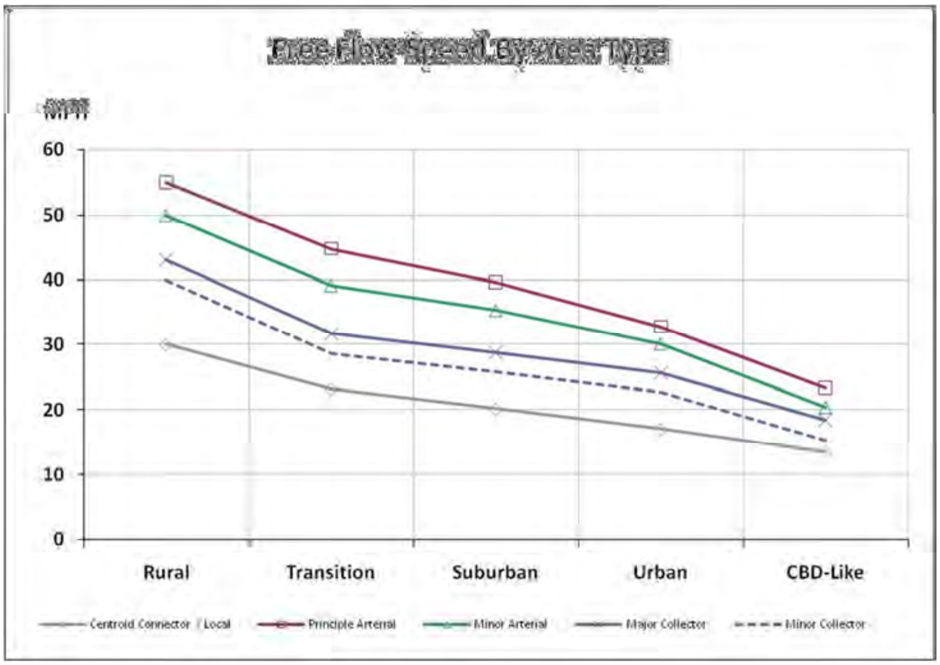



**Figure 9: Graph of Free-flow Speeds for FT 1 to FT 5**

## Free Flow Speed

| FT | Functional Type | Speed | (These do not vary by Area Type) |
|---|---|---|---|
| 9 | Innovative intersection, cross-street | 38 | |
| 10 | Innovative intersection, primary street | 42 | |
| 11 | Multilane Hwy | 41.4 | |
| 22 | Rural Hwy - Principal Arterial | 45.0 | |
| 23 | Rural Hwy - Minor Arterial | 40.0 | |
| 24 | Rural Hwy - Collector | 35.0 | |
| 29 | Fwy: system-to-system loop ramp | 40 | |
| 30 | Fwy: Lower spd, higher access CD roads | 40 | |
| 31 | Fwy: lower capacity | 67 | |
| 32 | Fwy: higher capacity | 67 | |
| 33 | Fwy: CD roads | 55 | |
| 34 | Fwy: HOV lanes | 70 | |
| 35 | Fwy: Rural/High spd | 75 | |
| 36 | Fwy: On-ramp | 23 | |
| 37 | Fwy: Off-ramp | 26 | |
| 38 | Fwy: Managed Ln access | 70 | |
| 39 | Fwy: Toll lanes | 70 | |
| 40 | Fwy: Tollway | 77.5 | |
| 42-44 | One-way couplet (P,M,C) | Same as 2,3,4, but factored by 1.05 | |

6-8, 12-21, 25-28, 41 - Unused (USTM uses 7-8)

**Notes**

Speeds are reduced by 1 mph if only 1-lane per direction to account for inability to pass

Loop ramps that are governed by a signal on one end are coded as FT 36 or 37, not 29

**Figure 10: Free-flow Speed Assumptions for FT > 5**

## 5.5 Estimation of Roadway Link Capacities

Methodologies in NCHRP 357 and HCM 2001 were used to estimate capacities, and in model version 7 these capacity rules were adjusted based on a review of estimated capacities compared to observed traffic volumes on roads of each functional type. Link capacities are attributed to a link based on functional type using a lookup table. The current default values for capacity are shown in Figure 11. Capacities are estimated by factoring a saturation flow rate by the percentages of heavy vehicles, bus blockages, lane utilization, area type and green time. Capacities for specific links known to have unusually high or low capacities can be manually adjusted using the capacity factor field on the master network.

**Capacities for Model V7.0**

| FT, Funclass | # lanes | LOS E, in vphpl (Cap1hr1ln) | Equiv. AWDT (0.09 in pkhr) | Atype | Sat. Flow Rate | Heavy Vehicle Fhv | Bus Block Fbb | Lane Utiliz. Flu | green / cycle, Fgrn |
|---|---|---|---|---|---|---|---|---|---|
| 1 Centroid | 7 | 10,000 | | | | | | | |
| 2 Principle Arterial | 1 | 930 | 21,000 | 3 | 1900 | 0.96 | 0.98 | 1 | 0.52 |
| 2 Principle Arterial | 2 | 892 | 40,000 | 3 | 1900 | 0.96 | 0.99 | 0.95 | 0.52 |
| 2 Principle Arterial | 3 | 854 | 57,000 | 3 | 1900 | 0.96 | 0.99 | 0.91 | 0.52 |
| 3 Minor Arterial | 1 | 857 | 19,000 | 3 | 1900 | 0.96 | 1 | 1 | 0.47 |
| 3 Minor Arterial | 2 | 814 | 36,000 | 3 | 1900 | 0.96 | 1 | 0.95 | 0.47 |
| 3 Minor Arterial | 3 | 780 | 52,000 | 3 | 1900 | 0.96 | 1 | 0.91 | 0.47 |
| 4 Major Collectors | 1 | 666 | 15,000 | 3 | 1700 | 0.98 | 1 | 1 | 0.40 |
| 4 Major Collectors | 2 | 633 | 28,000 | 3 | 1700 | 0.98 | 1 | 0.95 | 0.40 |
| 5 Minor Collectors | 1 | 515 | 11,000 | 3 | 1500 | 0.98 | 1 | 1 | 0.35 |
| 6-8 Unused (USTM uses 7-8) | | | | | | | | | |
| 9 innovative intersection, cross-street | 2 | 821 | 36,000 | | 1900 | 0.96 | 1 | 1 | 0.45 |
| 10 innovative intersection, primary st. | 3 | 1,003 | 67,000 | | 1900 | 0.96 | 1 | 1 | 0.55 |
| 11 High spd Multilane Hwy | 3 | 912 | 61,000 | | 1900 | 0.96 | 1 | 1 | 0.50 |
| 12-21 Unused | | | | | | | | | |
| 22-24 Rural Hwy (P,M,C) | N/A | 773 | | | 1400 | 0.92 | 1 | 1 | 0.60 |
| | Cap, x-sec | Cap1hr1ln | AWDT | Ln | Sat. | PHF | Fle | Fhv | Aux |
| 29 Fwy: system-to-system loop ramp | 1,758 | 1,758 | 20,000 | 1 | 2000 | 0.95 | 1 | 0.925 | 0 |
| 30 Fwy: Lower spd, higher access CD | 2,141 | 1,070 | 24,000 | 2 | ;20% more capacity than similar FT 2 | | | | |
| 31 Fwy: lower capacity | 5,760 | 1,920 | 128,000 | 3 | 2300 | 0.95 | 0.95 | 0.925 | 0 |
| 32 Fwy: higher capacity | 8,380 | 2,095 | 186,000 | 4 | 2400 | 0.95 | 0.91 | 0.925 | 700 |
| 33 Fwy: High spd CD (same as 29) | 1,758 | 1,758 | 20,000 | 1 | 2000 | 0.95 | 1 | 0.925 | 0 |
| 34 Fwy: HOV lanes | 2,280 | 2,280 | 25,000 | 1 | 2400 | 0.95 | 1 | 1 | 0 |
| 35 Fwy: Rural/High spd (same as 31) | 5,760 | 1,920 | 128,000 | 3 | 2300 | 0.95 | 0.95 | 0.925 | 0 |
| 36 Fwy: On ramp | 1,300 | 650 | 14,000 | 2 | | | | | |
| 37 Fwy: Off ramp (same as FT 2) | 1,962 | 981 | 22,000 | 2 | Same as FT 2, but 10% higher Fgrn | | | | |
| 38 Fwy: Managed Ln access | | Same as 34 | | | | | | | |
| 39 Fwy: Toll lanes | | Same as 34 | | | | | | | |
| 40 Fwy: Tollway | | Same as 34 | | | | | | | |
| 42-44 One-way couplet (P,M,C) | Same as 2,3,4, but factored by 1.20 for better green time from reduced phases | | | | | | | | |

**Non-freeway calculations & adjustments**

Cap1hr1ln = _SatRate * Fhv * Fbb * Flu * Fgrn * Fatype

FT 2-5 is factored up or down by the following Fatype factors

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | Rural | Trans | Sub. | Urb. | CBD |
| Fatype | 1.10 | 1.05 | 1.00 | 0.95 | 0.90 |

* An internal calculation tries to detect the likelihood of protected lefts at an intersection, and reduces Fgrn by .05

**Freeway calculations & adjustments**

Cap1hr = (Sat * LANES * PHF * Fle * Fhv) + AuxVolAtCapacity ;AuxVol = 0 for FT 31; 700 for FT 32

Cap1hr1ln = Cap1hr / LANES ;distributes AuxVolAtCapacity across the GP lanes

FT 31-32 capacities are reduced by "Lane Efficiency" factors (Fle)

| | 3-ln | 4-ln | 5-ln | 6-ln | 7+ln |
|---|---|---|---|---|---|
| Fle | 0.95 | 0.91 | 0.88 | 0.86 | 0.84 |

Fhv = 1/(1+ PCThv * (Ehv - 1)) Ehv = 2.0 (Meaning a heavy vehicle has effect of 2 autos in urban areas)

* V7.0 currently assumes 8% trucks on all FT 31-32, which makes Fhv = .925.

* It is possible to connect this to a link attribute (PCThv by location), or to a truck model

The base year calibrated network also has "CFAC07", which if not zero, will be multiplied by Cap1hr1ln

CFAC < 1 means the road has less capacity than normal (side friction, heavy cross streets, no center turn lane, single-left pockets, no right pockets, etc)

CFAC > 1 means the road has better capacity than normal (good access control, light cross streets, high-efficiency intersections, etc).

**Figure 11: Capacity Estimation**

## 5.6 Toll & HOV/HOT Lanes

Model version 7 allows explicit representation of HOV and toll trips (including HOT lanes). This was done by extending the nested logit mode choice model to consider toll and HOV highway travel separately from general purpose lane highway travel, in the same way that the model differentiates between local, express, and rail transit modes. This section describes how to code the highway networks to utilize the managed lanes functionality of the WFRC/MAG models. The coding convention is different for mixed facilities (where managed lanes (HOV/HOT) parallel general purpose lanes) than it is for tollways.

### 5.6.1 Coding Dedicated Toll Facilities

A tollway is defined for these purposes as a limited access highway where every lane is tolled (i.e. there is no free capacity). The functional type for a tollway is FT=40, the free flow speed is 68 mph, and the capacity is 2400 veh/hour/lane. Coding a tollway is the same as coding a regular freeway facility, and you can test freeway vs. tollway scenarios by setting up multiple scenarios in the master network where the FT is different.

The toll cost is assessed on a per-mile basis; the farther one travels on the tollway, the higher the toll cost. To set this toll rate, go to the ControlCenter file and search for "FT40_cost_Pk". The toll rate can vary by period (peak or offpeak), and by facility type (HOT lanes can have different rates than tollways). The cost is in cents per mile. The offpeak toll cost for tollways is set using the variable "FT40_cost_Ok".

Do not adjust the variables "FT40_value_Pk" or "FT40_value_Ok". These are values of time that are used to convert the toll cost to time for the purposes of finding the shortest toll path. The mode choice model needs to know how the toll path is different from the non-toll path in terms of time/cost, and this value of time is used to determine the minimum cost toll path.

### 5.6.2 Coding Mixed Facilities (Freeways with HOV/HOT lanes)

Mixed facilities are coded with the managed lane links inside the general purpose links. HOV links are functional type 34. HOT links are functional type 39. Links that connect the HOV/HOT links to the general purpose network are functional type 38. These links all have a free-flow speed of 68 mph and a capacity of 2400 veh/hour/lane. The links are all one-way links and other freeway coding conventions apply, such as access being controlled by interchanges. The one important difference is that access to and/from the general purpose lanes is controlled via FT 38 links. Carefully code access to/from the managed lane consistent with the design of the managed lane. For the currently non-barrier separated I-15 HOV lane, we simply provide one on and one off access link per direction between each set of interchanges.

It is important to note that the trip distribution phase of the model does not "see" the managed lanes as existing. While these lanes will carry some traffic and probably affect mainline speeds, the managed lane assignment process only is used during the final assignment step, after mode choice. To account for the extra capacity provided by managed lanes, the distribution model artificially inflates the general purpose capacity if a managed lane is parallel to the general purpose lanes. For example, the general purpose link might have LN = 4 on the mainline, and LN = 1 on the managed facility, for a total of 5 freeway lanes of potential "throughput". Since trip distribution will see only one the mainline link with 4 lanes, the idea is to increase mainline capacity.

The network includes an attribute on the mainline that identifies that link as having a parallel managed lane (the "HOV_LYEAR" field). This field is a five-number variable, with the first number indicating the number of parallel managed lanes in each direction, and the second number indicating the year which those lanes are opened to the general public. For example, "12010", means "1 lane, drivable in 2010". If the model finds non-zero values in this field, it thinks there is a managed lane there, so be careful.

The master network has managed lanes coded for significant sections of I-15 as a reference.

# 6.0 TRANSIT NETWORK

## 6.1 Transit Modes in the Model

The starting point for transit network is the current transit system. All bus and rail routes are included in the network, with the exception of ski routes, vanpools and other commuter services to specific workplaces. Future transit networks are developed to be consistent with the current Transit Development Program developed cooperatively by the MPOs and UTA. Transit networks include local buses, express buses, bus rapid transit routes, light rail lines, and commuter rail lines.

The primary transit input is the transit line file. The line file describes the route characteristics and alignment. The information needed for each transit line includes:

- Route name
- Mode number
    - Local bus (mode 4)
    - Bus rapid transit (mode 5)
    - Express bus (mode 6)
    - Light rail (mode 7)
    - Commuter rail (mode 8)
    - Special use (mode 9) – to be discussed later in this chapter
- Route stops
- Speed (typically used for fixed guideway only)
- Peak/Off-peak period headway

## 6.2 Transit Access/Egress Support Links

Access and egress links are necessary in the model so that trips can get from the TAZ or roadway network onto the transit network. The access/egress links specify which TAZs are connected to which bus and rail stops. There are separate links for walk access/egress, for transferring between transit lines, and for drive access to transit.

- **Walk access/egress**: Two-way links between zone centroids and transit stop nodes. These are auto-generated based on the distance from the centroid to the transit stop (mode 11 links). Where the user wants to assure walk access connectivity, access/egress links can be added manually (mode 12 links).
- **Drive access**: These directional links provide a connection from TAZ centroids to park-and-ride (PNR) and transit stop nodes on the roadway network. Separate links are built to PNR lots for each transit mode and the drive access links are modes 40, 50, 60, 70, 80. Drive access links can be manually added to the network using the same mode numbering.
- **Transfer links**: Two direction walk link to facilitate transfers between pairs of stop nodes that are nearby (mode 21 for auto-generated links, mode 22 for user-specified links).

Coding walk and drive access support links and specifying the walk distance is an arduous and potentially arbitrary and inconsistent element of aggregate mode choice models. In order to facilitate the use of the model in a consistent manner for transit path-building, a set of routines were developed to automate the construction of support links in the travel model. While user judgment must never be removed, these processes are run as part of the path building process and ensure generally consistent transit access coding regardless of whose using the model.

## 6.2.1 Walk Access/Egress Links

Walk access and egress links are developed based on the X-Y distance between the TAZ centroid and a transit stop. The walk access/egress link generator identifies and builds the shortest access link to each transit stop that falls within the maximum walking distance threshold. The routine was complicated to develop in Voyager scripting, but there are two very important features that distinguish this approach from past versions of the model, which also had a simple form of this functionality. First, the X-Y distance between centroids and transit stops is used, and not the over-the-network distance, which now essentially ensures that an access link is built to all transit lines that run on links that form the border of a TAZ. Secondly, there is a maximum walking distance threshold, which is always a detail that is hard to specify in aggregate models because the sizes of TAZs are not uniform. The walk distance threshold varies by TAZ size, and this approach is used to assure that larger TAZs are connected to the transit system.

**Table 8: Maximum Walk Access/Egress Link Distances (X-Y distance)**

| TAZ Area (Sq. Miles) | Example Dimensions (square TAZ) | Maximum Walk Link Length | Typical Location |
|---|---|---|---|
| <= .0625 | .25 mi X .25 mi | 1/4 mile | CBD/Urban |
| .0625 to .25 | .5 mi X .5 mi | 4/10 mile | Suburban |
| > .25 | > .5 mi X .5 mi | 6/10 mile | Transition/Rural |

This approach was developed based on a review of transit use in the recent on-board surveys, but it is admittedly not without flaw. This approach is better than the approach in v6 and earlier version of the model because it utilizes the X-Y distance and not a network-based distance. However, for the large TAZs it is impractical that all portions of the TAZ would have access to transit lines that run on a particular side of the TAZ polygon. However, to ensure access for anyone in the TAZ to each of these lines, we made the assumption to connect the TAZs uniformly, but with a long walk link. The outcome of this, relative to older versions of the model, is that transit access has increased.

Figure 12 shows a sample of the walk access and egress links that are generated from this process, with the link color distinguishing links of different lengths (green <.25 mi, red <.4 mi, and purple>.4 mi). The walk links tend to reach only to the edge of the TAZ boundary, generally in all directions (if there is a transit line adjacent to each edge). This figure illustrates that walk access links in the suburbs extend to the TAZ boundary but do not tend extend beyond. This graphic was made using model version 6.1 and so is consistent with the v6 TAZ structure.

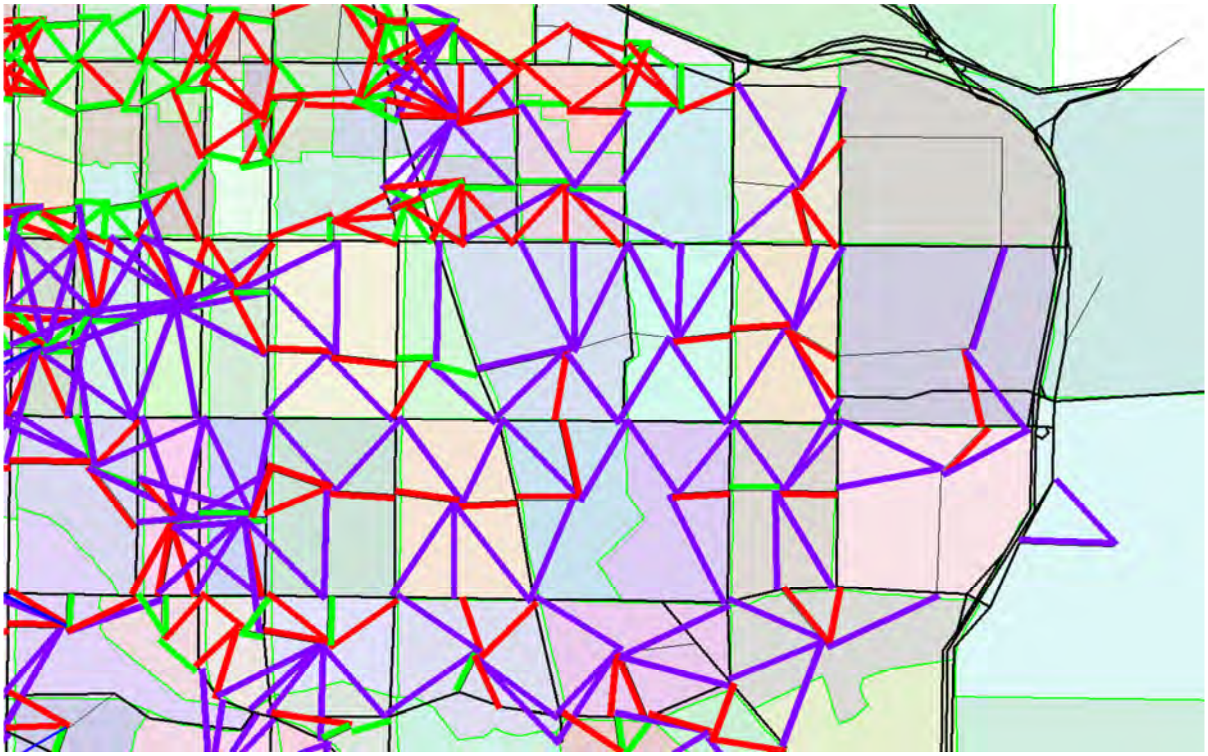


**Figure 12: Automated Walk Access/Egress Links (portion of South Salt Lake City near Parley's Canyon)**

### 6.2.2 Walk Access Buffers

A walk access link does not necessarily mean the entire TAZ has walk access to transit. The model uses a GIS process to estimate transit walk accessibility. The methodology assumes a 0.4 mile buffer around transit services. Buffering is done around a point shape representing the transit stops for rail lines, BRT lines and express bus routes. For local bus routes, the buffering is done around a line shape to account for frequent stopping by a local bus. These buffers are intersected with the TAZ to calculate the percentage of the TAZ area within walking distance of transit. The percentages calculated for local bus routes and transit stops are considered independently and the maximum of the individual percentages is used to estimate the transit walk accessibility for the zone.

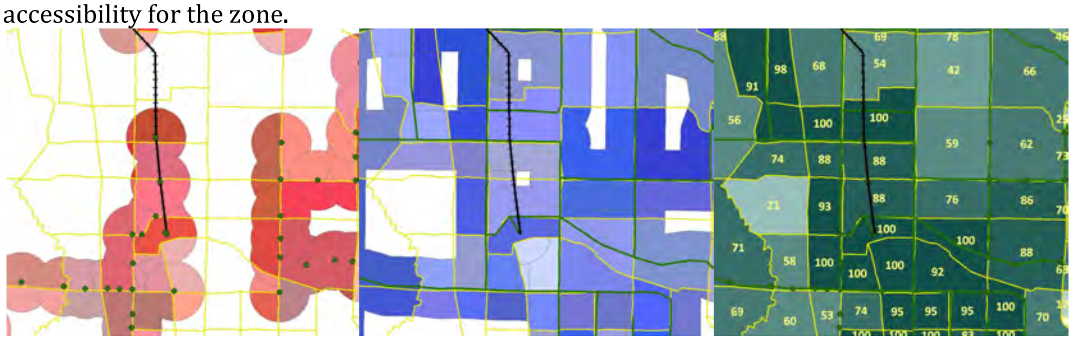


**Figure 13: Example of Walk Buffers for Limited Stop Services (Red), Local Bus (Blue) and combined (Green)**

### 6.2.3 Drive Access Links

The drive access links are also automatically generated based on a process that has been reviewed and refined over the years. Drive access trips can utilize a park-and-ride lot, or not (where a passenger is dropped off). Regardless, drive access links are developed based on an automated process that requires the user to specify the location of the drive access location (referred to as a park and ride lot). Separate mode numbers are used for drive access locations that serve different modes, which helps display, understand and control drive access to each mode. The park and ride lot is coded onto the roadway network, adjacent to a transit stop. A model script identifies the closest "n" PNR lots for each transit mode and generates drive access links. Here is a brief description of that process:

- **(User) Code PNR lots on roadway network**: All PNR lots or drive access locations are coded as node attributes on the master street network.
- **(Model) Confirm that lot coincides with routes for scenario**: First, the model identifies all transit stops by node and mode. The script then writes out a list of nodes where a transit stop node was identified as a PNR lot and that mode actually stops at that node.
- **(Model) Print PNR access links from TAZs to nearby PNR nodes with transit service (separately for each mode)**: The nearest lots to a given zone are identified, and a PNR record is printed for that path. The number of access links printed varies by mode. For commuter rail, the nearest two lots are printed. For light rail, BRT, and express bus, the nearest three lots are identified from each TAZ.

Locations for which drive access is allowed must be coded with a PNR lot on the network node and can represent a UTA lot, an important informal parking location such as a side street or business lot, or a drop-off location. The lots are identified based on what modes stop at the PNR lot, and access links are generated to allow each TAZ to access each type of service, with some exceptions or restrictions.

## 6.3 Transit Operating Speeds

### 6.3.1 Bus Speeds

Bus speeds are estimated inside the model, and pivot off the auto speeds. A relationship was calibrated comparing bus scheduled times to observed auto travel times. In general, bus speeds are slower than auto speeds and this relationship varies considerably by the type of road on which the bus is traveling. Bus speeds closely approximate auto speeds on freeways, where buses are not stopping or merging in and out of traffic, but on arterials buses travel measurably slower than autos due to the need to pick up and drop off passengers.

The estimated relationship between local bus speeds and auto speeds is as follows:

- Freeways – buses travel at 95% of auto speeds
- Principal arterials – buses travel at 60% of auto speeds
- Minor arterials
  - Urban areas – buses travel at 55% of auto speeds
  - Suburban/rural areas – buses travel at 65% of auto speeds
- Collectors – buses travel at 60% of auto speeds

The above relationships were estimated for the buses operating in 2003 but have been validated as recently as 2009.

It is understood that in some models computing transit speeds as a function of auto speeds can be problematic because the auto speeds drop to extremely low values and then the transit speeds are even lower. This does not appear to be a problem in the model.

### 6.3.2 Rail Speeds

Rail lines are typically coded on dedicated rail links, rather than on the roadway network (even if the rail line runs in the road median). One of the necessary details, in addition to coding the rail links, is the coding of a rail operating speed.

To assist with this, WFRC developed a rail speed calculator based on observed rail speed and relating the observed speed to operating conditions. Key variables in the model include acceleration/deceleration ability of the rail vehicle, maximum cruise speeds, distance between stations, station dwell times, number of stop lights and speed limit if in street operation. Figure 14 highlights the estimated speed vs. the observed speed for the north-south TRAX line.

This approach has been refined using observed speeds on the existing Sandy and University Lines, which operate in very different settings. This calculator is an off-model tool that is useful in defining plausible speeds, though other estimates can certainly be used.

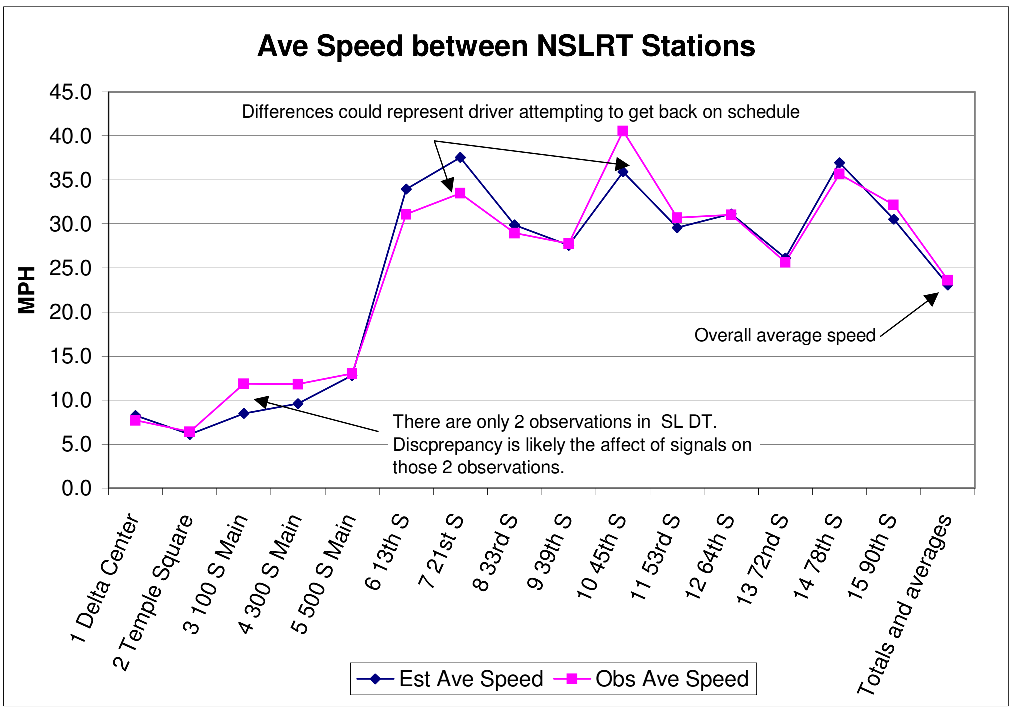



**Figure 14: Validation of the Rail Speed Calculator**

## 6.4 Bus Rapid Transit & Mode 9

Bus Rapid Transit (BRT) was introduced as a new mode in the model because BRT is a bus service with some premium service enhancements and speed advantage over typical local buses. However, the range of service amenities and the magnitude of the speed advantage can vary widely. Ignoring this reality for a moment, the following default rules are built into the model to distinguish the BRT mode from local bus and rail.

- First, for path-building and mode identification, the BRT mode is considered more premium than local bus, but less so than rail, so in the hierarchy of the mode choice model a path with BRT is considered a BRT path, unless rail is included, then the path is a rail path.
- The BRT fare is assumed to be the same fare as LRT and local bus ($1). These fares represent approximate out-of-pocket costs per rider per trip and were developed from on-board survey data, accounting for the distribution of types of fares paid by riders.
- BRT lines by default are assumed to have higher operating speeds than local buses. The following factors can affect the speed of transit:
    - Congestion on the roadway
    - Percent of exclusive right of way - local buses have none, BRT lines may have partial or completely exclusive right of way
    - Passenger loading - BRT lines are assumed to have multiple door loading, resulting in less time stopped at stations than local bus service
    - Fare payment methods - BRT lines are assumed have off-vehicle fare collection, resulting in quicker loading than local bus service

BRT buses are assumed to operate at slightly higher speeds than local buses (80% of auto speeds on arterials; approximately 30% faster than local buses) to reflect longer distances between stops and shorter dwell times, but these defaults can and should be modified where appropriate by hand.

By default, the BRT mode-specific constants are assumed to be half of the rail constants. This means that BRT is assumed to have half of the "unobserved" advantage over local bus that rail does. These "unobserved" advantages are due to attributes that may not be explicit inputs in the model, but can have a significant impact to ridership. These attributes are accounted for in the mode-specific constant. The following attributes can increase ridership without decreasing travel time or cost by making the traveling experience more pleasant:

- Branding and promotion
- Better schedule reliability
- Simplicity of route structure
- Fare collection and media
- More comfortable seats
- Real-time passenger info
- Intrinsic motivators, such as attractiveness of mode, etc

The mode choice models have a premium walk access coefficient, which provides a bonus to travelers that can access premium transit services directly by walking. This parameter acts in accordance with transfer penalties to assure calibration of the access-to-linehaul behavior in the model. The rationale for this parameter is that the general population is assumed to be more aware of nearby premium services, for a variety of reasons, such as promotion, presence, and simplicity of service. The BRT and express bus premium walk access coefficient is assumed to be 5 minutes, which is half of the LRT premium walk access coefficient.

### 6.4.1 Using Mode 9 for BRT

BRT is mode number 5 in the transit network coding convention. In the long-range plan, there are several proposed BRT lines throughout the region. Sensitivity tests have shown that the mode-specific constant is the single biggest factor in determining the ridership forecast for BRT. The mode specific constant for BRT is set at half the LRT constant, and this assumption applies to all BRT lines in the model. This universal application does not account for the fact that some BRT lines are more bus-like, and some are more rail-like, resulting in the need for different proportions of the LRT constant applied to each BRT line. This presents a bit of a challenge when a specific BRT line is evaluated in a corridor study and the modeler wants to vary the mode-specific constant assumption.

To rectify this issue for the on-going Utah County Rapid Transit project, which is a Small Starts evaluation of a BRT alternative, a second BRT mode (mode number 9) was created to allow for changing the constant without affecting every other BRT line in the model. This new BRT mode produces the same forecast as mode 5 with comparable inputs and assumptions.

While this functionality exists in the model, as a general rule-of-thumb, Mode 9 should not be used. This functionality will only work as intended in cases like the Utah County BRT project where the proposed service is geographically isolated from other BRT services. If other mode 5 services exist generally in the same corridor the use of mode 9 will result in artificially higher ridership on the system due to the basic mathematics of logit models.

# 7.0 SURVEY DATASETS USED FOR MODEL DEVELOPMENT

There are a few survey datasets that are central to the development of the statistical models of traveler behavior that will be presented in this document. Before discussing the models, it is useful to highlight the surveys.

## 7.1 Household Trip Diary Survey (1993)

A household trip diary survey was conducted in 1993. The central purpose of the trip diary survey was to gather data from Wasatch Front residents about their normal weekday trip-making activity:

- Demographic information.
- When did they make trips?
- Where did their trips start and end?
- What was the purpose of each trip?
- What mode of transport did they use to make each trip?

The trip diary survey provides the source of information for six key components to the travel model: auto ownership, trip generation, trip distribution, mode choice, diurnal distribution (time of day) and auto occupancy. The trip generation model estimates the number of trips a household will make based on factors such as household size and number of vehicles owned by the household. The trip generation model outputs the number of person trips produced by and attracted to each TAZ in the model.

The sampling design for the survey stratified the sample of households by Urbanized Area (Ogden, Salt Lake, and Provo/Orem), by auto ownership (0,1,2,3+) and by household size (1,2,3,4,5,6+).

The geographic breakdown allocated a slightly larger portion of the sample to the Salt Lake Urbanized Area, which has over 50% of the population of the region. The targeted distribution of households was:

- Salt Lake UA: 1200 households
- Ogden UA: 900 households
- Provo-Orem UA: 900 households

A minimum sample size was chosen to achieve an overall error rate of .05 with a 90% level of confidence. The minimums would have been satisfied with a smaller sample size than the actual sample. As a result, the sample was more than sufficient to meet the desired accuracy levels. The process of sample selection is described in the 1993 Home Interview Travel Survey Methods Report issued in December of 1993.

Expansion factors were developed to convert the survey data into a data set for the entire area. The expansion factors were determined based on auto ownership, household size and geographic area. Auto ownership and household size are the two major variables in determining the sampling process in the home interview survey and therefore should be considered in the factoring procedure. The geographic area is an essential variable to correct any geographical bias, which greatly affect travel patterns (in terms trip generation and trip distribution), during the sampling procedure and the course of the survey.

The 1990 Census was used as the basis for expansion because it allowed derivation of the percentages of households by auto ownership and household size.

## 7.2 National Household Travel Survey (2001/2008)

Conducted periodically since 1969 by the Federal Highway Administration (FHWA), the National Household Travel Survey (NHTS) is the nation's inventory of daily and long-distance travel. The NHTS is the nation's flagship survey to quantify the travel behavior of the American public. The survey has provided the nation with useful data on travel by all modes of transportation, for all travel purposes, and all travel distances. The NHTS series provide vital data on American passenger travel and can be used to examine the relationship among social and demographic change, land development patterns, and transportation.

The 2008 NHTS is the most recent available survey, and surveys were done somewhat recently in 2001 and 1995. The survey collected data from over 200 households along the Wasatch Front, and is a useful indicator of travel patterns and how they may have changed in the decade or so since the Wasatch Front travel diary survey was conducted. These data have been used to validate trip generation rates and trip length distributions in the model.

## 7.3 Census Transportation Planning Package (2000)

The Census Transportation Planning Package (CTPP) is a set of special tabulations from the decennial census designed for transportation planners. The data are tabulated from answers to the Census 2000 long form questionnaire, mailed to one in six U.S. households. Because of the large sample size, the data are reliable and accurate. CTPP provides comprehensive and cost-effective data, in a standard format, across the United States. These data are useful in understanding mode share to work, time of day leaving for work and trip lengths. Like the NHTS, they are a good indicator of work travel trends over time and whether or not they are changing.

## 7.4 On-board Transit Survey (2002/2006)

System-wide on-board transit surveys for the purpose of travel model development have been recently collected in 2002 and again in 2006. The 2002 survey was developed and collected by UTA staff, while the 2006 survey was contracted out. The central purpose of the on-board surveys was to gather data from transit users along the Wasatch Front about the trip they were making when the survey was conducted:

- Demographic information.
- When did they make trips?
- Where did their trips start and end?
- What was the purpose of each trip?
- What are the characteristics of their transit path?

The surveys were collected to make refinements to the regional travel models and for use in FTA New Starts analyses and before-and-after studies. The on-board survey data have been specifically used to calibrate the mode choice model parameters and to adjust transit path-building parameters and assumptions.

Data collection for the 2006 UTA On-board Survey occurred between late March 2006 and early May 2006. A report detailing the methods used to collect the 2006 On-board is available upon request from WFRC, but here are excerpts discussing the sampling plan.

Of the approximately 110 regular routes in the UTA system, 93 routes were sampled, containing both TRAX Rail lines (Routes 701 and 702), and fixed route bus service. A sampling plan was designed to be statistically significant at the route level, and to provide a sample size adequate for analysis of both rail and bus service. The survey data collection resulted in 5,600 returned questionnaires, and approximately 4,500 were usable upon careful data cleaning.

# 8.0 AUTO OWNERSHIP

The auto ownership model is a multinomial logit model that estimates auto ownership levels based on characteristics of the population and the home location. It uses household characteristics from the socio-economic and household income files and land-use variables from the employment-within-30-minutes-of-transit and zonal urbanization files in generating auto ownership.

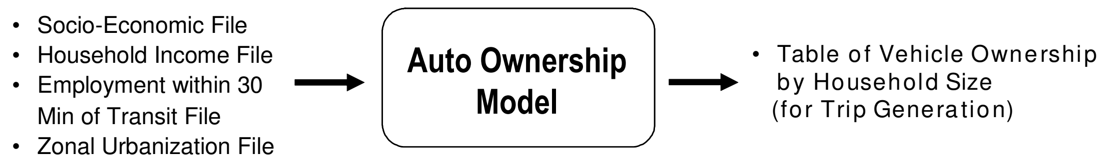



**Figure 15: Auto Ownership Model Data I/O**

The autos-by-HH size table includes six household categories (1, 2, 3, 4, 5, and 6+ persons per household) and four vehicle categories (0, 1, 2, or 3+ vehicles per household). This information, along with some summary information, is estimated for every TAZ and is input to the trip generation phase of the model.

Household and land-use characteristics used by the auto ownership model were estimated from the 1993 Home Interview Survey. The variables determined to be significant in replicating the behavioral characteristics of a household's decision to own or not to own vehicles are the key parameters used in the logit model's utility equations. The constants were calibrated to reflect auto ownership patterns by socioeconomic class from the 2000 Census.

All parameters in the utility equations are significant at the .05 level, except the parameter for (pop. density for nearest 9 zones) for the 2-vehicle choice, which is significant at 0.10.

Low-income or smaller household sizes or households with fewer workers are less likely to own as many vehicles as larger-income households or households with more people or more workers. Higher density locations correlate with lower auto ownership and that households with fewer vehicles were seen to live in more transit-accessible neighborhoods.

The coefficients of the household parameters, HH1 through HH4, are relative to the households with five or more persons in them. As such, the HH5 and HH6+ parameters are set to zero. Since these parameters are set to zero, the HH5 and HH6+ parameters are excluded from the utility equations. Likewise, the worker parameters, WRK0 through WRK2, are relative to 3+ workers per household, so the WRK3+ parameter is also set to zero and excluded from the equations. The other parameters displaying zero coefficients in the utility equations are listed for clarification purposes. The 0, 1, and 2 vehicle utility equations are relative to the 3+ vehicle utility, hence the 3+ vehicle utility is set to zero.

**Equation 1: Auto Ownership Model Utility Equations**

$$
\begin{aligned}
\text{Utility for Owning 0 Vehicles} = \; & -4.2944 + 3.361 * HH1 + 0.999 * HH2 + 0 * HH3 + 0 * HH4 \\
& + 0.998 * WRK0 + 0 * WRK1 + 0 * WRK2 \\
& + 2.733 * INCL + 0.05159 * POPDEN \\
& + 0.00001990 * EMP30TRAN
\end{aligned}
$$

$$
\begin{aligned}
\text{Utility for Owning 1 Vehicles} = \; & -3.0894 + 2.971 * HH1 + 1.008 * HH2 + 0 * HH3 + 0 * HH4 \\
& + 1.947 * WRK0 + 1.985 * WRK1 + 1.433 * WRK2 \\
& + 1.557 * INCL + 0.07346 * POPDEN \\
& + 0.000008342 * EMP30TRAN
\end{aligned}
$$

$$
\begin{aligned}
\text{Utility for Owning 2 Vehicles} = \; & -1.0604 + 0.593 * HH1 + 0.438 * HH2 - 0.320 * HH3 - 0.289 * HH4 \\
& + 1.638 * WRK0 + 1.719 * WRK1 + 1.708 * WRK2 \\
& + 0.538 * INCL + 0.02366 * POPDEN
\end{aligned}
$$

$$
\text{Utility for Owning 3+ Vehicles} = 0
$$

where:

HH1 = 1 if a 1 person household, 0 otherwise

HH2 = 1 if a 2 person household, 0 otherwise

HH3 = 1 if a 3 person household, 0 otherwise

HH4 = 1 if a 4 person household, 0 otherwise

WRK0 = 1 if a 0 worker household, 0 otherwise

WRK1 = 1 if a 1 worker household, 0 otherwise

WRK2 = 1 if a 2 worker household, 0 otherwise

INCL = 1 if lowest income quartile, 0 otherwise

POPDEN = population density of nearest 9 zones (population/acres)

EMP30TRAN = employment within 30 minutes of transit

# 9.0 TRIP GENERATION

The trip generation module estimates daily person trips produced in and attracted to each TAZ. These estimates result from multiplying the land use data for each TAZ, such as the number of dwelling units and employment numbers, by regional trip generation coefficients.

Trip generation is done in four steps:

1) Generating productions and attractions,
2) Adjusting productions and attractions for special-generator zones,
3) Estimating trips to and from external stations, and
4) Balancing total productions and attractions.

Trip generation uses the auto ownership by household-size file output from the auto ownership model as well as the socio-economic file, internal-external zone data file, home-based college trip table, and the district lookup file to calculate TAZ productions and attractions. Productions and attractions are reported for five trip purposes (HBW/HBO/NHB/IXXI/COMM) and are used in the trip distribution phase of the Model.


**Figure 16: Trip Generation File I/O**

## 9.1 Trip Generation Model Structure

Each trip has two trip ends—an origin or starting zone, and a destination or ending zone. For modeling purposes, trip ends also can be categorized as "productions" and "attractions." Productions and attractions are different from origins and destinations. Trip generation estimates productions and attractions by multiplying key variables by trip generation rates. The trip rates represent an average of the three surveyed urbanized areas: Ogden, Salt Lake, and Provo/Orem.

Production ends occur at the trip maker's residence. When one leaves home for work in the morning, the origin (home) is also the production. In the afternoon, when one returns home from work, the destination (home) is the production. Thus, productions are based on the number of housing units within a TAZ. For non-home-based trips, where the residence is typically not on either end of the trip, productions are calculated based on the predilections of households to make these types of trips. This predilection is estimated statistically from the household trip diary data. The location of NHB trips, however, is estimated from trip attraction models.

Attraction ends are non-home land uses including workplaces, other peoples' homes, shops, and schools. The total number of attractions for each trip type is set equal to the total number of productions. If productions and attractions are out of balance, the attractions must compete with each other for trip ends.

# 9.2 Estimating Trip Generation Rates

## 9.2.1 Trip Production Rates

**HBW** — Auto Ownership (HH Size)

| HH Size | 0 Veh | 1 Veh | 2 Veh | 3+ Veh |
|---|---|---|---|---|
| 1 Person | 0.32 | 0.70 | 1.07 | 1.14 |
| 2 Person | 1.04 | 1.23 | 1.52 | 1.92 |
| 3 Person | 1.47 | 1.54 | 1.79 | 2.38 |
| 4 Person | 1.77 | 1.76 | 1.97 | 2.70 |
| 5 Person | 2.01 | 1.93 | 2.12 | 2.95 |
| 6+ Person | 2.20 | 2.24 | 2.31 | 3.32 |

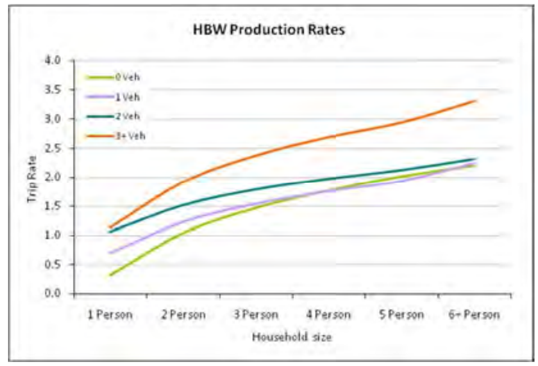



**Figure 17: HBW Trip Production Rates**

**HBO** — Auto Ownership (HH Size)

| HH Size | 0 Veh | 1 Veh | 2 Veh | 3+ Veh |
|---|---|---|---|---|
| 1 Person | 1.99 | 2.51 | 2.45 | 1.91 |
| 2 Person | 3.62 | 4.13 | 4.14 | 4.52 |
| 3 Person | 5.01 | 5.90 | 5.98 | 7.10 |
| 4 Person | 6.33 | 7.96 | 8.19 | 9.77 |
| 5 Person | 7.63 | 10.42 | 10.85 | 12.62 |
| 6+ Person | 8.96 | 13.59 | 16.42 | 18.67 |

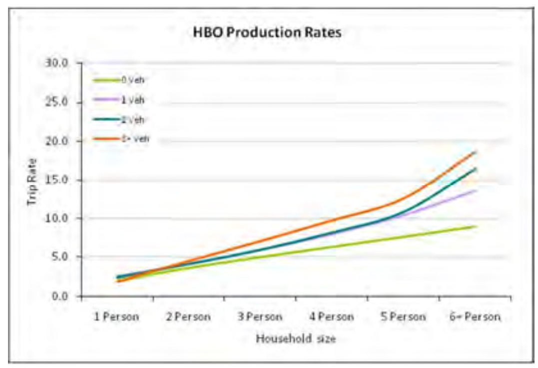



**Figure 18: HBO Trip Production Rates**

**NHB** — Auto Ownership (HH Size)

| HH Size | 0 Veh | 1 Veh | 2 Veh | 3+ Veh |
|---|---|---|---|---|
| 1 Person | 1.43 | 2.01 | 2.14 | 2.30 |
| 2 Person | 2.61 | 2.85 | 3.42 | 3.42 |
| 3 Person | 3.25 | 3.81 | 4.59 | 4.90 |
| 4 Person | 4.39 | 4.79 | 5.00 | 6.08 |
| 5 Person | 4.73 | 5.23 | 5.99 | 6.32 |
| 6+ Person | 5.59 | 6.09 | 6.70 | 7.41 |

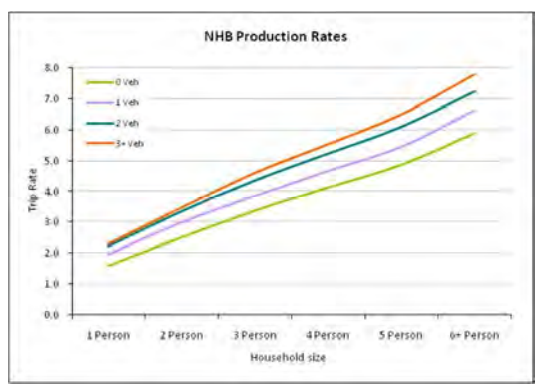



**Figure 19: NHB Trip Production Rates**

### 9.2.2 Trip Attraction Rates

Attraction ends are non-home land uses such as workplaces, shops, schools, hospitals, and other people's residences. The number of trip-ends each employment class attracts was initially estimated from a regression analysis based on the 1993 trip diary survey. For model v7, trip attraction rates were adjusted using professional judgment to make them somewhat more intuitive.

The following variables were determined to be the key variables in estimating attractions:

- Total Households (TOTHH)
- Total Employment (TOTEMP)
- Retail Employment (RETEMP)
- Industrial Employment (INDEMP)
- Other Employment (OTHEMP)

**Equation 2: Trip Attraction Equations**

HBW Attractions = TOTEMP*1

HBO Attractions = RETEMP*10 + OTHEMP*3 + TOTHH*4

NHB Attractions = RETEMP*6 + INDEMP*.8 + OTHEMP*2 + TOTHH*2

COMM Attractions = RETEMP*.5 + INDEMP*1.25 + OTHEMP*.25 + TOTHH*.1

## 9.3 Balancing Attractions to Productions

After all productions and attractions have been calculated, total attractions are adjusted to equal total productions by trip purpose. It is common practice in transportation network modeling to balance attractions to productions. The rationale is that productions are more fundamental. More housing will produce more trips; more retail space may simply draw customers from other retail space.

This practice has important implications for using the model to analyze regional traffic impacts emanating from changes in employment land use. For example, if traffic impacts of a proposed major employer are to be analyzed, the projected amount of new employment must be inserted into appropriate TAZ. These new jobs will attract new trips. However, without also increasing by some amount the number of residences in the region, no net increase in trips will result. Thus, these types of scenarios must be carefully considered as to their employment and residential impacts in order for the model to lend proper insight into transportation implications.

## 9.4 Special Generators

Certain traffic zones require special trip generation techniques because the intensity of activity is not accurately modeled with basic trip generation methods. These special generator zones include locations such as universities, airports, sports complexes, and major attractions such as the SLC library and Temple Square. Total trip-ends in special generator zones are predicted using unique attraction equations that were estimated for each special generator zone. Table 9 documents the special generators in the model, along with the trip attraction equations.

**Table 9: Special Generator Zones and Trip Attractions**

| TAZ | Location | Attraction Equation |
|---|---|---|
| 812 | Temple Square | 13,700 visitors per day (2005), meaning 27,400 trip-ends, times 1.5% annual growth |
| 861 | SLC Library | 8,500 visitors per day (2005), meaning 17,000 trip-ends, times 1.5% annual growth |
| 241,744,921,922,<br>796,972,996,1338,<br>1559,1924,1925, 1959 | College/Universities | FTE * 2.4 vehicle trips/FTE * 1.7 persons/veh |
| 589 | Airport | See trip distribution section |

## 9.5 External Trips

There are two types of external trips. The first, so-called internal-external or external-internal trips (IX-XI trips), includes trips with one trip-end outside of the model area. The second type of external trips are external-external trips (XX trips), which do not stop in the region.

Total external trips (IXXI plus XX) are controlled to traffic counts at the external stations in the base year. For future years, external trips are factored up from the base year based on an asserted growth rate of around 2%. To split the external traffic counts into IXXI and XX trips, it is assumed that only major external stations (the interstates) carry XX trips, and the percentage of XX on these facilities is asserted based on professional judgment and a review of count data outside the external. For example, it is assumed that the XX demand on I-80 is proportionate and not higher than the vehicular demand either in the west desert of Utah or near the Wyoming border. An initial XX percentage of 13% was assumed for each major external, based n external survey data from the Phoenix metro area. This assumption was increased in some cases.

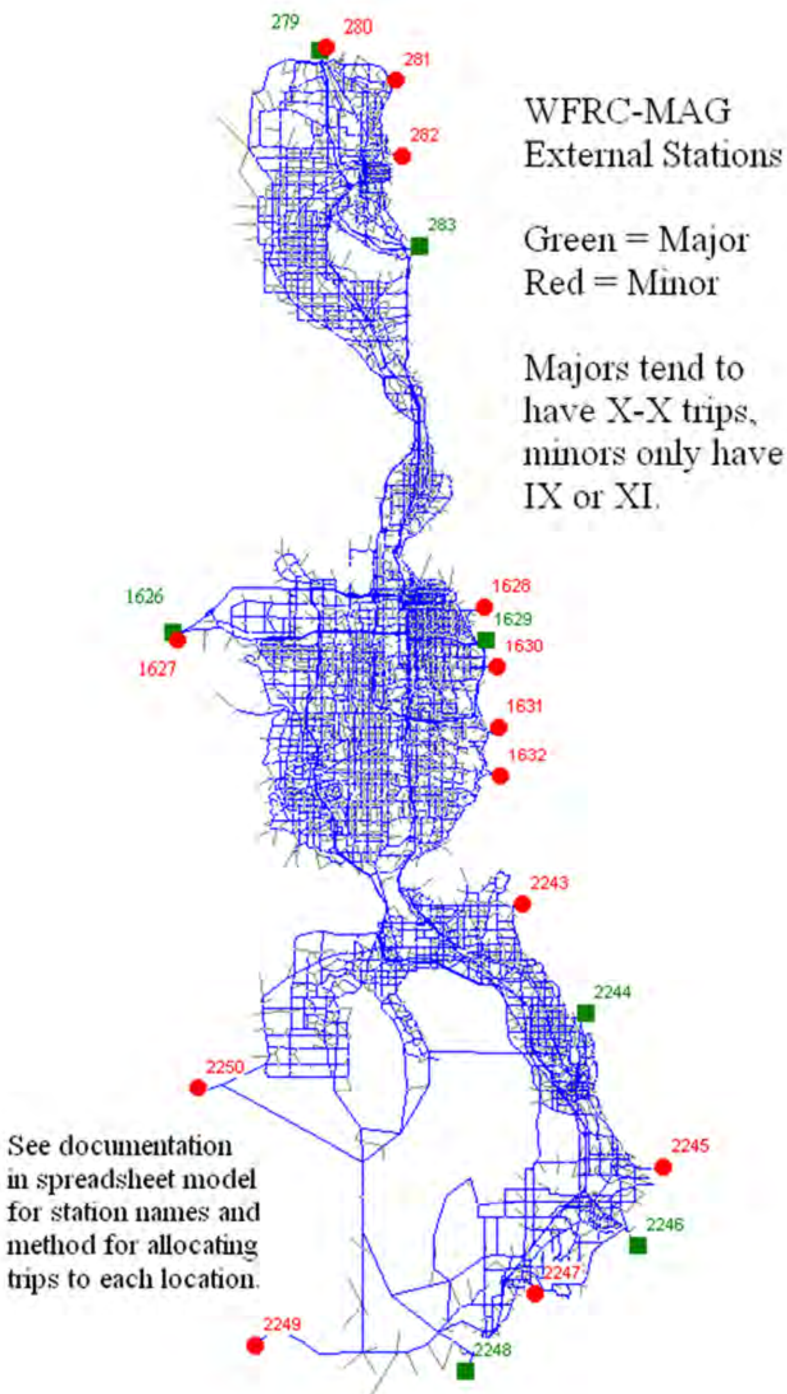



**Figure 20: Location of Major and Minor External Zones**

**Table 10: External Vehicle Demand**

| TAZ | Location | 2007 AWDT | 2040 AWDT | % XX Trips |
|---|---|---|---|---|
| 281 | N Ogden Pass | 1,800 | 3,500 | - |
| 279 | I-15 Box Elder/Weber | 47,000 | 90,300 | 13% |
| 280 | 89 Box Elder/Weber | 12,100 | 23,300 | - |
| 282 | Ogden Canyon | 8,100 | 15,500 | - |
| 283 | I-84 East | 16,600 | 31,900 | 13% |
| 1626 | I-80 at SR 201, Tooele | 23,200 | 44,500 | 26% |
| 1627 | SR 201 at I-80, Tooele | 16,100 | 30,900 | - |
| 1628 | Emigration Canyon | 8,800 | 17,000 | - |
| 1629 | I-80 East Parley's | 50,700 | 97,400 | 13% |
| 1630 | Millcreek Canyon | 1,000 | 1,900 | - |
| 1631 | Big Cottonwood | 3,800 | 7,200 | - |
| 1632 | Little Cottonwood | 5,500 | 10,600 | - |
| 2248 | I-15 Juab/Utah | 29,600 | 56,800 | 20% |
| 2249 | Goshen | 1,400 | 2,700 | - |
| 2247 | Payson Canyon | 600 | 1,200 | - |
| 2246 | SF Canyon (Hwy 6) | 9,900 | 19,000 | - |
| 2245 | Hobble Ck. Can (Spgville) | 2,500 | 4,800 | - |
| 2244 | Provo Canyon | 18,300 | 35,200 | - |
| 2243 | AF Canyon | 2,600 | 5,000 | - |
| 2250 | Tooele line near Cedar Fort | 1,600 | 3,100 | - |

The distribution of XX trips is developed primarily using judgment. A matrix balancing routine was developed to estimate the XX distribution consistent with the XX trip-ends at each external, and consistent with assumptions about what percentage of trips for each external head to other externals.

| | 279 | 283 | 1626 | 1629 | 2248 | |
|---|---|---|---|---|---|---|
| **279 I-15 Box Elder/Weber** | - | 1,094 | 204 | - | 1,767 | **3,065** |
| **283 I-84 East** | 1,094 | - | - | - | - | **1,094** |
| **1626 I-80 at SR 201, Tooele** | 204 | - | - | 2,463 | 326 | **2,993** |
| **1629 I-80 East Parley's** | - | - | 2,463 | - | 846 | **3,309** |
| **2248 I-15 Juab/Utah** | 1,767 | - | 326 | 846 | - | **2,939** |
| | **3,065** | **1,094** | **2,993** | **3,309** | **2,939** | **13,400** |

**Figure 21: 2007 XX Demand**

| | 279 | 283 | 1626 | 1629 | 2248 | |
|---|---|---|---|---|---|---|
| **279 I-15 Box Elder/Weber** | - | 2,090 | 392 | - | 3,393 | **5,876** |
| **283 I-84 East** | 2,090 | - | - | - | - | **2,090** |
| **1626 I-80 at SR 201, Tooele** | 392 | - | - | 4,737 | 610 | **5,738** |
| **1629 I-80 East Parley's** | - | - | 4,737 | - | 1,628 | **6,365** |
| **2248 I-15 Juab/Utah** | 3,393 | - | 610 | 1,628 | - | **5,631** |
| | **5,876** | **2,090** | **5,738** | **6,365** | **5,631** | **25,700** |

**Figure 22: 2040 XX Demand**

XI trips represent 75% of the total estimated IXXI counts estimated at each station, while IX trips are assumed to be 25%. The 75-25 split assumes that on an average weekday there are more people coming from outside the region to attractions within the region than there are people going from the region to attractions outside the region.

The internal trip-ends for IX trips are estimated for HBW, NHB and each of the HBO purposes, based on the percentage of trips that they represented in the 1993 home interview survey. District-based factors were derived to split the total internal trip-ends (for each purpose) into internal-internal trip-ends and IX trip-ends. The average IX internal trip-end ratios (as a function of total trip-ends) were developed for the large districts. The average IX trip-end ratios are shown for each district in Table 11.

**Table 11: IX Trip Rates for Internal TAZs (by Large District)**

| Large District | % HBW Trips that are IX | % HBO Trips that are IX | % NHB Trips that are IX |
|---|---|---|---|
| 1 | 0.036 | 0.017 | 0.014 |
| 2 | 0.018 | 0.009 | 0.01 |
| 3 | 0.011 | 0.006 | 0.003 |
| 4 | 0.006 | 0.004 | 0.004 |
| 5 | 0.013 | 0.015 | 0.013 |
| 6 | 0.013 | 0.015 | 0.013 |
| 7 | 0.006 | 0.008 | 0.007 |
| 8 | 0.006 | 0.009 | 0.005 |
| 9 | 0.011 | 0.007 | 0.007 |
| 10 | 0.011 | 0.007 | 0.007 |
| 11 | 0.014 | 0.006 | 0.005 |
| 12 | 0.012 | 0.006 | 0.005 |
| 13 | 0.011 | 0.005 | 0.004 |
| 14 | 0.01 | 0.004 | 0.003 |
| 15 | 0.009 | 0.004 | 0.003 |

# 10.0 TRIP DISTRIBUTION

Trip distribution is the pairing of origins and destinations to form complete trips. This is done separately within each trip type. For example, HBW productions from residences are paired with HBW attractions at work places.

## 10.1 Gravity Model

The trip distribution within a trip type is done using a gravity model, and then for home-based work trips another distribution is done using a destination choice model (to be discussed). The concept underlying a gravity model is that trip-end locations that are closer together will exhibit a stronger attraction than those that are farther apart will. It is also true, however, that the longer trips have a larger travel radius and therefore more potential destinations within that radius. This is similar to a body of larger mass having a greater gravitational pull. Ultimately, the distribution of trip lengths will include a greater number of shorter trips and fewer longer trips than if the trips were distributed randomly.

The functional form of the gravity model is shown in Equation 3. The gravity model is a doubly-constrained gravity model. This means that an iterative process is used that alternatively balances productions by evaluating the first equation and then balances to attractions by evaluating the second equation. The iterative process is complete when either the convergence criterion is met, or the maximum number of iterations is reached.

**Equation 3: Doubly- Constrained Gravity Model Equations**

$$T_{ij} = P_i * \frac{A_j * f(d_{ij})}{\sum_{all\ zones\ z} A_z * f(d_{iz})} \quad \text{(Constrained to Productions)}$$

$$T_{ij} = A_j * \frac{P_i * f(d_{ij})}{\sum_{all\ zones\ z} P_z * f(d_{iz})} \quad \text{(Constrained to Attractions)}$$

Where:

| | | | |
|---|---|---|---|
| Where: | $T_{ij}$ | = | the forecast flow produced by zone *i* and attracted to zone *j* |
| | $P_i$ | = | the forecast number of trips produced by zone *i* |
| | $A_j$ | = | the forecast number of trips attracted to zone *j* |
| | $d_{ij}$ | = | the impedance between zone *i* and zone *j* |
| | $f(d_{ij})$ | = | the friction factor between zone *i* and zone *j* |

The inputs to trip distribution include the productions and attractions from trip generation and an impedance matrix. The travel impedance for HBW, HBO and NHB trips is a generalized cost that is a function of time, distance (auto operating cost) and toll cost (if applicable). The impedance used for external trips and commercial trips is travel time.

### 10.1.1Gravity Model Calibration

A Voyager script has been written that iteratively calibrates gravity model friction factors until an observed impedance distribution is matched by the model. The inputs to the calibration script are trip impedance distributions (by trip purpose), trip generation output and modeled travel times and costs between all TAZ pairs. The initial calibration of the friction factors is based on observed trip lengths from the trip diary survey.

The gravity model parameters were then adjusted after replication to correspond to 2000 Census Journey to Work data and NHTS data.

The friction factors for IXXI and commercial trips were transferred from V6 of the model.

## 10.2 HBW Destination Choice Model

Destination choice models were estimated and implemented for the HBW trip purpose. The destination choice model form has some advantages over the traditional gravity model. First, the destination choice models are stratified by market segment and based on behavioral choice theory, making them more theoretically sound than gravity models. Further, they are more flexible, capturing multiple variables into a utility equation. The models use the logsum calculated in mode choice as the primary measure of travel impedance. This makes the destination choice model consistent with and sensitive to all transportation modes. If transit system improvement results in more trips between locations, then these new trips will use the new transit improvement. This feature is fundamental in the evaluation of any proposed transit system extension.

The HBW destination choice model adds a few hours of run time to the travel model, and therefore full feedback through the destination choice model was deemed impractical. As such, the model reaches convergence on auto times using a gravity model, and then runs the HBW destination choice model. The model flow diagram is presented in Figure 23.

**Figure 23: Model Flow Diagram with Destination Choice**

Destination choice models are very similar to mode choice models in that both are based on a type of discrete choice model called the logit model. Discrete choice models compute the probability of selecting an alternative amongst a set of possible alternatives. As applied to destination choice models, the logit formulation is:

**Equation 4: Logit Model Formulation**

$$P_i(k) = \frac{\exp(U_{k|i})}{\sum_{j \in D} \exp(U_{j|i})}$$

where:

$P_i(k)$ is the probability of selecting attraction , given production zone ,

$j \in D$ are the unique alternatives (attractions) in the sample set, and

$U_j$ is the utility of selecting an attraction zone, given production zone .

The equation states that for a production zone i, the probability of selecting an attraction zone k is a function of the exponential utility of selecting k over the sum of exponential utilities of all attractions zones in the choice set. The larger the utility of travel between production zone i and attraction zone j, the greater the probability of travel between the zones.

The utility of a particular alternative $(U_k)$ is a linear function of the attributes that describe the alternative. In a destination choice model, the attributes that describe the selection of a zone include its accessibility, other variables that describe the quality of the choice, and variables that describe the quantity of activity in the attraction zone:

**Equation 5: Utility of Each Destination**

$$U_{j|i} = \beta_0 \times \beta_1 \times accessibility_{j|i} + \beta_2 \times quality_{j|i} + \ln(\beta_3 \times quantity_{j|i})$$

Utility functions for destination choice look different the comparable functions for mode choice models due to the logarithmic term. This term is referred to as the size term. As an example, the HBW destination choice model uses the amount of employment in the attraction as the size term.

Destination choice models that use mode choice logsums as a measure of impedance have a special interpretation. The destination and mode models can be interpreted as sequentially estimated nested models. Mode choice becomes a nested choice under the choice of destination. The coefficient estimated on the mode choice logsum is interpreted as a nesting coefficient. Thus the coefficient must range be between 0 and 1. A value of 1 implies that there is no nesting. A value greater than 1 implies that the nesting order is incorrect.

### 10.2.1 Destination Choice Model Estimation

The data used for model estimation come from two sources, a 1992 home interview survey and a 2002 transit onboard. Both surveys were expanded to represent the 2002 population in the region. The estimation data set used auto and non-motorized trips from the home interview survey and transit trips from the onboard. Estimation weights were computed by purpose, mode, and household auto ownership level (0, 1, 2+). Illogical observations, e.g. drive alone trips in a 0 auto household, and observations not connected in the path builder were dropped. The estimation file contains 7,024 usable records, 5,111 are from the home interview survey, and 1,913 are from the onboard survey.

The data were grouped into two income categories, low and high household income. Low income was defined as those earning less than $25,000 in 2002 dollars. This definition corresponds to the lowest three income categories in the onboard survey. The income categories for the 1992 home interview survey were inflated into 2002 dollars using the consumer price index. After inflation, the low income definition included the two lowest income categories.

The primary accessibility variable in the destination choice model is the mode choice logsum variable. This variable is the primary separation measure.

In the final model, the logsum coefficients vary between 0.2 and 0.4. These coefficients are between 0 and 1 as the nested logit theory mandates. The values of the logsum coefficients imply that there are unobserved attributes of attractions or travelers that result in less than an equal change in an attraction's utility given a change in the accessibility to that attraction.

This model indicates that 0 auto households and 2 or more auto households are more sensitive to changes in accessibility than are 1 auto households. Travelers from 0 auto households are especially sensitive to the presence of transit. Opening a new light rail transit line, for example, generates dramatic increases in accessibility for this market that is not present in households with autos. Households with 2 or more autos have a slightly higher logsum parameter than 1 auto households. These households may be more able to trade off residential and work location based on accessibility due to their higher wealth. The remaining group – 1 auto households – is comprised of workers with relatively less sensitivity to changes in accessibility in comparison to the other groups.

TAZs with a high percentage of retail employment tend to attract workers from lower income households. The signs and magnitudes of the coefficients are as expected. The 0 auto market segment has a positive coefficient meaning that this segment prefers attraction zones with high ratios of retail employment. High income market segments have larger negative coefficients on this ratio than do low income segments.

The effect of industrial employment to the utility of choosing an attraction is harder to predict than retail employment. Retail employment includes relatively few highly paid positions. That is not the case for industrial employment. Industrial employment includes worker types of varying skill and pay levels such as managers, engineers, and high and low skilled workers. The estimation results suggest that high income workers tend not to select alternatives with larger ratios of industrial employment.

**Table 12: HBW Destination Choice Model Estimation Results**

| Variable | Coefficient |
|---|---|
| Logsum - 0 Auto | 0.311 |
| Logsum - 1 Auto, Low Income | 0.212 |
| Logsum - 1 Auto, High Income | 0.212 |
| Logsum - 2 Auto, Low Income | 0.399 |
| Logsum - 2 Auto, High Income | 0.428 |
| | |
| Highway Distance | -0.089 |
| | |
| Retail Ratio - 0 Auto | 0.458 |
| Retail Ratio - 1 Auto, High Income | -0.524 |
| Retail Ratio - 2 Auto, High Income | -0.718 |
| | |
| Industrial Ratio - 1 Auto, Low Income | -1.269 |
| Industrial Ratio - 1 Auto, High Income | -0.921 |
| Industrial Ratio - 2 Auto, High Income | -0.459 |

## 10.3 Airport Trip Table

A 1995 airport passenger trip table was estimated from 1995 survey data and this table provides a baseline estimate of travel to the airport in order to estimate ground access models for airport customers in the region. The survey data were collected at Salt Lake International Airport and one of the data items was the ground access origin for airport access trips.

The 1995 survey data were used to estimate regression models to forecast the ground access location in the region of a trip to/from Salt Lake International. This model is applied to estimate the number of airport person trips to/from each TAZ on an average day.

**Table 13: Airport Passenger Trip Distribution Regression Model Coefficients**

| Variable | Coefficient |
|---|---|
| Population (if TAZ Income < $35K) | 0.015 |
| Population (if TAZ Income < $70K) | 0.020 |
| Population (if TAZ Income < $100K) | 0.027 |
| Population (if TAZ Income > $100K) | 0.036 |
| Retail Employment | 0.110 |
| Industrial Employment | 0.040 |
| Other Employment | 0.040 |

## 10.4 College Student Trip Tables (HBC)

The HBC trip matrix is estimated based on data on where college students currently live. The HBC trip matrix estimates trips between home and college for students, and is based on a combination of student address data (to identify home locations), enrollment totals, and trip generation rates estimated from the home interview survey and compared to other published rates.

The base year college trip table is derived from college student address data, where available. A regression model is then used to forecast the incremental growth in college student demand (i.e. where college students live) based on how the region's population changes. In other words, the base year distribution is a constant, and a regression model is used to forecast the change in residential locations of college students based on housing growth in relation to proximity to each school.

**Table 14: HBC Trip Distribution Regression Model Coefficients**

| Variable | WSU, LDS, UVU, Westminster | BYU | SLCC | U of U |
|---|---|---|---|---|
| TotPop (if dist to campus < 3 mi) | .00000478 | 0.000007495 | 0.00000193 | 0.000005666 |
| TotPop (if dist to campus 3-5 mi) | .00000289 | 0.000001959 | 0.00000149 | 0.000003024 |
| TotPop (if dist to campus 5-20 mi) | .00000156 | 0.000000160 | 0.000000744 | 0.000000495 |
| TotPop (if dist to campus > 20 mi) | .0000000205 | .0000000205 | .0000000205 | .0000000205 |
| TotPop (if transit with 0 xfers) | .000000125 | .000000125 | .000000125 | .000000125 |
| TotPop times HH/Dev. Acre | .0000000068 | .0000000068 | .0000000068 | .0000000068 |

# 11.0 NETWORK PATH-FINDING AND SKIMMING

## 11.1 Auto Paths

Auto skims are inputs to the trip distribution and mode choice models. The best auto paths are determined based on a function of travel time, distance and toll cost, and are computed separately for peak and off-peak conditions.

**Equation 6: Auto Impedance Function**

$$impedance = time + distance * \frac{operating\ cost}{value\ of\ time} + \frac{toll\ cost}{value\ of\ time}$$

The operating cost is 13 cents per mile, and the value of time is 16 cents/min (approx. $10/hour). The rationale for incorporating distance and cost in the auto impedance function is that people weight more than just travel time in their route choice decision-making and it seems important to include the out-of-pocket and operating costs associated with a trip. In version 6 of the model, a geometric mean of a toll and non-toll skims was used, but this approach is no longer necessary in version 7 since toll cost is directly included in the shortest path finder.

### 11.1.1 Skims for Trip Distribution

The first iteration of the gravity model uses free-flow skims. This iteration is considered a warm-up and the sole purpose is to load traffic on the network in order to estimate congested skims. The result of this first iteration of the gravity model is that congested corridors will carry an unreasonably high amount of traffic, and then the skims for the next iteration of distribution will represent overly congested conditions. To counteract this to some extent, the first iteration of the gravity model is only used to get congested skims, which are then averaged with free-flow skims to minimize the likelihood the next iteration will see very low speeds. These averaged skims are input into the second iteration of the gravity model.

The HBW distribution uses congested AM skims after the second iteration of the gravity model. The distribution models for the non-work purposes all use average skims (average of free-flow and congested skims).

### 11.1.2 Intra-zonal Auto Travel Times

Even though the typical TAZ is not a perfect square, for the purposes of computing an approximate average internal distance it is assumed that the average internal distance is ½ of the square root of the TAZ area. Intra-zonal travel times are computed assuming this average distance and a 20 mph average travel speed.

### 11.1.3 Terminal Times

Origin and destination terminal times are asserted based on the densities within and surrounding each TAZ. An automated process has been developed that asserts a terminal time based on the area type surrounding a TAZ. Rural to suburban densities have terminal times equal to 1 minute, while TAZs on the urban fringe have 2 minute terminal times. Terminal times at major shopping centers and in most urban areas are 3 minutes. A few TAZs in the Salt Lake CBD, the airport, and the major universities have terminal times of 5-7 minutes.

## 11.2 Toll and HOV/HOT Paths

Model version 7 allows explicit representation of HOV and toll trips (including HOT lanes). This was done by extending the nested logit mode choice model to consider toll and HOV highway travel separately from general purpose lane highway travel, in the same way that the model differentiates between local, express, and rail transit modes.

In order to distinguish auto sub-modes in the mode choice model, skims need to be developed distinguishing each option. A simple hierarchy is assumed whereby a toll path consists of any path that involves a tolled link (can be a dedicated tollway or an HOT lane); an HOV path involves any path that contains no toll links but contains an HOV lane; and finally a general purpose (toll free, non-HOV) path is any path that does not include HOV or toll links.

The mode choice model is not included in the model's global feedback loop (only distribution and assignment are). This means that level-of-service on the toll/HOV paths must be asserted so that the time on these facilities can be estimated and used in mode choice. The model assumes that all managed facilities will operate at LOS D or better, and more to the point, the travel speed on HOV/toll links is assumed be free-flow. After the final assignment step is run, this assumption should be taken into consideration when evaluating HOV/toll demand on a particular facility. If the assignment model indicates congested speeds that are notably different from free-flow, then the path-building assumptions should be revisited (either price or FF time).

Toll paths are skimmed assuming a 50 cent/min (approximately $30/hour) value-of-time. This value-of-time is higher than what is assumed in the mode choice model, and the reason for that is to counteract the fact that the assignment skimming process is essentially a shortest path all-or-nothing process, particularly in relatively uncongested conditions. If the path-finding process did not use a higher value-of-time, then toll paths with relatively high probabilities in mode choice would be excluded in path-finding simply because the shortest weighted path was non-toll. In reality, the population has a distribution of values-of-time and in the future it would be worth considering how to account for this in a consistent manner throughout the model stream. For now, this is a planning model, and it is sufficient to understand the assumptions employed. However, the user of the model needs to employ significant judgment when analyzing toll paths in particular.

## 11.3 Transit Paths

The following parameters and assumptions are used to define transit paths specific to each transit sub-mode. These parameters are generally consistent with the mode choice model, and have been arrived at based on several years of careful testing of the model and comparing the modeled transit paths to transit paths in the on-board survey datasets. The perceived/weighted time is used to identify the fastest path by sub-mode. These parameters are used to define a feasible transit choice set, and the perceived/weighted time is not actually seen by the mode choice model.

**Table 15: Global Transit Path-finding Parameters**

| Variable | Value |
|---|---|
| Transfer penalty (1, 2+ transfers) | (10, 60) min |
| Walk speed | 2.5 mph |
| Minimum wait time (bus/rail) | (3, 5) min |

| Variable | Value |
|---|---|
| Weight applied to initial wait time | Factor of 2 |
| Weight applied to transfer wait time | Factor of 3 |
| Weight applied to walk access/egress time | Factor of 2 |
| Weight applied to drive access time | Factor of 1.5 |
| Combine headways if headways are within | 10 min |
| Max perceived path time | 240 min |

Table 16 summarizes the hierarchy and definition of transit modes in the model. Each row in the table indicates the transit modes that can be included in a path for each primary mode. The “path type” is synonymous with “mode” as far as the model is concerned. For a “path type” to be included in a mode choice set, the mode in the path type description MUST be included in the path. For example, looking across the express bus row, express bus paths in the model can include local bus, BRT, express bus or light rail as part of the express bus path. However, of all these sub-modes, express bus must be part of the path for this mode to be included as a choice.

**Table 16: Transit Mode Hierarchy and Transfer Restrictions**

| Path Type | Local Bus allowed? | BRT allowed? | Exp. Bus allowed? | LRT allowed? | CRT allowed? |
|---|---|---|---|---|---|
| **Local Bus** | **REQUIRED** | no | no | no | no |
| **BRT** | YES | **REQUIRED** | no | no | no |
| **Express Bus** | YES | YES | **REQUIRED** | YES | no |
| **Light Rail** | YES | YES | no | **REQUIRED** | no |
| **Commuter Rail** | YES | YES | no | YES | **REQUIRED** |

Table 17 summarizes the secondary mode weights used in transit path-building. The path weights are used to encourage the model to find paths for the primary mode in each path type.

**Table 17: Weight Applied to Secondary Transit Modes**

| Path Type | Local Bus weight | BRT weight | Exp. Bus weight | LRT weight | CRT weight |
|---|---|---|---|---|---|
| **Local Bus** | **1** | N/A | N/A | N/A | N/A |
| **BRT** | 3 | **1** | N/A | N/A | N/A |
| **Express Bus** | 3 | 3 | **1** | 3 | N/A |
| **Light Rail** | 3 | 3 | N/A | **1** | N/A |
| **Commuter Rail** | 3 | 3 | N/A | 3 | **1** |

## 11.3.1 Validation of Transit Paths

As mentioned previously, the on-board survey has been assigned to the transit network to reveal surveyed trips that could not be assigned to the correct path. The result led to increasing the park-n-ride travel sheds, adding new PNR lots, and adjusting the path favoring weights. In the table below we present the comparison of modeled (skimmed) and reported transfer rates by mode.

| | | Skimmed Transfer | | | | | |
|---|---|---|---|---|---|---|---|
| **Reported Transfer** | | **0** | **1** | **2** | **3** | **4** | **total** |
| *drive-express* | 0 | *125* | 8 | 1 | | | **134** |
| | 1 | 6 | *18* | 0 | | | **24** |
| | **total** | **131** | **26** | **1** | | | **158** |
| *drive-local* | 0 | *142* | 31 | 5 | 0 | 0 | **178** |
| | 1 | 31 | *18* | 2 | 1 | 0 | **52** |
| | 2 | 2 | 4 | *0* | 0 | 1 | **7** |
| | 3 | 1 | 0 | 0 | *0* | 0 | **1** |
| | **total** | **176** | **53** | **7** | **1** | **1** | **238** |
| *drive-LRT* | 0 | *365* | 76 | 1 | | | **442** |
| | 1 | 84 | *339* | 6 | | | **429** |
| | 2 | 7 | 50 | *1* | | | **58** |
| | 3 | 0 | 3 | 0 | | | **3** |
| | 4 | 0 | 1 | 0 | | | **1** |
| | **total** | **456** | **469** | **8** | | | **933** |
| *walk-express* | 0 | *7* | 7 | 2 | | | **16** |
| | 1 | 2 | *3* | 5 | | | **10** |
| | **total** | **9** | **10** | **7** | | | **26** |
| *walk-local* | 0 | *931* | 145 | 10 | 2 | 0 | **1088** |
| | 1 | 150 | *265* | 9 | 1 | 1 | **426** |
| | 2 | 9 | 16 | *3* | 0 | 0 | **28** |
| | **total** | **1090** | **426** | **22** | **3** | **1** | **1542** |
| *walk-LRT* | 0 | *335* | 46 | 8 | 0 | 0 | **389** |
| | 1 | 65 | *378* | 61 | 2 | 0 | **506** |
| | 2 | 14 | 67 | *110* | 6 | 0 | **197** |
| | 3 | 0 | 3 | 7 | *6* | 0 | **16** |
| | 4 | 0 | 0 | 0 | 0 | *1* | **1** |
| | **total** | **414** | **494** | **186** | **14** | **1** | **1109** |

### 11.3.2 Rules to Exclude Illogical Transit Paths

There are two simple rules used to exclude transit paths from the mode choice set for specific OD pairs. These rules target unreasonable transit trips and simply zero-out the transit skims so that the mode choice model does not assign even a small share of travelers to these paths. These rules are:

- If the transit access/egress distance plus the in-vehicle distance is greater than 50% of the auto distance, then exclude the path
- No drive access trips are allowed if the auto distance is less than three miles

These rules are designed as "cliffs". That is, the rule either applies or does not apply, and the distinction is made at very specific values in the skim matrices. Cliffs can present problems in calculating user benefits, but it is assumed that the potential for this is low and outweighed by the positives.

The first rule could potentially result in different transit connectivity from one transit alternative to the next, if the skims for either alternative happen to fall on opposite sides of the cliff. Given this, it is important to review SUMMIT output to see if there are illogical benefits/disbenefits potentially arising from this rule.

The second rule (no drive-transit paths if the auto distance is less than 3 miles) does not appear to be cause for concern because the auto skims do not change in this model from one transit alternative to the next.

## 11.4 Walk/Bike Paths

The mode choice model accounts for non-motorized trips in a relatively simplistic manner. The utility of walking or biking in the mode choice model is a function of the estimated travel time for that mode, and mode specific constants. The travel time for walk and bike is a function of the X-Y distance between TAZ centroids, and the assumed average walk speed is 2.5 mph and the assumed average bike speed is 10 mph. No walk trips are allowed over 3 miles and no bike trips are allowed over 6 miles. In reality, these decisions are typically much more complicated that simply considering travel time, so in this sense the model is essentially serving as an accounting mechanism towards more sophisticated forecasting of motorized travel.

# 12.0 MODE CHOICE MODEL

A nested multinomial logit mode choice model is used to estimate the split among auto, walk/bike, and transit trips. The mode choice model has been estimated separately for HBW, HBO, HBC and NHB trips. The actual equations used to determine the split of person-trips among modes are of the logit form. A simplified binomial logit model used to compute relative mode shares is shown in Equation 7.

**Equation 7: Auto Ownership Model Utility Equations**

$$Transit\ \ Mode\ \ Share\ = \frac{1}{1 - e^{(V_{auto} - V_{transit})}}$$

$$Auto\ \ Mode\ \ Share\ = 1 - Transit\ \ Share$$

$$\begin{aligned} Where:\ V_{auto} &= f(auto\ \ service,\ traveler\ \ attributes) \\ V_{transit} &= f(transit\ \ service,\ traveler\ \ attributes) \end{aligned}$$

The “utility functions” (Vs) in this equation are a function of mode-specific travel time, cost and access variables as well as traveler-specific variables, with each variable multiplied by statistically-estimated parameters.

The multinomial logit model is an extension of this form that allows comparisons among more than two alternative modes. A further extension, the nested logit model, allows for differential competition among modes. A simple multinomial logit model assumes that each alternative mode draws in fixed proportions from all other alternatives. This is an appropriate assumption when the alternatives are unique but becomes less appropriate when subsets of the alternatives have important shared attributes. For example, auto and carpool share many attributes and these modes are nested in the model so that there is more competition between them than with other modes.

## 12.1 Mode Nesting Structure

The nesting structure and model parameters are shown in Figure 24. The mode choice model structure and specification has been extensively reviewed by industry experts. The model coefficients were estimated and calibrated using an estimation dataset blended from home interview survey data and transit onboard survey data, with appropriate model skims appended to each survey. In some cases, parameters have been adjusted based on professional judgment and experience with the model. The level-of-service parameters all have values that fall within a range that is typical of best practice models. When evaluating the reasonableness of model constants and coefficients, keep in mind that some coefficients in the coefficients table are alternative specific and ultimately affect the values of the constants. For example, bus-rail trips include a transfer penalty, which is not included in the constant, and rail trips are modeled with a function that discourages excessive short trips.

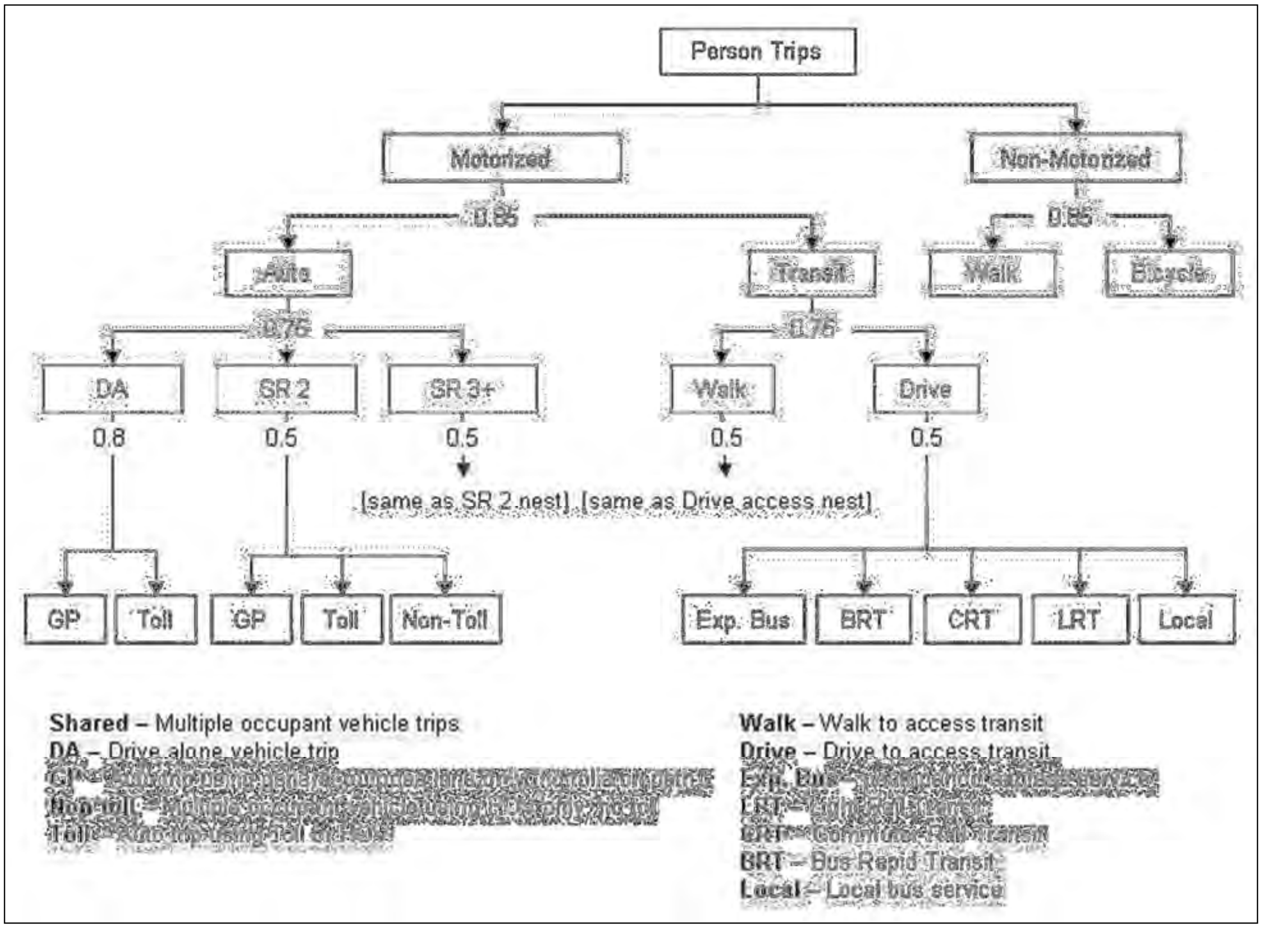



**Figure 24: Mode Choice Model Nesting Structure**

## 12.2 Mode Choice Model Coefficients

The mode choice model coefficients are presented below in Figure 25. Changes made in Version 6.1 include lower transfer penalties (they are now 12 minutes), lower drive access to transit coefficients (they are now 1.5 times IVT) and the removal of the CBD bias. Additionally, a new variable was added to discourage relatively long drive access trips (relative to the total drive distance). This function is the ratio of the drive access distance divided by the door-to-door auto distance. The changes in Version 6.1 were all made to improve the story that the model itself tells about transit behavior and make that story generally more intuitive.

Transfers are penalized in the model, at a value equivalent to 12 minutes of in-vehicle time. However, if the transit path includes only one rail-to-rail transfer, this transfer is only penalized at 6 minutes. There are two reasons for this difference. First, this distinction was necessary to calibrate the existing rail transfer patterns. Second, rail transfers are currently simple cross-platform transfers, and tend to be more reliable. It is assumed that this advantage will exist in the future as the rail network is increased.

| | HBW | HBO | NHB | HBC | |
|---|---|---|---|---|---|
| **ivt** | -0.0221 | -0.0160 | -0.0233 | -0.0221 | IN-VEHICLE TIME |
| | | | | | |
| **initwait** | -0.0442 | -0.0320 | -0.0466 | -0.0442 | FIRST TRANSIT WAIT TIME |
| **xferwait** | -0.0500 | -0.0480 | -0.0663 | -0.0500 | TRANSIT TRANSFER WAIT TIME |
| | | | | | |
| **walk_1** | -0.0442 | -0.0320 | -0.0466 | -0.0442 | FIRST MILE OF WALK/OUT-OF-VEHICLE TIME |
| **walk_gt_1** | -0.0663 | -0.0480 | -0.0699 | -0.0663 | OVER 1 MILE WALK/OUT-OF-VEHICLE TIME |
| | | | | | |
| **drive** | -0.0332 | -0.0240 | -0.0350 | -0.0332 | DRIVE ACCESS TO TRANSIT TIME |
| | | | | | |
| **bike** | -0.0500 | -0.0320 | -0.0514 | -0.0500 | BIKE TIME |
| | | | | | |
| **cost_lowinc** | -0.0099 | -0.0120 | -0.0049 | -0.0060 | AUTO OPERATING COST/TRANSIT FARE (LOW INCOME - IF APPLICABLE) |
| **cost_highinc** | -0.0023 | -0.0040 | | | AUTO OPERATING COST/TRANSIT FARE (HIGH INCOME) |
| | | | | | |
| **parkcost_lowinc** | -0.0099 | -0.0120 | -0.0389 | -0.0060 | PARKING COST (LOW INCOME - IF APPLICABLE) |
| **parkcost_highinc** | -0.0023 | -0.0040 | | | PARKING COST (HIGH INCOME) |
| | | | | | |
| **tollcost_lowinc** | -0.0050 | -0.0060 | -0.0025 | -0.0030 | TOLL COST (LOW INCOME - IF APPLICABLE) |
| **tollcost_highinc** | -0.0012 | -0.0020 | | | TOLL COST (HIGH INCOME) |
| | | | | | |
| **ML_distance_disutility_constant** | -1 | -1 | -1 | -1 | MANAGED LANE DISUTILITY CONSTANT (TRIPS <2 MILES) |
| **ML_distance_disutility_slope** | 0.5 | 0.5 | 0.5 | 0.5 | MANAGED LANE DISUTILITY SLOPE (TRIPS <2 MILES) |
| | | | | | |
| **Sliding_toll_bias_max_value** | 0.1105 | 0.0400 | 0.1165 | 0.1105 | PEAK TOLL BIAS THAT INCREASES TO MAX VALUE WITH TIME SAVINGS |
| | | | | | |
| **premium bus direct walk** | 0.1105 | 0.0800 | 0.1165 | 0.1105 | WALK DIRECTLY TO EXPRESS DUMMY |
| **rail direct walk** | 0.2210 | 0.1600 | 0.2330 | 0.2210 | WALK DIRECTLY TO RAIL DUMMY |
| | | | | | |
| **drive_time_to_ivt** | 0 | 0 | 0 | 0 | DRIVE TO TRANSIT ACCESS TIME DIVIDED BY IVT |
| **drive_dist_ratio** | -0.332 | -0.24 | -0.35 | -0.332 | DRIVE TO TRANSIT DISTANCE DIVIDED BY AUTO DISTANCE |
| | | | | | |
| **transfers - walk** | -0.265 | -0.192 | -0.280 | -0.265 | TRANSIT TRANSFERS - WALK ACCESS TRIPS |
| **transfers - drive** | -0.265 | -0.192 | -0.280 | -0.265 | TRANSIT TRANSFERS - DRIVE ACCESS TRIPS |
| | | | | | |
| **1/distance on rail - walk** | -1 | -1 | -1 | 0 | WALK-RAIL DISTANCE COEFFICIENT TO MATCH TLF |
| **1/distance on rail - drive** | -3 | -3 | -3 | -1 | DRIVE-RAIL DISTANCE COEFFICIENT TO MATCH TLF |
| | | | | | |
| **CBD_dummy_transit** | 0 | 0 | 0 | 0 | TRANSIT BIAS - CBD DUMMY |
| **CBD_dummy_walk** | 0 | 0 | 0 | 0 | WALK BIAS - CBD DUMMY |
| | | | | | |
| **zonal_urbanization** | 0.0044 | 0.0032 | 0.0047 | 0 | TRANSIT BIAS - ZONAL URBANIZATION DENSITY MEASURE (ATTRACTION) |

**Figure 25: Mode Choice Model Coefficients**

## 12.3 Transit Mode Specific Constants

The mode choice model constants are presented here and expressed in equivalent minutes relative to local bus. These values indicate a preference for rail in Version 6.1 that is generally about 20 minutes. For reference, the mode specific constants from version 4.3 and 6.0 are also presented.

One reason for Version 6.1 was to refine the mode choice model and path-builder so that the calibrated rail bias constants were not inordinately large. The following changes were made between V6.0 and V6.1 that all led to the improved constants.

- Data review
    - Lowered the 2005 target for rail boardings to 44,000 (in V6.1/V7) from 49,000 (in V6.0).
    - Identified and corrected 2005 employment data errors in key employment centers along the rail line.
    - Carefully coded UTA's park-and-ride lots, removing some from the base year model.
    - Reduced the walk-time from transit to the University of Utah.
- Model changes
    - Increased the home-based college trip rate per FTE student from 1.1 to 1.5 HBC trips per day
    - Modified the walk-access to transit buffer calculation by defining the walk accessibility as the maximum portion of the TAZ that is accessible to any one transit line (rather than the union of all the buffers). This effectively reduced walk accessibility in the areas with larger TAZs, and is intended to reflect reasonable walking distances.
- Fixed an error in the transit path-builder where too much drive access was being assumed to bus lines – too many access links were being generated.
- Excluded drive access trips if the auto distance is less than three miles.
- Exclude transit paths if the in-vehicle and out-of-vehicle transit distance is 1.5 times greater than the auto distance.
- Refined the park-and-ride access links to build shorter access links to less formal bus lots.
- Lowered the transfer penalties to 12 minutes (from 20 minutes).
- Removed the CBD bias constant in the mode choice model (instead using a continuous urbanization/density variable).
- Lowered the drive-access time coefficient to 1.5 times IVT coefficient.

Another important consideration was to calibrate the model without trying to match the survey data with such precision that the constants get too large. This generally entails a balance between the desire to match precisely the calibration values (which have inherent error) and develop a set of model parameters and decision rules that make sense.

**Table 18: Rail to Local Bus Constant Comparison (expressed in terms of in-vehicle minutes)**

| | **Model Version 4.3** | | **Model Version 6.0** | | **Model Version 6.1/7** | |
|---|---|---|---|---|---|---|
| Trip Purp | Walk | Drive | Walk | Drive | Walk | Drive |
| HBW PK | 12 | 20 | 39 | 43 | 20 | 20 |
| HBW OK | 20 | 60 | 34 | 42 | 19 | 18 |
| HBO PK | 26 | 98 | 34 | 110 | 18 | 20 |
| HBO OK | 51 | 132 | 42 | 140 | 20 | 21 |
| NHB PK | 22 | 9 | 43 | 40 | 10 | 12 |
| NHB OK | 26 | 26 | 29 | 28 | 10 | 12 |
| HBC Daily | 36 | 73 | 25 | 63 | 16 | 20 |

# 13.0 TIME-OF-DAY SPLIT

The trip generation and trip distribution models estimate daily trips. The mode choice model estimates peak and off-peak mode split. The traffic assignment model then assigns traffic based on four time periods (AM peak, Midday, PM peak and night/off-peak).

The estimate of trips by time of day originally came from the 1993 home interview survey. The time-of-day split was updated for Version 7 using NHTS data and based on a comparison of modeled volumes to traffic counts by time-of-day. The time-of-day split for commercial vehicles was estimated using FHWA's Quick Response Freight Manual, and the split for external trips was based on traffic counts at the major externals.

The time-of-day split for home based trips are distinctly different by direction of travel (to or from home).

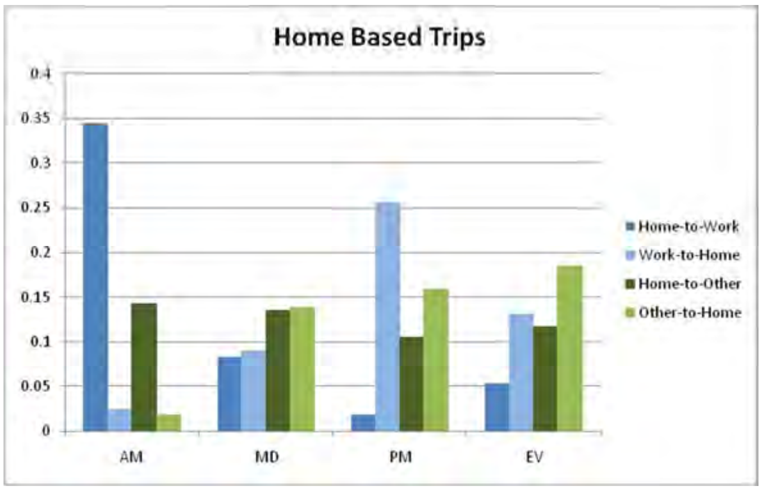



**Figure 26: Time-of-Day Split for HBW and HBO Trips**

The time-of-day split for non-home based, commercial and external trips are not distinctly different by direction of travel.

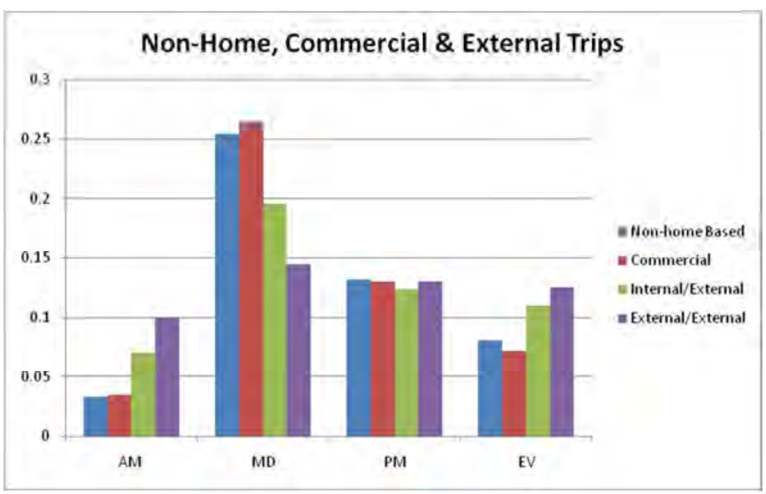



**Figure 27: Time-of-Day Split for NHB, COMM and EXT Trips**

This following table shows all of the parameters used to convert productions/attractions to origins/destinations by time-of-day, for each trip purpose.

**Table 19: Time-of-Day Factors by Trip Purpose and Direction**

| Parameter | Old Models | Model V7 | Parameter | Old Models | Model V7 |
|---|---|---|---|---|---|
| IX_AM_PA | 0.020 | 0.070 | XI_AM_PA | 0.250 | 0.099 |
| IX_AM_AP | 0.250 | 0.099 | XI_AM_AP | 0.020 | 0.070 |
| IX_MD_PA | 0.100 | 0.196 | XI_MD_PA | 0.100 | 0.197 |
| IX_MD_AP | 0.100 | 0.197 | XI_MD_AP | 0.100 | 0.196 |
| IX_PM_PA | 0.220 | 0.124 | XI_PM_PA | 0.060 | 0.102 |
| IX_PM_AP | 0.060 | 0.102 | XI_PM_AP | 0.220 | 0.124 |
| IX_EV_PA | 0.160 | 0.110 | XI_EV_PA | 0.090 | 0.101 |
| IX_EV_AP | 0.090 | 0.101 | XI_EV_AP | 0.160 | 0.110 |
| COM_AM_PA | 0.034 | 0.090 | XX_AM_PA | 0.100 | 0.085 |
| COM_AM_AP | 0.034 | 0.090 | XX_AM_AP | 0.100 | 0.085 |
| COM_MD_PA | 0.265 | 0.200 | XX_MD_PA | 0.145 | 0.196 |
| COM_MD_AP | 0.265 | 0.200 | XX_MD_AP | 0.145 | 0.196 |
| COM_PM_PA | 0.130 | 0.095 | XX_PM_PA | 0.130 | 0.113 |
| COM_PM_AP | 0.130 | 0.095 | XX_PM_AP | 0.130 | 0.113 |
| COM_EV_PA | 0.072 | 0.115 | XX_EV_PA | 0.125 | 0.106 |
| COM_EV_AP | 0.072 | 0.115 | XX_EV_AP | 0.125 | 0.106 |
| HBW_AM_PA | 0.345 | 0.348 | HBO_AM_PA | 0.143 | 0.112 |
| HBW_AM_AP | 0.025 | 0.024 | HBO_AM_AP | 0.018 | 0.013 |
| HBW_MD_PA | 0.083 | 0.072 | HBO_MD_PA | 0.135 | 0.158 |
| HBW_MD_AP | 0.090 | 0.077 | HBO_MD_AP | 0.138 | 0.151 |
| HBW_PM_PA | 0.019 | 0.019 | HBO_PM_PA | 0.105 | 0.107 |
| HBW_PM_AP | 0.255 | 0.248 | HBO_PM_AP | 0.159 | 0.152 |
| HBW_EV_PA | 0.053 | 0.062 | HBO_EV_PA | 0.117 | 0.124 |
| HBW_EV_AP | 0.131 | 0.151 | HBO_EV_AP | 0.185 | 0.184 |
| HBC_AM_PA | 0.345 | 0.348 | NHB_AM_PA | 0.033 | 0.040 |
| HBC_AM_AP | 0.025 | 0.024 | NHB_AM_AP | 0.033 | 0.040 |
| HBC_MD_PA | 0.083 | 0.072 | NHB_MD_PA | 0.254 | 0.236 |
| HBC_MD_AP | 0.090 | 0.077 | NHB_MD_AP | 0.254 | 0.236 |
| HBC_PM_PA | 0.019 | 0.019 | NHB_PM_PA | 0.132 | 0.107 |
| HBC_PM_AP | 0.255 | 0.248 | NHB_PM_AP | 0.132 | 0.107 |
| HBC_EV_PA | 0.053 | 0.062 | NHB_EV_PA | 0.081 | 0.117 |
| HBC_EV_AP | 0.131 | 0.151 | NHB_EV_AP | 0.081 | 0.117 |

# 14.0 TRAFFIC ASSIGNMENT

The purpose of the traffic assignment model is to locate a specific route along links and through intersections for every vehicle trip. The vehicle trips calculated in the mode choice model, which are in the form of an origin/destination matrix, are "assigned" to the network based on a user equilibrium model. The assignment model uses an iterative process to achieve a convergent solution in which no travelers can improve their travel impedance by switching to another route. The impedance function is a function of time, distance and cost, and was described in the section on path finding.

In order to accommodate managed lanes forecasting capabilities, a multi-class, multi-user assignment (MMA) algorithm is used in the model. This assignment algorithm is very flexible, allowing different assignment rules for different types of trips and/or facilities. For example, managed lane trips (as determined by the mode choice model) are the only trips allowed on managed lanes.

Another distinct feature of the vehicle assignment model is that the number of iterations the assignment routine runs has been fixed at a specific number, rather than allowing the assignment to converge at an arbitrary iteration. To implement this technique the convergence criteria were set at an unachievable level and a variable was used that defines the maximum iterations. The maximum iterations vary by time period (50 in the AM, 20 in the Midday, 50 in the PM and 20 in the evening). These parameters were determined by running the model and determining a number of iterations that still allowed for convergence under otherwise reasonable convergence criteria. These assumptions can be modified if appropriate to reduce run-time assuming calibration results are not adversely affected. The rationale for fixing the number of iterations is one of assignment stability. It has been clearly demonstrated that assignment results oscillate or flip-flop from one iteration to the next between alternating shortest paths. As convergence is more closely achieved, the oscillation is less apparent, but nonetheless exists. This approach attempts to minimize differences between different loaded networks due to oscillations by fixing the number of iterations, preventing different assignments from stopping at different iterations. This helps make networks changes outside a corridor of interest (away from where the change occurred) more logical and less noticeable. The current default max iterations are large enough that previous convergence criteria will be satisfied, but run-time will increase.

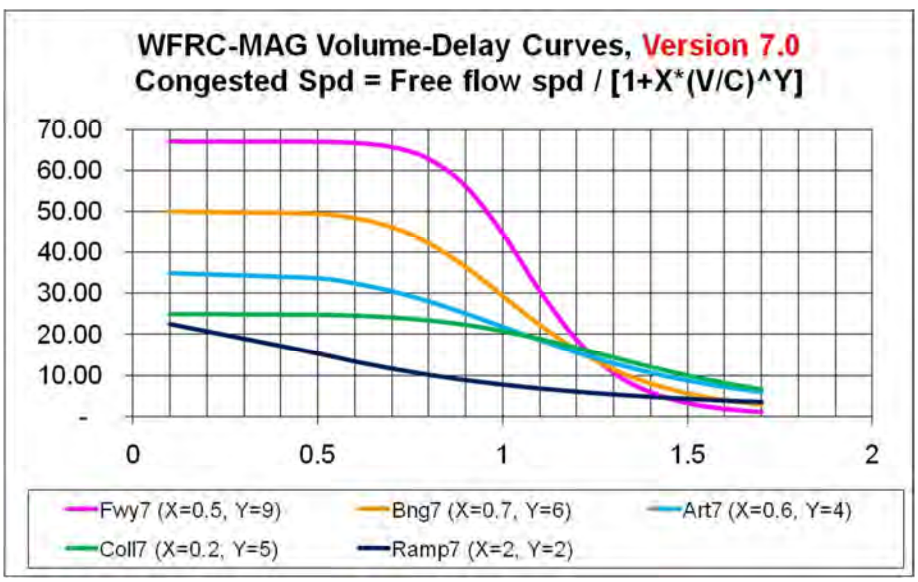



**Figure 28: Traffic Volume-Delay Functions**

# 15.0 BASE YEAR MODEL VALIDATION

## 15.1 Approach to Validation

Model validation is performed at all levels of the model: land use, trip generation, trip distribution, mode split, and assignment. The model is ready for use when various model-generated outputs such as road volumes, trip lengths, mode shares and transit ridership closely represent reality.

Model validation is a process of verifying that the model is producing reasonable results, and it is inherently an ongoing process. With each transportation study undertaken in the region there is an opportunity to exercise the model and potentially a need to refine the model or its inputs. It is very challenging to verify all details and dynamics are right in a regional context, so model refinement is to some degree a continuous learning process in the interest of meeting the needs of particular projects and long-range planning efforts.

The following documentation demonstrates the validity of the model with summaries that have been produced over the last 5 years of model development work. Some of the summaries are from version 6 and some are from version 7. The decision was made to not update every summary if the work was recent enough that it still served its purpose of demonstrating the validity of a modeling approach. For example, time-of-day factors were revisited for version 6.1, and these refinements were adopted without modification in version 7. When validating model version 7 the peak period count data were not available any longer on the new roadway network, so this comparison was not possible at the time.

Moreover, as of April 2011, UTA is in the process of collecting new on-board transit data, new Census data were recently released (and the ACS is forthcoming), and the MPOs and DOTS are preparing to collect a statewide home interview survey. Because of these upcoming data development efforts, in cases where the model approach was not changed in a notable way, the time was not takes to revisit every model validation exercise. The following documentation clarifies the model used as a basis for validation and the rationale for not updating the summary at this time.

The primary goal of the regional validation exercise is to ensure that the model is ready for regional planning and refined corridor analysis. As such, the regional validation must demonstrate that the model is "reasonable", with an understanding that corridor-specific refinement may be necessary from one study to the next.

## 15.2 Traffic Assignment Validation

The following summaries compare the modeled traffic volumes and the modeled traffic speeds with base year observed traffic count and speed data. Additionally, modeled vehicle miles traveled (VMT) is compared to VMT estimated for highway performance monitoring (HPMS). These comparisons are all from model version 7, compared to 2007 data.

The following section details the various statistics used to assess roadway assignment validation. Individual link errors are calculated by subtracting the modeled volume from the count for that link.

### 15.2.1 Count vs. Model Volume Summary Statistics

#### *15.2.1.1 Coefficient of Correlation*

The coefficient of correlation, "R", is commonly used to measure the linear relationship between two variables. An R-value of 1.0 would indicate a perfect one to one correlation between the two variables, an R-value of 0 would indicate a completely random relationship, and an R-value of -1 would indicate a perfect inverse correlation (one variable increases while the other decreases. The correlation is measured using the following formula.

$$r = \frac{\sum(x \cdot y) - n \cdot \bar{x} \cdot \bar{y}}{\sqrt{\left(\sum(x^2) - n \cdot \bar{x}^2\right)\left(\sum(y^2) - n \cdot \bar{y}^2\right)}}$$

where:

x = Ground count

y = Calibration volume

n = Number of observations

Several references in the modeling literature recommend a minimum correlation coefficient of 0.88, which corresponds to an R-squared value of .77.

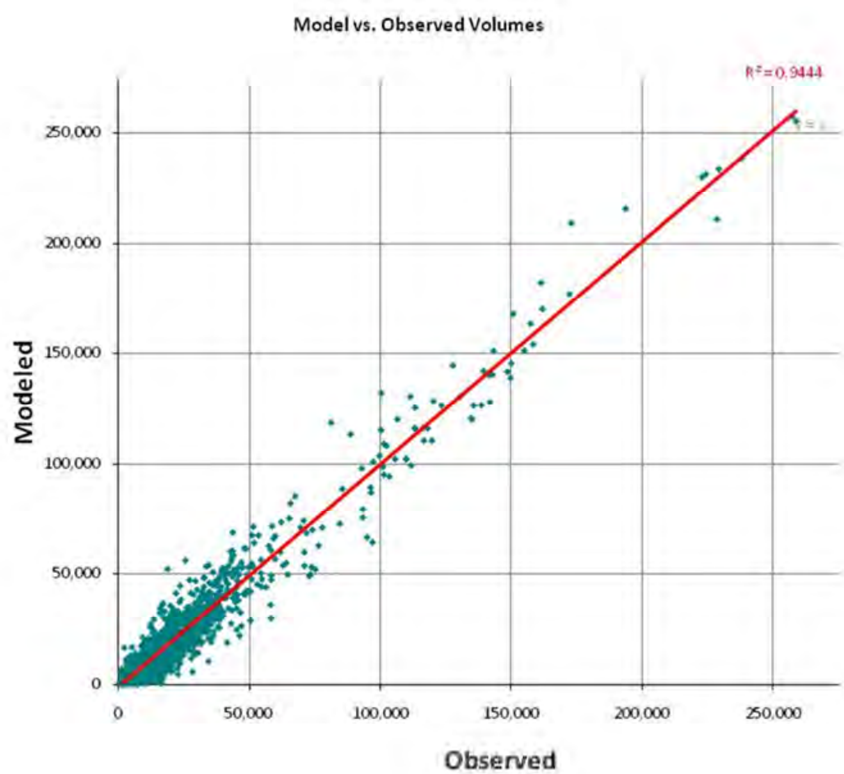



**Figure 29: Correlation between Model and Counts (2007 Average Weekday Traffic)**

#### 15.2.1.2 Percent Root Mean Squared Error

The root mean squared error (RMSE) is a measurement of error that weights the larger errors by more than they would be in an average error computation. The percent RMSE compares the RMSE statistic to the average observed value. The RMSE is always higher than the actual average network error because of the weighting. The percent RMSE is calculated as:

$$\text{RMSE} = \frac{\sqrt{\dfrac{\sum\left[(x-y)^2\right]}{n}}}{\dfrac{\sum x}{n}}$$

where:

x = Ground count

y = Calibration volume

n = Number of observations

The percent RMSE should generally be less than 40%, overall, with higher values acceptable for low volume links and lower values expected for high volume links.

#### 15.2.1.3 Average Error

The sum of differences is the average error of the network. This measure is usually expressed as a percent error.

$$\text{SumDif} = \sum(y-x) \quad \text{or} \quad \frac{\sum(\text{y - x})}{n} \times 100\%$$

Several references in the modeling literature recommend an average error for VMT and overall traffic volumes between +/-7% for freeways, +/-10% for major arterials and +/-15% for minor arterials. It is common for models to perform relatively poorly on collector roads and local roads, where the data resolution simply does not exist.

**Regional Validation Summary**

| | |
|---|---|
| **All Facilities** | |
| Avg Count Volume | 23,208 |
| RMSE | 7,043 |
| %RMSE | 30% |
| Sum of Suared Diff | 74,754,701,684 |
| Number of Observations | 1,508 |
| Average Error | (919.82) |
| Average % Error | -4% |
| **Freeways** | |
| Avg Count Volume | 102548 |
| RMSE | 12,835 |
| %RMSE | 13% |
| Sum of Suared Diff | 16,639,507,240 |
| Number of Observations | 102 |
| average error | 28 |
| average % error | 0% |
| **Principal** | |
| Avg Count Volume | 30095 |
| RMSE | 8,162 |
| %RMSE | 27% |
| Sum of Suared Diff | 19,985,999,010 |
| Number of Observations | 301 |
| average error | 1,002 |
| average % error | 3% |
| **Minor** | |
| Avg Count Volume | 18460 |
| RMSE | 6,401 |
| %RMSE | 35% |
| Sum of Suared Diff | 24,457,613,296 |
| Number of Observations | 598 |
| average error | (774) |
| average % error | -4% |
| **Collector** | |
| Avg Count Volume | 8758 |
| RMSE | 5,198 |
| %RMSE | 59% |
| Sum of Suared Diff | 13,671,582,138 |
| Number of Observations | 507 |
| average error | (2,424) |
| average % error | -28% |

**Figure 30: Regional Weekday Count/Volume Comparison (2007)**

| Weber County Validation Summary | | Davis County Validation Summary | |
|---|---|---|---|
| **All Facilities** | | **All Facilities** | |
| Avg Count Volume | 17,696 | Avg Count Volume | 23,400 |
| RMSE | 5,511 | RMSE | 6,199 |
| %RMSE | 31% | %RMSE | 26% |
| Sum of Suared Diff | 6,135,377,713 | Sum of Suared Diff | 6,917,473,793 |
| Number of Observations | 203 | Number of Observations | 181 |
| Average Error | (1,108.95) | Average Error | (1,168.04) |
| Average % Error | -6% | Average % Error | -5% |
| | | | |
| **Freeways** | | **Freeways** | |
| Avg Count Volume | 68975 | Avg Count Volume | 113469 |
| RMSE | 7,123 | RMSE | 7,967 |
| %RMSE | 10% | %RMSE | 7% |
| Sum of Suared Diff | 558,121,639 | Sum of Suared Diff | 952,162,451 |
| Number of Observations | 12 | Number of Observations | 16 |
| average error | (2,198) | average error | (176) |
| average % error | -3% | average % error | 0% |
| | | | |
| **Principal** | | **Principal** | |
| Avg Count Volume | 23597 | Avg Count Volume | 34486 |
| RMSE | 7,118 | RMSE | 11,690 |
| %RMSE | 30% | %RMSE | 34% |
| Sum of Suared Diff | 1,975,965,950 | Sum of Suared Diff | 1,229,881,326 |
| Number of Observations | 40 | Number of Observations | 10 |
| average error | 1,600 | average error | 3,082 |
| average % error | 7% | average % error | 9% |
| | | | |
| **Minor** | | **Minor** | |
| Avg Count Volume | 16420 | Avg Count Volume | 16714 |
| RMSE | 5,556 | RMSE | 6,124 |
| %RMSE | 34% | %RMSE | 37% |
| Sum of Suared Diff | 2,346,046,616 | Sum of Suared Diff | 3,450,178,483 |
| Number of Observations | 77 | Number of Observations | 93 |
| average error | (1,845) | average error | (1,074) |
| average % error | -11% | average % error | -6% |
| | | | |
| **Collector** | | **Collector** | |
| Avg Count Volume | 7519 | Avg Count Volume | 8399 |
| RMSE | 4,147 | RMSE | 4,590 |
| %RMSE | 55% | %RMSE | 55% |
| Sum of Suared Diff | 1,255,243,508 | Sum of Suared Diff | 1,285,251,533 |
| Number of Observations | 74 | Number of Observations | 62 |
| average error | (1,631) | average error | (2,251) |
| average % error | -22% | average % error | -27% |

**Figure 31: Weber and Davis County Count/Volume Comparison (2007)**

| Salt Lake County Validation Summary | |
|---|---|
| **All Facilities** | |
| Avg Count Volume | 26,592 |
| RMSE | 8,264 |
| %RMSE | 31% |
| Sum of Suared Diff | 51,493,938,750 |
| Number of Observations | 755 |
| Average Error | (576.18) |
| Average % Error | -2% |
| **Freeways** | |
| Avg Count Volume | 110095 |
| RMSE | 16,518 |
| %RMSE | 15% |
| Sum of Suared Diff | 14,187,383,168 |
| Number of Observations | 53 |
| average error | 1,477 |
| average % error | 1% |
| **Principal** | |
| Avg Count Volume | 34196 |
| RMSE | 9,204 |
| %RMSE | 27% |
| Sum of Suared Diff | 12,877,043,008 |
| Number of Observations | 153 |
| average error | 1,666 |
| average % error | 5% |
| **Minor** | |
| Avg Count Volume | 21373 |
| RMSE | 7,156 |
| %RMSE | 33% |
| Sum of Suared Diff | 15,566,063,717 |
| Number of Observations | 305 |
| average error | 23 |
| average % error | 0% |
| **Collector** | |
| Avg Count Volume | 10210 |
| RMSE | 6,039 |
| %RMSE | 59% |
| Sum of Suared Diff | 8,863,448,857 |
| Number of Observations | 244 |
| average error | (3,176) |
| average % error | -31% |

| Utah County Validation Summary | |
|---|---|
| **All Facilities** | |
| Avg Count Volume | 19,222 |
| RMSE | 5,267 |
| %RMSE | 27% |
| Sum of Suared Diff | 10,207,911,428 |
| Number of Observations | 369 |
| Average Error | (1,397.11) |
| Average % Error | -7% |
| **Freeways** | |
| Avg Count Volume | 94365 |
| RMSE | 6,862 |
| %RMSE | 7% |
| Sum of Suared Diff | 941,839,982 |
| Number of Observations | 21 |
| average error | (2,202) |
| average % error | -2% |
| **Principal** | |
| Avg Count Volume | 25895 |
| RMSE | 6,343 |
| %RMSE | 24% |
| Sum of Suared Diff | 3,903,108,726 |
| Number of Observations | 98 |
| average error | (489) |
| average % error | -2% |
| **Minor** | |
| Avg Count Volume | 13835 |
| RMSE | 5,037 |
| %RMSE | 36% |
| Sum of Suared Diff | 3,095,324,480 |
| Number of Observations | 123 |
| average error | (1,851) |
| average % error | -13% |
| **Collector** | |
| Avg Count Volume | 6865 |
| RMSE | 4,242 |
| %RMSE | 62% |
| Sum of Suared Diff | 2,267,638,240 |
| Number of Observations | 127 |
| average error | (1,525) |
| average % error | -22% |

**Figure 32: Salt Lake & Utah County Count/Volume Comparison (2007)**

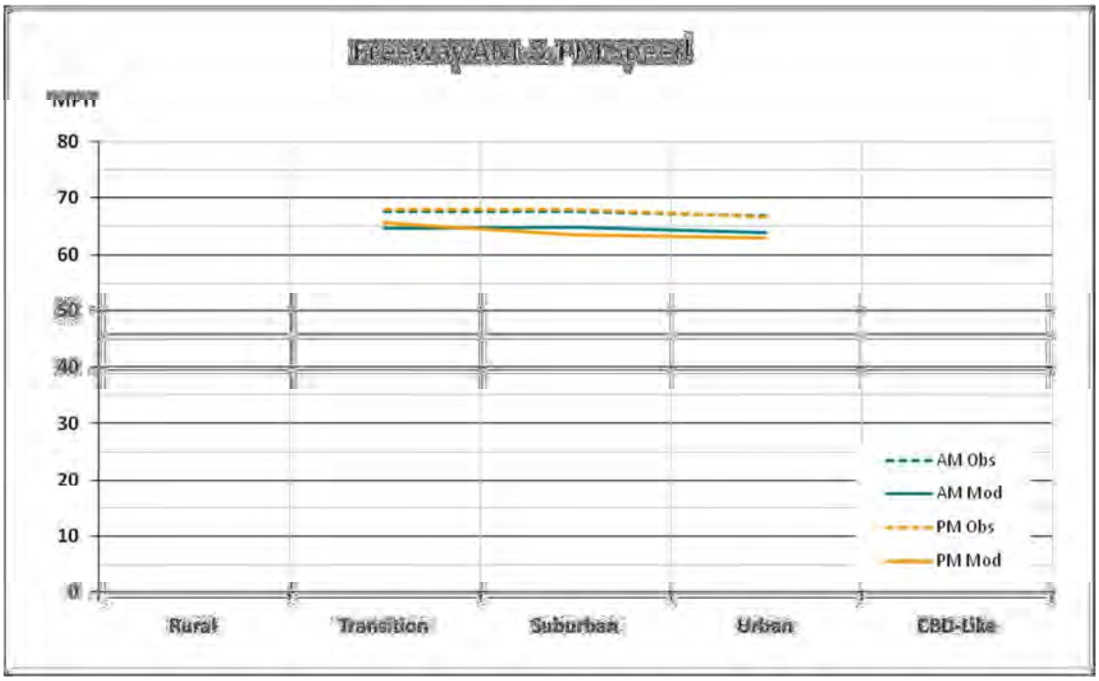
### 15.2.2 VMT Summary Statistics

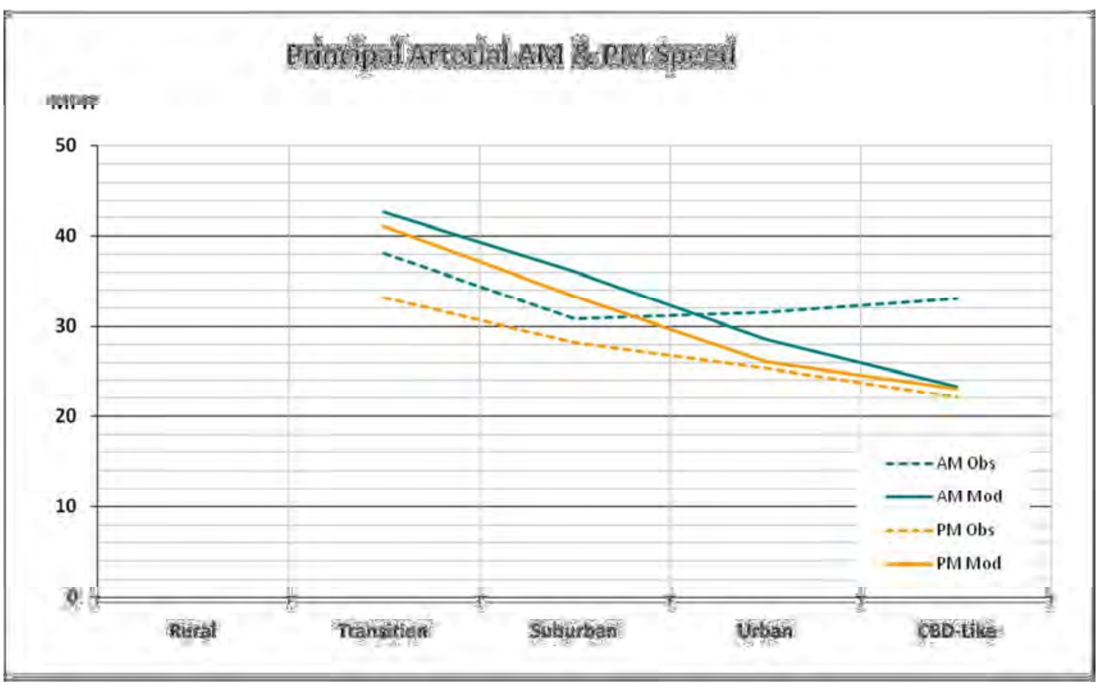
**Table 20: VMT Comparison (average weekday, 2007)**

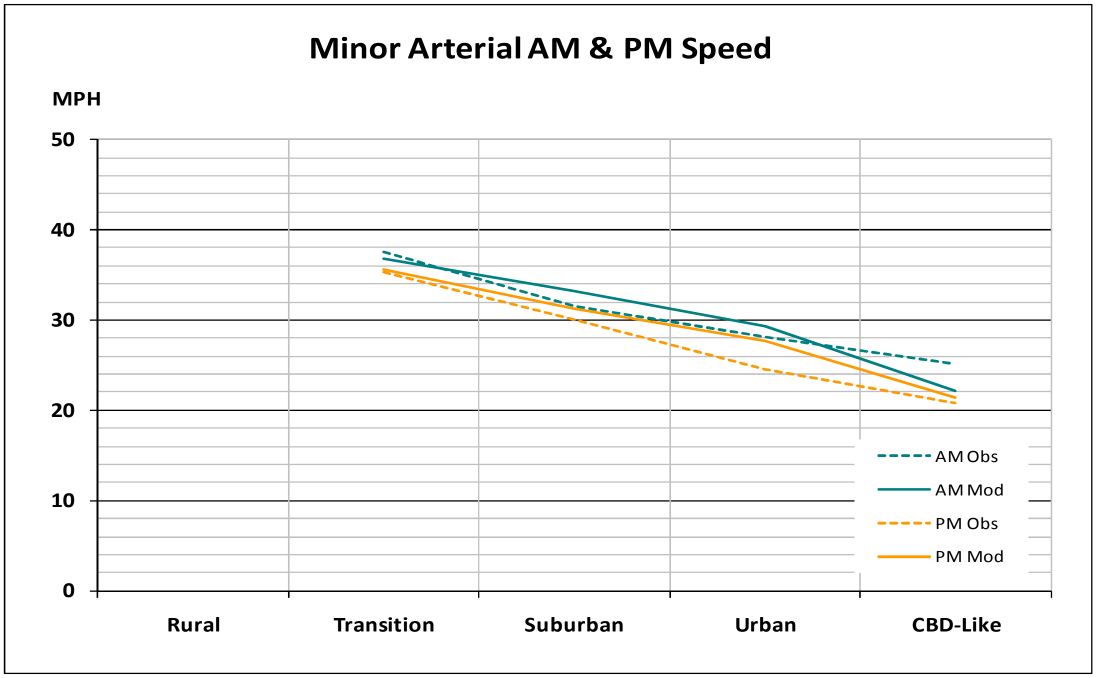
| Geography | Source | Freeway | Arterial | Fwy+Art | Local |
|---|---|---|---|---|---|
| Weber County | Modeled | 1,132,965 | 2,399,978 | 3,532,943 | 405,702 |
| | UDOT | 1,105,608 | 2,638,403 | 3,744,011 | 1,058,248 |
| | % Diff | 2.5% | -9.0% | -5.6% | -61.7% |
| Davis County | Modeled | 3,491,514 | 2,451,049 | 5,942,563 | 484,028 |
| | UDOT | 3,508,552 | 2,436,777 | 5,945,329 | 1,486,558 |
| | % Diff | -0.5% | 0.6% | 0.0% | -67.4% |
| Salt Lake County | Modeled | 10,142,361 | 11,763,713 | 21,906,074 | 1,630,344 |
| | UDOT | 9,730,230 | 11,321,725 | 21,051,955 | 5,266,024 |
| | % Diff | 4.2% | 3.9% | 4.1% | -69.0% |
| Utah County | Modeled | 4,025,398 | 4,949,700 | 8,975,097 | 635,783 |
| | UDOT | 4,072,782 | 4,637,565 | 8,710,348 | 2,223,076 |
| | % Diff | -1.2% | 6.7% | 3.0% | -71.4% |
| Region | Modeled | 18,792,237 | 21,564,440 | 40,356,676 | 3,155,857 |
| | UDOT | 18,417,172 | 21,034,470 | 39,451,642 | 10,033,906 |
| | % Diff | 2.0% | 2.5% | 2.3% | -68.5% |

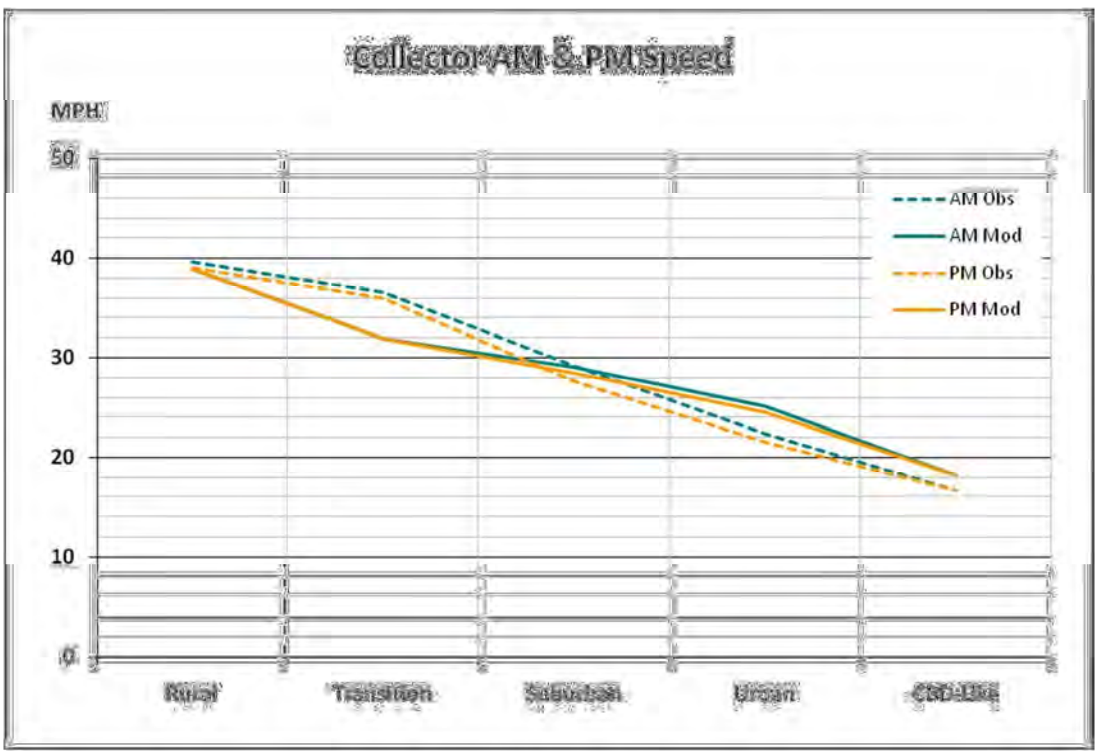
### 15.2.3 Speed Comparison

Speed estimates from model version 7 are compared below to GPS speed data collected by the University of Utah throughout the model region.




Minor Arterial AM & PM Speed
MPH
50
40
30
20
10
0
Rural
Transition
Suburban
Urban
CBD-Like
AM Obs
AM Mod
PM Obs
PM Mod


Collector AM & PM Speed
MPH
50
40
30
20
10
0
Rural
Transition
Suburban
Urban
CBD-Like
AM Obs
AM Mod
PM Obs
PM Mod

## 15.3 Transit Validation

The reasonableness of the transit modeling components has been assessed based on comparisons to observed transit trip patterns by mode. In general, the model does a good job reflecting transit availability, competitiveness and ridership. Some of the summaries below are from model version 6.1 and have not been updated, while some are from version 7. The reasons the version 6.1 summaries have not been updated are due to the model geography changing from version 6.1 to 7, and however the mode choice and transit models did not change appreciably since 6.1 so the thought is that the version 6.1 comparisons are still valid. As mentioned, UTA is currently undertaking a regionwide onboard survey (Spring 2011), so there will soon be current data with which to look at these measures.

### 15.3.1 Bus Boarding Comparison

The following figures present comparisons of modeled and observed boarding data both for individual routes and then for groups of routes that generally serve the same market. These comparisons were done with model version 7, compared to recent 2008/2009 data from UTA.

As previously stated, the goal of the transit validation exercise is to get reasonably "close" to observed data. Transit data are difficult to collect and transit demand can fluctuate significantly from season to season and with macroeconomic conditions such as gas prices and the overall economy. 2008/2009 in particular were problematic years due to the recession, dramatically fluctuating gas prices, and UTA service cuts and price increases. That said, the numbers from the model are close enough to observed data and can easily be refined at a sub-area level on a case-by-case basis.

Transit networks are difficult to code, requiring a fair amount of judgment about walk/drive accessibility and frequencies, among other things. For this reason the transit networks are often changing, which can have a big impact on the validation comparisons for specific routes.

**Table 21: Weber/Davis Bus Boarding Comparison**

| | | Route-Level | | | Market-Level | | |
|---|---|---|---|---|---|---|---|
| **Market** | **Routes** | **Model** | **Count 08** | **Count 09** | **Model** | **Count 08** | **Count 09** |
| **Davis County to SLC** | **460** | 60 | 110 | 38 | 473 | 421 | 282 |
| | **461** | 71 | 99 | 96 | | | |
| | **462** | 170 | 100 | 86 | | | |
| | **463** | 172 | 111 | 62 | | | |
| **Weber Co. - Davis Co. - SLC (local)** | **455** | 2,769 | 1,396 | 1,797 | 8,191 | 5,196 | 5,645 |
| | **470** | 5,422 | 3,800 | 3,848 | | | |
| **Weber Co. - Davis Co. - SLC (express)** | **456** | 0 | 138 | 65 | 1,712 | 2,820 | 1,266 |
| | **471** | 16 | 350 | 104 | | | |
| | **472** | 1,003 | 1,671 | 500 | | | |
| | **473** | 694 | 662 | 597 | | | |
| **Weber Co., North Davis Co.** | **603** | 1,654 | 1,713 | 2,301 | 6,709 | 7,295 | 8,309 |
| | **604** | 427 | 466 | 506 | | | |
| | **612** | 1,451 | 1,957 | 2,429 | | | |
| | **613** | 211 | 388 | 355 | | | |
| | **625** | 633 | 566 | 534 | | | |
| | **626** | 128 | 235 | 237 | | | |
| | **627** | 154 | 269 | 295 | | | |
| | **630** | 94 | 383 | 330 | | | |
| | **640** | 1,404 | 738 | 786 | | | |
| | **645** | 553 | 581 | 536 | | | |
| **Total Weber/Davis** | | | | | **17,085** | **15,732** | **15,502** |

**Table 22: Utah County Bus Boarding Comparison**

| | | Route-Level | | | Market-Level | | |
|---|---|---|---|---|---|---|---|
| **Market** | **Routes** | **Model** | **Count 08** | **Count 09** | **Model** | **Count 08** | **Count 09** |
| **Utah County to SLC** | **801** | 490 | 324 | 265 | 3,026 | 4,100 | 4,035 |
| | **802** | 14 | 531 | 374 | | | |
| | **803** | 74 | 197 | 172 | | | |
| | **804** | 286 | 226 | 193 | | | |
| | **805** | 495 | 206 | 146 | | | |
| | **807** | 98 | 186 | 186 | | | |
| | **810** | 356 | 190 | 128 | | | |
| | **811** | 1,041 | 1,846 | 2,209 | | | |
| | **817** | 172 | 395 | 362 | | | |
| **Utah County Internal** | **808** | 265 | 125 | 133 | 11,416 | 10,824 | 10,796 |
| | **820** | 304 | 271 | 288 | | | |
| | **822** | 444 | 714 | 642 | | | |
| | **830** | 5,955 | 3,510 | 3,742 | | | |
| | **831** | 975 | 1,092 | 1,261 | | | |
| | **832** | 815 | 2,510 | 2,206 | | | |
| | **833** | 86 | 630 | 554 | | | |
| | **850** | 1,773 | 1,345 | 1,303 | | | |
| | **862** | 800 | 627 | 667 | | | |
| **Total Utah County** | | | | | **14,443** | **14,925** | **14,831** |

Note: the 2008 count for route 807 is actually a 2009 count.

**Table 23: Salt Lake County Bus Boarding Comparison**

| | | Route-Level | | | Market-Level | | |
|---|---|---|---|---|---|---|---|
| **Market** | **Routes** | **Model** | **Count 08** | **Count 09** | **Model** | **Count 08** | **Count 09** |
| **Avenues** | **3** | 123 | 616 | 762 | 1,382 | 1,899 | 2,244 |
| | **6** | 643 | 822 | 916 | | | |
| | **11** | 615 | 460 | 566 | | | |
| **Parleys/Millcreek** | **223** | 648 | 390 | 320 | 1,451 | 1,176 | 923 |
| | **228** | 803 | 785 | 603 | | | |
| **13th East** | **213** | 1,334 | 1,171 | 1,228 | 3,974 | 3,416 | 3,399 |
| | **220** | 2,639 | 2,245 | 2,171 | | | |
| **33rd South** | **33** | 1,592 | 1,357 | 1,494 | 1,592 | 1,357 | 1,494 |
| **45th & 39th South** | **39** | 1,306 | 1,376 | 1,525 | 6,539 | 6,198 | 6,246 |
| | **41** | 1,488 | 1,867 | 1,977 | | | |
| | **45** | 1,430 | 1,027 | 952 | | | |
| | **47** | 2,315 | 1,927 | 1,792 | | | |
| **Kearns/WVC/West Jordan** | **227** | 1,649 | 864 | 853 | 4,956 | 3,531 | 3,047 |
| | **232** | 924 | 611 | 540 | | | |
| | **236** | 269 | 230 | 167 | | | |
| | **240** | 1,072 | 1,023 | 684 | | | |
| | **248** | 1,043 | 803 | 803 | | | |
| **35th South** | **35** | 2,552 | 2,490 | 1,325 | 2,552 | 2,490 | 1,325 |
| **Midvale/Sandy** | **72** | 610 | 427 | 441 | 1,446 | 1,512 | 1,501 |
| | **94** | 102 | 220 | 220 | | | |
| | **201** | 284 | 552 | 556 | | | |
| | **207** | 449 | 313 | 284 | | | |
| **9th East** | **209** | 5,291 | 2,305 | 2,445 | 5,291 | 2,305 | 2,445 |
| **78th & 90th South** | **78** | 390 | 352 | 362 | 778 | 660 | 638 |
| | **90** | 388 | 308 | 276 | | | |
| **Redwood Road** | **217** | 3,431 | 2,756 | 3,002 | 4,371 | 3,817 | 4,087 |
| | **218** | 940 | 1,061 | 1,085 | | | |
| **Rose Park** | **516** | 421 | 797 | 1,007 | 2,306 | 2,637 | 3,199 |
| | **517** | 980 | 861 | 1,189 | | | |
| | **519** | 265 | 722 | 860 | | | |
| | **522** | 640 | 257 | 143 | | | |
| **17th & 21st South** | **17** | 435 | 431 | 434 | 3,905 | 2,418 | 2,559 |
| | **21** | 3,471 | 1,987 | 2,125 | | | |
| **Misc SLC** | **500** | 650 | 578 | 571 | 1,518 | 1,029 | 1,032 |
| | **550** | 868 | 451 | 461 | | | |
| **3rd & 5th East** | **203** | 51 | 443 | 490 | 2,619 | 2,695 | 2,990 |
| | **205** | 2,568 | 2,253 | 2,500 | | | |
| **SL Co. Fast Bus** | **307** | 277 | 208 | 224 | 2,711 | 2,224 | 2,106 |
| | **313** | 152 | 187 | 144 | | | |
| | **320** | 135 | 239 | 203 | | | |
| | **323** | 589 | 0 | 0 | | | |
| | **327** | 649 | 463 | 482 | | | |
| | **335** | 142 | 94 | 96 | | | |
| | **346** | 65 | 84 | 84 | | | |
| | **347** | 167 | 303 | 330 | | | |
| | **348** | 216 | 216 | 211 | | | |
| | **354** | 111 | 206 | 159 | | | |
| | **356** | 196 | 126 | 74 | | | |
| | **389** | 12 | 98 | 99 | | | |
| **State St** | **9** | 468 | 555 | 569 | 3,665 | 4,309 | 4,829 |
| | **200** | 3,197 | 3,754 | 4,260 | | | |
| **Tooele** | **451** | 0 | 443 | 413 | 58 | 808 | 804 |
| | **453** | 58 | 365 | 391 | | | |
| **Total Salt Lake County** | | | | | **51,115** | **44,480** | **44,868** |

Note: the 2008 counts for routes 35 and 94 are actually 2006 counts.

## 15.3.2 TRAX Boarding Comparison

The following comparison documents modeled TRAX boardings compared to UTA data for 2006. This comparison is produced using version 7. In general, the comparison and correlation is quite good. It is likely that with some minor refinements to access links around the 2100 S (for example) to reflect reasonable access to land-uses in the area the model would look even better.

**Table 24: Comparison of Version 7 Modeled (2007) and Observed (2006) TRAX Boardings**

| **Downtown** | **COUNTS** | **MODEL** |
|---|---|---|
| Delta | 3,199 | 2,232 |
| Temple Square | 1,712 | 1,418 |
| CentCity | 3,156 | 4,239 |
| Gallivan | 7,211 | 7,967 |
| | **15,278** | **15,855** |

<table>
<tr><th>Downtown</th><th>COUNTS</th><th>MODEL</th></tr>
<tr><td>Delta</td><td rowspan="3">8,067</td><td rowspan="3">7,888</td></tr>
<tr><td>Temple Square</td></tr>
<tr><td>CentCity</td></tr>
<tr><td>Gallivan</td><td>7,211</td><td>7,967</td></tr>
<tr><td></td><td>15,278</td><td>15,855</td></tr>
</table>

| **University Extension** | **COUNTS** | **MODEL** |
|---|---|---|
| Library | 1,833 | 1,234 |
| Trolley | 1,584 | 1,199 |
| 900 East | 1,533 | 1,684 |
| Stadium | 2,694 | 4,367 |
| South Campus | 1,229 | 288 |
| Ft Douglas | 325 | 491 |
| Med Center | 1,235 | 1,684 |
| | **10,433** | **10,947** |

<table>
<tr><th>University Extension</th><th>COUNTS</th><th>MODEL</th></tr>
<tr><td>Library</td><td>1,833</td><td>1,234</td></tr>
<tr><td>Trolley</td><td rowspan="2">3,117</td><td rowspan="2">2,883</td></tr>
<tr><td>900 East</td></tr>
<tr><td>Stadium</td><td rowspan="4">5,483</td><td rowspan="4">6,830</td></tr>
<tr><td>South Campus</td></tr>
<tr><td>Ft Douglas</td></tr>
<tr><td>Med Center</td></tr>
<tr><td></td><td>10,433</td><td>10,947</td></tr>
</table>

| **Sandy Extension** | **COUNTS** | **MODEL** |
|---|---|---|
| Court House | 1,471 | 1,684 |
| 900 S | 680 | 639 |
| Ballpark | 1,605 | 1,274 |
| Central Pointe (2100) | 1,457 | 2,369 |
| Millcreek (3300) | 1,892 | 2,268 |
| Meadowbrook (3900) | 1,710 | 2,203 |
| Murray N (4500) | 1,302 | 1,703 |
| Murray C (5300) | 1,482 | 1,977 |
| Fashion Place (6400) | 1,204 | 1,212 |
| Ft Union (7200) | 1,161 | 1,167 |
| Midvale Center (7700) | 1,335 | 1,452 |
| Historic Sandy (9000) | 1,397 | 1,689 |
| Sandy Expo (9400) | | 167 |
| Sandy Civic (10000) | 3,057 | 2,587 |
| | **19,753** | **22,394** |

<table>
<tr><th>Sandy Extension</th><th>COUNTS</th><th>MODEL</th></tr>
<tr><td>Court House</td><td>1,471</td><td>1,684</td></tr>
<tr><td>900 S</td><td rowspan="2">2,285</td><td rowspan="2">1,913</td></tr>
<tr><td>Ballpark</td></tr>
<tr><td>Central Pointe (2100)</td><td>1,457</td><td>2,369</td></tr>
<tr><td>Millcreek (3300)</td><td rowspan="2">3,602</td><td rowspan="2">4,472</td></tr>
<tr><td>Meadowbrook (3900)</td></tr>
<tr><td>Murray N (4500)</td><td rowspan="2">2,784</td><td rowspan="2">3,681</td></tr>
<tr><td>Murray C (5300)</td></tr>
<tr><td>Fashion Place (6400)</td><td rowspan="3">3,700</td><td rowspan="3">3,832</td></tr>
<tr><td>Ft Union (7200)</td></tr>
<tr><td>Midvale Center (7700)</td></tr>
<tr><td>Historic Sandy (9000)</td><td rowspan="3">4,455</td><td rowspan="3">4,443</td></tr>
<tr><td>Sandy Expo (9400)</td></tr>
<tr><td>Sandy Civic (10000)</td></tr>
<tr><td></td><td>19,753</td><td>22,394</td></tr>
</table>

## 15.3.3 Transit Trip Table Analysis (Version 6.1)

The next table shows a comparison of modeled (2005) and observed (2006) daily transit productions and attractions by medium district (version 6 medium districts). In general, the model does a good job identifying locations with the most transit demand. Comparisons are provided for all transit and for TRAX only.

**Table 25: Comparison of Transit Productions and Attractions (Version 6.1)**

| Version 6 Medium District | Survey Prods Total Transit | Model Prods Total Transit | Survey Attrs Total Transit | Model Attrs Total Transit | Survey Prods TRAX | Model Prods TRAX | Survey Attrs TRAX | Model Attrs TRAX |
|---|---|---|---|---|---|---|---|---|
| 1 | 1,276 | 1,157 | 1,343 | 391 | 62 | 0 | 0 | 0 |
| 2 | 0 | 14 | 2 | 1 | 0 | 0 | 2 | 0 |
| 3 | 742 | 558 | 450 | 290 | 56 | 0 | 0 | 0 |
| 4 | 2,612 | 2,519 | 2,136 | 1,719 | 0 | 0 | 39 | 0 |
| 5 | 1,274 | 1,580 | 2,194 | 2,157 | 36 | 0 | 6 | 0 |
| 6 | 623 | 586 | 353 | 417 | 76 | 0 | 0 | 0 |
| 7 | 904 | 1,036 | 727 | 362 | 34 | 0 | 38 | 0 |
| 8 | 1,019 | 905 | 341 | 470 | 152 | 0 | 9 | 0 |
| 9 | 1,683 | 1,464 | 479 | 525 | 148 | 18 | 2 | 0 |
| 10 | 1,100 | 1,440 | 162 | 672 | 113 | 222 | 8 | 37 |
| 11 | 2,577 | 2,447 | 456 | 838 | 427 | 511 | 8 | 112 |
| 12 | 8,453 | 5,226 | 28,529 | 35,432 | 4,624 | 3,043 | 16,833 | 20,647 |
| 13 | 16,194 | 17,229 | 24,689 | 22,494 | 7,725 | 9,061 | 13,221 | 12,081 |
| 14 | 5,173 | 6,989 | 1,806 | 2,072 | 1,478 | 2,682 | 400 | 277 |
| 15 | 7,554 | 8,625 | 6,865 | 7,081 | 3,106 | 4,863 | 2,666 | 3,485 |
| 16 | 5,236 | 4,805 | 2,767 | 2,595 | 1,489 | 1,618 | 684 | 660 |
| 17 | 9 | 51 | 584 | 254 | 0 | 11 | 146 | 62 |
| 18 | 876 | 992 | 368 | 165 | 320 | 500 | 56 | 24 |
| 19 | 6,859 | 8,375 | 5,004 | 3,940 | 3,542 | 4,245 | 1,356 | 586 |
| 20 | 5,225 | 5,091 | 1,403 | 1,053 | 3,021 | 2,994 | 414 | 181 |
| 21 | 386 | 260 | 6 | 3 | 183 | 245 | 6 | 1 |

| Version 6 Medium District | Survey Prods Total Transit | Model Prods Total Transit | Survey Attrs Total Transit | Model Attrs Total Transit | Survey Prods TRAX | Model Prods TRAX | Survey Attrs TRAX | Model Attrs TRAX |
|---|---|---|---|---|---|---|---|---|
| **22** | 2,723 | 2,056 | 586 | 361 | 1,600 | 1,236 | 90 | 74 |
| **23** | 7,023 | 6,810 | 2,144 | 2,468 | 5,254 | 4,376 | 1,108 | 1,165 |
| **24** | 3,804 | 3,695 | 1,847 | 1,556 | 3,232 | 2,679 | 1,193 | 762 |
| **25** | 514 | 816 | 41 | 39 | 423 | 714 | 24 | 13 |
| **26** | 1,263 | 1,255 | 86 | 259 | 436 | 339 | 18 | 1 |
| **27** | 285 | 578 | 63 | 96 | 41 | 135 | 8 | 4 |
| **28** | 1,292 | 821 | 56 | 223 | 444 | 130 | 0 | 0 |
| **29** | 2,481 | 3,474 | 3,643 | 4,006 | 231 | 146 | 148 | 0 |
| **30** | 6,190 | 7,111 | 5,970 | 7,120 | 226 | 109 | 114 | 0 |
| **31** | 511 | 827 | 176 | 174 | 32 | 71 | 2 | 0 |
| **32** | 74 | 284 | 11 | 37 | 2 | 45 | 0 | 0 |
| **33** | 22 | 21 | 0 | 0 | 0 | 18 | 0 | 0 |
| **34** | 157 | 101 | 0 | 0 | 118 | 101 | 0 | 0 |
| **35** | 113 | 66 | 23 | 0 | 31 | 56 | 0 | 0 |

## 15.4 Trip Distribution Validation

### 15.4.1 Trip Length Frequency Comparisons

Below is a comparison of modeled vs. observed trip length frequency distributions. The trip distribution model coefficients were originally estimated using travel time frequency distributions from the 1993 home interview survey, and then adjusted based on judgment so that the base year model outcome matched reasonably well along several dimensions (including trip lengths). The trip length validation is done against Census data (for work trips), NHTS data, and the 1993 home interview survey. The NHTS data rely on reported time/distance values, while the other sources represent a blend of model data for time/distance measurement and survey data for the geographic distribution.

The NHTS data represent the smallest sample but the most current sample (2001). In general, the trip length frequency comparison is acceptable when the model trends or matches similarly the observed distributions. The model was calibrated to fit travel time distributions, and the fact that the travel distance distributions also track closely with various data sources further suggests that model speeds are defensible.

These trip length frequency comparisons are made using model version 7, and however would clearly need to be redone with the upcoming home interview survey data.

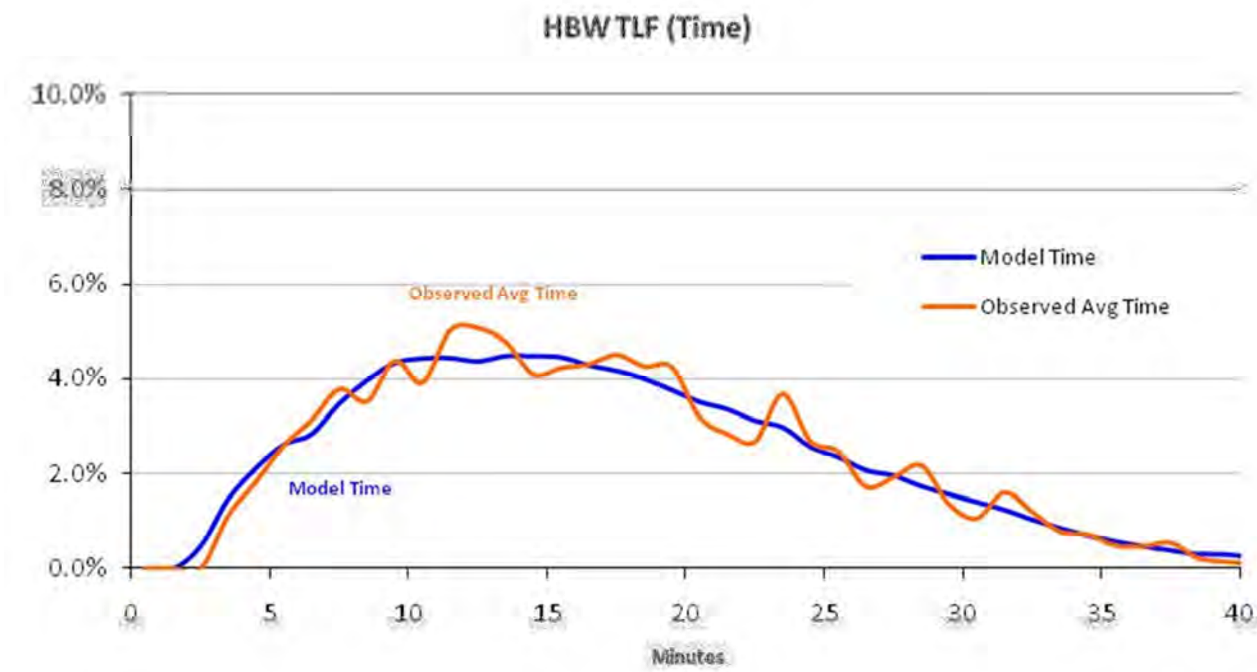



**Figure 33: HBW Trip Time Distribution Comparison**

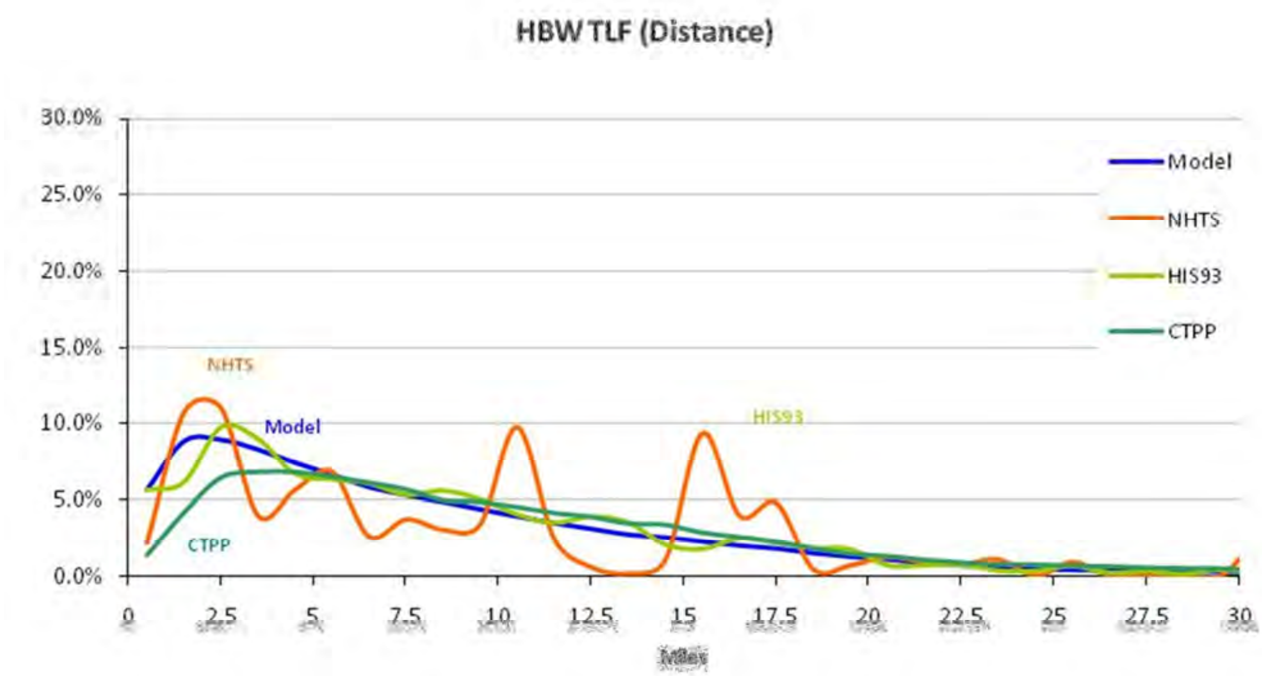



**Figure 34: HBW Trip Distance Distribution Comparison**

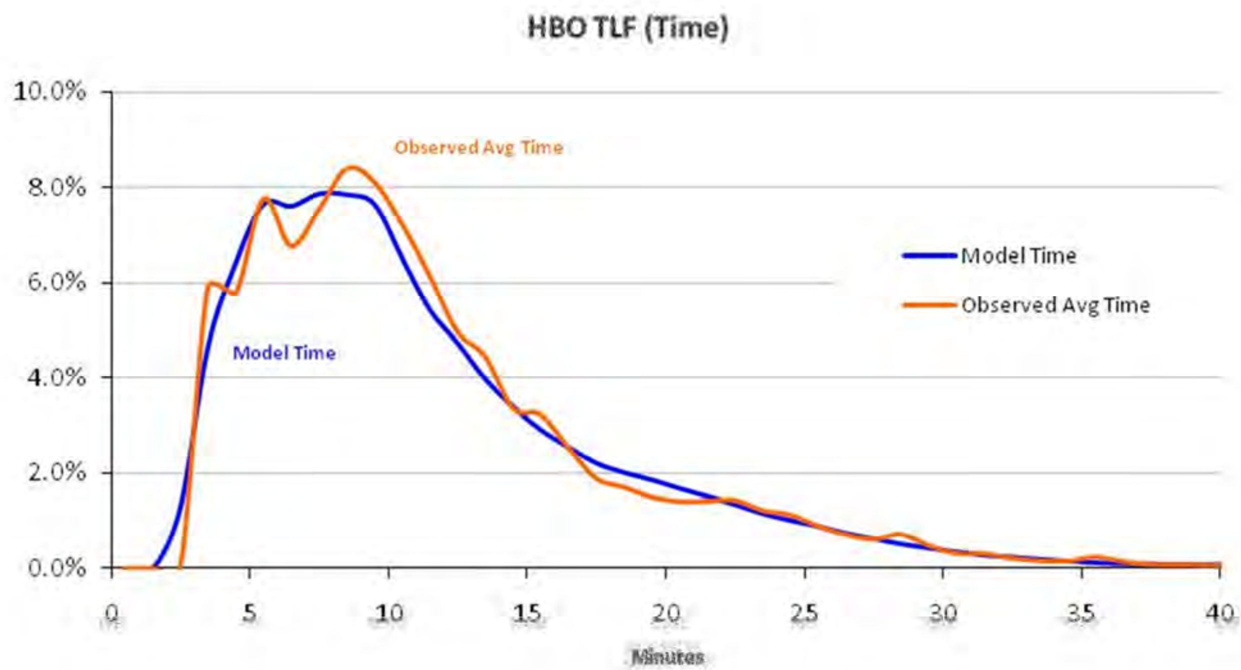



**Figure 35: HBO Trip Time Distribution Comparison**

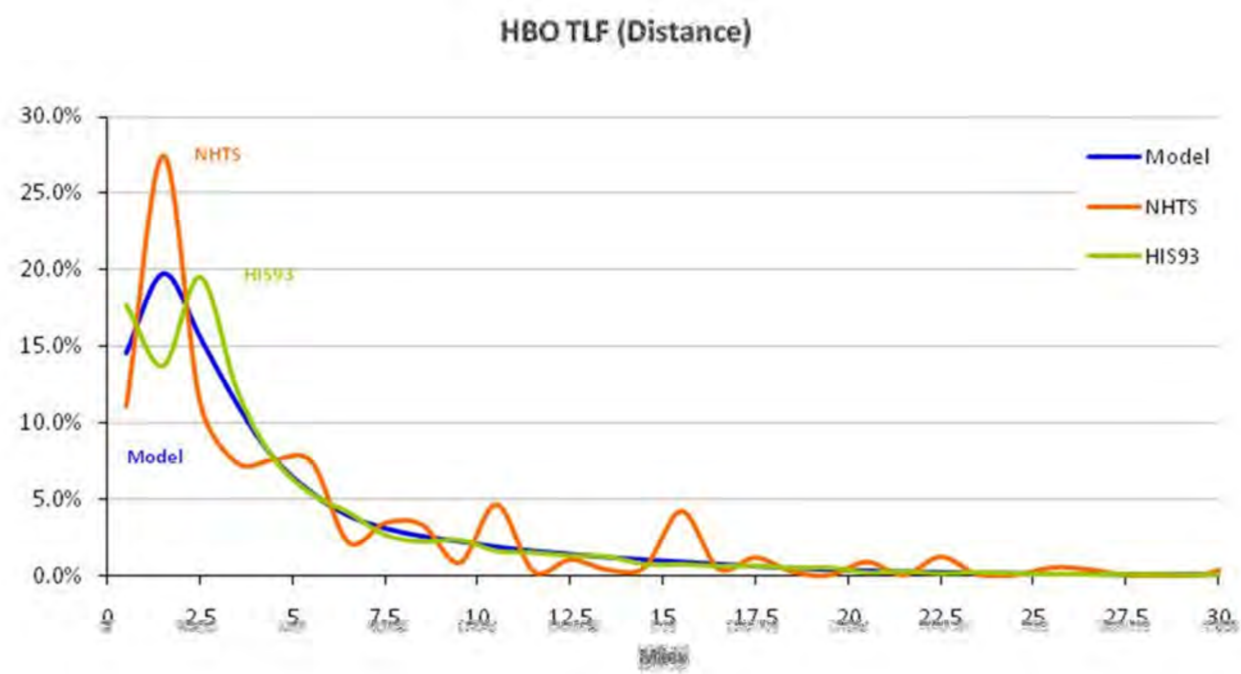



**Figure 36: HBO Trip Distance Distribution Comparison**

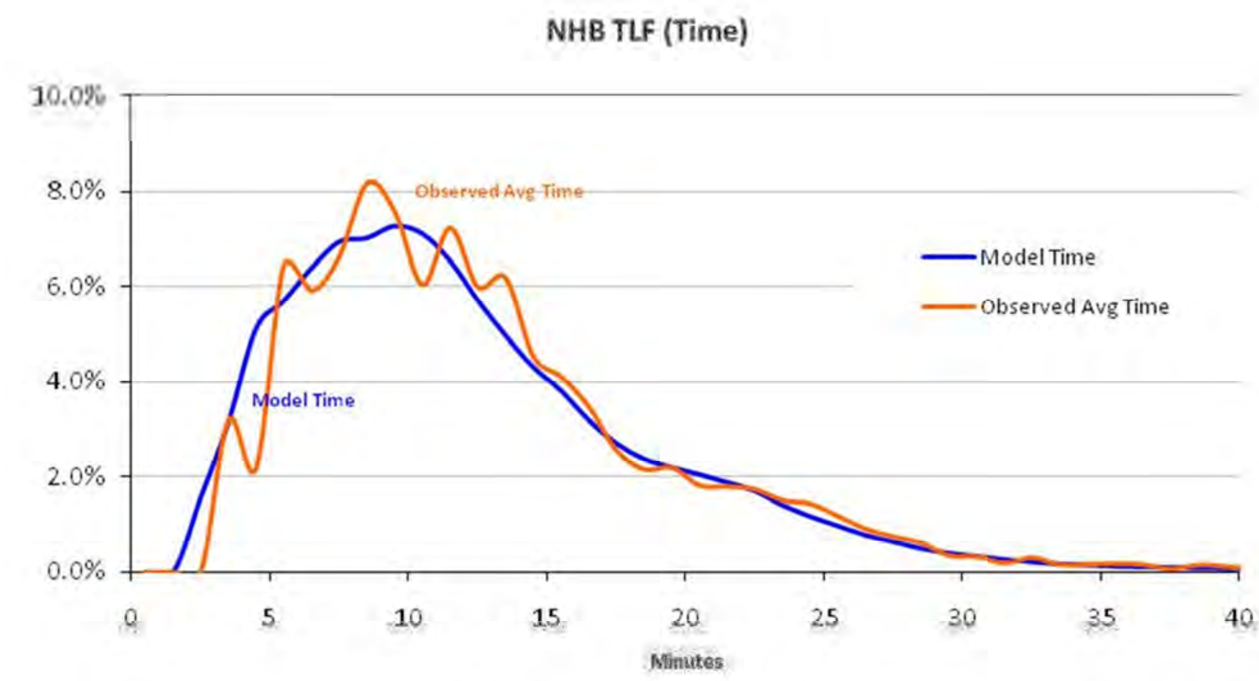



**Figure 37: NHB Trip Time Distribution Comparison**

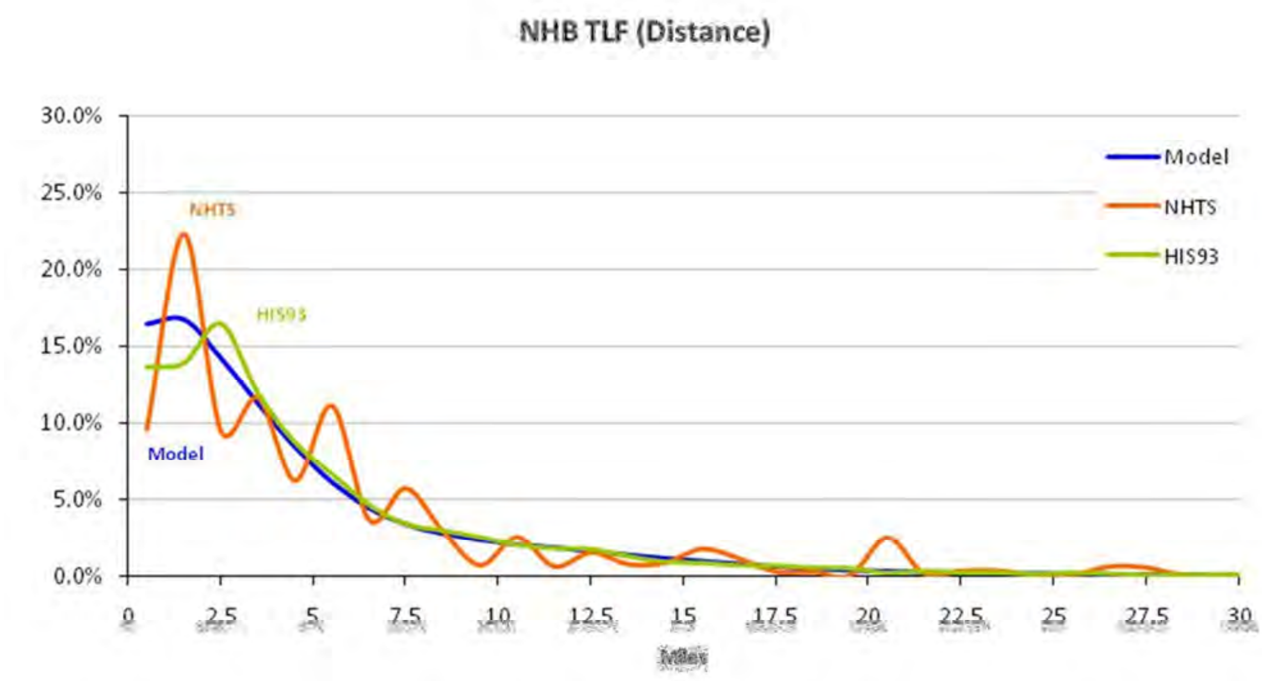



**Figure 38: NHB Trip Distance Distribution Comparison**

## 15.4.2 Work Trip Distribution Patterns

The following tables compare the Home-to-Work travel patterns from the version 6.1 2005 base year travel model against the 2000 Census Journey-to-Work data. The destination choice model has not changed in any way from version 6.1 to version 7, so this comparison was not revisited. Additionally, the 2000 CTPP data are getting somewhat old and the district structure changed somewhat with version 7, each of which would complicate redoing the comparison.

The data are summarized at the Medium District level, using the medium districts from version 6. The first comparison is of total Productions (home end) and Attractions (work end). The model output and the Census tabulations are not expected to have the same number of trips, for a variety of reasons, which is why the data are summarized in the right hand columns as percentages of the regional totals. In general, these comparisons suggest that the modeled productions and attractions are reasonably distributed.

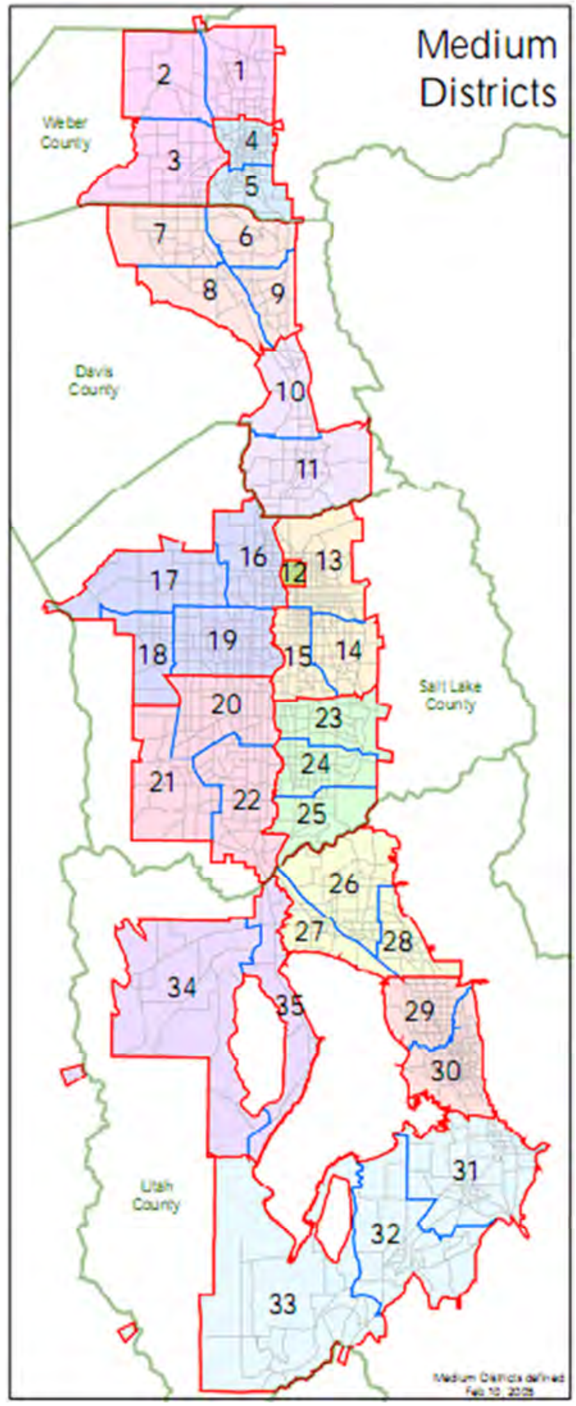



**Figure 39: Version 6 Medium Districts**

**Table 26: Comparison of Work Trip End Locations (2005 Model Version 6.1 vs.2000 Census)**

| District | Model Productions | Census Productions | Model Attractions | Census Attractions | Percent of Total Model Productions | Percent of Total Census Productions | Percent of Total Model Attractions | Percent of Total Census Attractions |
|---|---|---|---|---|---|---|---|---|
| 1 | 45,585 | 21,152 | 23,880 | 12,709 | 4.1% | 2.9% | 2.1% | 1.7% |
| 2 | 5,854 | 3,941 | 2,905 | 1,328 | 0.5% | 0.5% | 0.3% | 0.2% |
| 3 | 27,871 | 20,502 | 23,731 | 16,223 | 2.5% | 2.8% | 2.1% | 2.2% |
| 4 | 26,512 | 18,106 | 35,594 | 28,066 | 2.4% | 2.4% | 3.2% | 3.8% |
| 5 | 29,638 | 17,883 | 28,745 | 17,776 | 2.7% | 2.4% | 2.6% | 2.4% |
| 6 | 16,811 | 12,866 | 22,240 | 18,895 | 1.5% | 1.7% | 2.0% | 2.5% |
| 7 | 32,751 | 20,428 | 20,544 | 13,130 | 2.9% | 2.8% | 1.8% | 1.8% |
| 8 | 23,017 | 11,832 | 20,648 | 9,429 | 2.1% | 1.6% | 1.9% | 1.3% |
| 9 | 30,066 | 21,545 | 13,868 | 11,095 | 2.7% | 2.9% | 1.2% | 1.5% |
| 10 | 18,549 | 11,955 | 14,009 | 7,304 | 1.7% | 1.6% | 1.3% | 1.0% |
| 11 | 39,886 | 27,464 | 36,086 | 22,297 | 3.6% | 3.7% | 3.2% | 3.0% |
| 12 | 7,222 | 5,923 | 79,935 | 63,313 | 0.6% | 0.8% | 7.2% | 8.5% |
| 13 | 65,998 | 52,446 | 108,977 | 77,642 | 5.9% | 7.1% | 9.8% | 10.5% |
| 14 | 67,152 | 41,867 | 33,529 | 26,234 | 6.0% | 5.6% | 3.0% | 3.5% |
| 15 | 47,193 | 35,576 | 103,810 | 61,538 | 4.2% | 4.8% | 9.3% | 8.3% |
| 16 | 29,530 | 20,311 | 71,383 | 49,096 | 2.7% | 2.7% | 6.4% | 6.6% |
| 17 | 7,051 | 22 | 24,789 | 13,492 | 0.6% | 0.0% | 2.2% | 1.8% |
| 18 | 13,189 | 9,608 | 5,950 | 5,337 | 1.2% | 1.3% | 0.5% | 0.7% |
| 19 | 90,406 | 71,016 | 82,450 | 55,722 | 8.1% | 9.6% | 7.4% | 7.5% |
| 20 | 77,124 | 56,258 | 32,526 | 20,225 | 6.9% | 7.6% | 2.9% | 2.7% |
| 21 | 11,535 | 2,856 | 1,708 | 686 | 1.0% | 0.4% | 0.2% | 0.1% |
| 22 | 37,517 | 23,280 | 14,797 | 7,169 | 3.4% | 3.1% | 1.3% | 1.0% |
| 23 | 64,123 | 50,904 | 49,586 | 33,418 | 5.8% | 6.9% | 4.5% | 4.5% |
| 24 | 38,838 | 29,688 | 44,282 | 25,791 | 3.5% | 4.0% | 4.0% | 3.5% |
| 25 | 18,902 | 8,846 | 11,016 | 7,534 | 1.7% | 1.2% | 1.0% | 1.0% |
| 26 | 32,624 | 14,288 | 20,058 | 11,767 | 2.9% | 1.9% | 1.8% | 1.6% |
| 27 | 10,289 | 4,869 | 7,259 | 3,692 | 0.9% | 0.7% | 0.7% | 0.5% |
| 28 | 25,298 | 12,756 | 12,324 | 7,743 | 2.3% | 1.7% | 1.1% | 1.0% |
| 29 | 50,148 | 34,873 | 58,341 | 36,004 | 4.5% | 4.7% | 5.2% | 4.9% |
| 30 | 58,404 | 46,430 | 78,713 | 53,905 | 5.2% | 6.3% | 7.1% | 7.3% |
| 31 | 32,104 | 19,283 | 20,747 | 16,438 | 2.9% | 2.6% | 1.9% | 2.2% |
| 32 | 17,078 | 9,392 | 7,237 | 5,628 | 1.5% | 1.3% | 0.6% | 0.8% |
| 33 | 5,190 | 2,684 | 913 | 700 | 0.5% | 0.4% | 0.1% | 0.1% |
| 34 | 6,570 | 137 | 485 | 14 | 0.6% | 0.0% | 0.0% | 0.0% |
| 35 | 3,594 | 475 | 555 | 119 | 0.3% | 0.1% | 0.0% | 0.0% |
| 36 | 0 | 0 | 0 | 0 | 0.0% | 0.0% | 0.0% | 0.0% |

The next comparison examines the modeled and observed work trip-end locations by auto ownership or income class. The mode choice model is segmented by auto ownership and income. In this summary, the percentage of the regional total is presented. Clearly, the model is locating work trip productions and attraction by market segment reasonably well.

**Table 27: Percent of HBW Trip Productions by Market Segment, 2005 Model Version 6.1**

**Percent of Total Productions by Income or Vehicle Group**

| | Low Income | | High Income | | 0 Vehicles | | 1 Vehicle | | 2+ Vehicles | |
|---|---|---|---|---|---|---|---|---|---|---|
| District | Model | Census | Model | Census | Model | Census | Model | Census | Model | Census |
| 1 | 4.2% | 2.7% | 4.1% | 3.0% | 2.5% | 2.1% | 2.8% | 2.5% | 4.5% | 3.0% |
| 2 | 0.4% | 0.3% | 0.6% | 0.6% | 0.3% | 0.5% | 0.3% | 0.3% | 0.6% | 0.6% |
| 3 | 2.4% | 2.0% | 2.6% | 2.9% | 1.8% | 1.9% | 2.2% | 2.1% | 2.6% | 2.9% |
| 4 | 4.5% | 4.9% | 1.9% | 2.0% | 3.7% | 5.9% | 3.7% | 4.0% | 2.1% | 2.0% |
| 5 | 2.3% | 2.2% | 2.7% | 2.4% | 2.0% | 1.7% | 2.4% | 2.4% | 2.7% | 2.4% |
| 6 | 1.7% | 1.7% | 1.5% | 1.6% | 1.3% | 0.8% | 1.4% | 1.7% | 1.6% | 1.7% |
| 7 | 3.3% | 2.1% | 2.9% | 2.8% | 2.6% | 1.8% | 2.5% | 2.2% | 3.1% | 2.8% |
| 8 | 1.9% | 1.1% | 2.1% | 1.7% | 1.5% | 1.5% | 1.6% | 1.2% | 2.2% | 1.7% |
| 9 | 1.9% | 1.8% | 2.9% | 3.1% | 1.7% | 2.0% | 2.0% | 2.0% | 2.9% | 3.1% |
| 10 | 0.8% | 0.6% | 1.9% | 1.8% | 0.9% | 0.5% | 1.1% | 0.9% | 1.8% | 1.8% |
| 11 | 2.9% | 2.6% | 3.8% | 3.9% | 2.6% | 2.4% | 3.1% | 2.9% | 3.8% | 3.9% |
| 12 | 1.6% | 2.0% | 0.5% | 0.5% | 4.4% | 4.5% | 2.0% | 2.2% | 0.3% | 0.3% |
| 13 | 6.9% | 10.7% | 5.8% | 6.3% | 13.8% | 15.7% | 10.5% | 11.7% | 4.8% | 5.7% |
| 14 | 4.2% | 5.0% | 6.5% | 5.8% | 4.4% | 4.7% | 6.3% | 6.3% | 6.1% | 5.6% |
| 15 | 5.5% | 6.7% | 4.0% | 4.4% | 7.6% | 7.7% | 6.3% | 7.6% | 3.8% | 4.1% |
| 16 | 4.8% | 4.4% | 2.2% | 2.4% | 5.1% | 7.4% | 3.4% | 4.0% | 2.5% | 2.2% |
| 17 | 0.4% | 0.0% | 0.7% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.8% | 0.0% |
| 18 | 1.6% | 1.0% | 1.1% | 1.3% | 1.1% | 1.2% | 1.1% | 1.4% | 1.2% | 1.3% |
| 19 | 10.4% | 9.1% | 7.7% | 9.5% | 8.1% | 9.0% | 8.7% | 10.1% | 8.1% | 9.3% |
| 20 | 6.3% | 4.5% | 7.2% | 8.1% | 5.1% | 4.0% | 5.9% | 5.3% | 7.3% | 8.2% |
| 21 | 0.7% | 0.1% | 1.1% | 0.4% | 0.5% | 0.1% | 0.6% | 0.2% | 1.1% | 0.4% |
| 22 | 1.9% | 0.8% | 3.7% | 3.6% | 1.6% | 0.7% | 2.0% | 1.2% | 3.8% | 3.7% |
| 23 | 4.2% | 5.1% | 6.2% | 7.3% | 4.8% | 5.6% | 5.7% | 7.2% | 5.9% | 7.0% |
| 24 | 2.2% | 1.9% | 3.8% | 4.5% | 2.4% | 2.4% | 2.8% | 2.4% | 3.7% | 4.5% |
| 25 | 0.6% | 0.4% | 2.0% | 1.4% | 0.7% | 0.5% | 1.0% | 0.7% | 1.9% | 1.4% |
| 26 | 1.8% | 1.1% | 3.0% | 2.1% | 1.4% | 1.4% | 1.8% | 1.0% | 3.1% | 2.2% |
| 27 | 0.9% | 0.6% | 0.9% | 0.7% | 0.6% | 0.6% | 0.7% | 0.5% | 0.9% | 0.7% |
| 28 | 1.7% | 1.4% | 2.3% | 1.9% | 1.3% | 0.8% | 1.5% | 1.1% | 2.3% | 2.0% |
| 29 | 4.0% | 5.0% | 4.4% | 4.8% | 3.9% | 2.8% | 4.4% | 4.2% | 4.3% | 5.0% |
| 30 | 8.5% | 14.7% | 4.3% | 4.6% | 8.8% | 7.9% | 7.9% | 7.8% | 4.3% | 5.7% |
| 31 | 2.6% | 2.2% | 2.8% | 2.7% | 1.9% | 1.0% | 2.3% | 2.0% | 2.9% | 2.8% |
| 32 | 1.4% | 1.1% | 1.5% | 1.3% | 0.9% | 0.7% | 1.0% | 0.7% | 1.6% | 1.5% |
| 33 | 0.4% | 0.3% | 0.5% | 0.4% | 0.2% | 0.1% | 0.3% | 0.2% | 0.5% | 0.4% |
| 34 | 0.6% | 0.0% | 0.6% | 0.0% | 0.3% | 0.0% | 0.3% | 0.0% | 0.6% | 0.0% |
| 35 | 0.3% | 0.0% | 0.3% | 0.1% | 0.2% | 0.0% | 0.2% | 0.0% | 0.3% | 0.1% |

The next comparison examines the Home-to-Work trip distribution in a matrix form, showing the linkage between specific districts. To simplify the comparison, row percentages are used, summing to 100% for each row and representing the relative fraction of trip attractions from any one district. This comparison presents a lot of data, and the trip table distributions are similar between the model and Census.

**Table 28: HBW Trip Distribution (Home-to-Work Row %), 2005 Model Version 6.1**

| Dist. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 28% | 2% | 10% | 22% | 11% | 5% | 4% | 3% | 2% | 1% | 2% | 2% | 2% | 0% | 1% | 2% | 1% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2 | 18% | 13% | 12% | 16% | 8% | 5% | 4% | 3% | 2% | 1% | 2% | 2% | 3% | 0% | 2% | 2% | 1% | 0% | 1% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 3 | 7% | 1% | 23% | 13% | 11% | 9% | 8% | 5% | 3% | 2% | 3% | 3% | 3% | 1% | 2% | 3% | 1% | 0% | 2% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 4 | 11% | 1% | 10% | 36% | 15% | 5% | 3% | 3% | 2% | 1% | 2% | 2% | 2% | 0% | 1% | 2% | 1% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 5 | 6% | 1% | 9% | 16% | 30% | 6% | 4% | 4% | 3% | 2% | 3% | 3% | 3% | 0% | 2% | 2% | 1% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 6 | 3% | 0% | 5% | 7% | 7% | 20% | 8% | 10% | 7% | 3% | 5% | 5% | 5% | 1% | 3% | 4% | 1% | 0% | 2% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 7 | 4% | 1% | 9% | 7% | 7% | 14% | 22% | 8% | 4% | 2% | 4% | 3% | 4% | 1% | 2% | 3% | 1% | 0% | 2% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 8 | 2% | 0% | 4% | 4% | 4% | 9% | 11% | 27% | 6% | 3% | 5% | 4% | 5% | 1% | 3% | 4% | 1% | 0% | 2% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 9 | 2% | 0% | 3% | 4% | 5% | 7% | 6% | 10% | 17% | 5% | 7% | 6% | 7% | 1% | 4% | 6% | 2% | 0% | 3% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 10 | 1% | 0% | 1% | 1% | 2% | 2% | 2% | 3% | 3% | 22% | 14% | 10% | 11% | 1% | 6% | 9% | 3% | 0% | 5% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 11 | 0% | 0% | 0% | 1% | 1% | 1% | 1% | 1% | 1% | 4% | 30% | 13% | 14% | 2% | 7% | 11% | 3% | 0% | 6% | 1% | 0% | 0% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 12 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 41% | 24% | 2% | 8% | 9% | 2% | 0% | 5% | 1% | 0% | 0% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 13 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 21% | 35% | 4% | 11% | 9% | 2% | 0% | 6% | 1% | 0% | 0% | 3% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 14 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 11% | 22% | 14% | 18% | 8% | 2% | 0% | 8% | 2% | 0% | 1% | 6% | 3% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 15 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 10% | 15% | 6% | 31% | 7% | 2% | 0% | 9% | 3% | 0% | 1% | 7% | 4% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 16 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 5% | 19% | 18% | 2% | 10% | 23% | 4% | 0% | 9% | 1% | 0% | 0% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 17 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 18% | 18% | 3% | 11% | 12% | 7% | 2% | 14% | 3% | 0% | 1% | 3% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 18 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 9% | 12% | 2% | 10% | 14% | 9% | 10% | 19% | 4% | 0% | 1% | 2% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 19 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 8% | 10% | 3% | 15% | 12% | 6% | 1% | 26% | 5% | 0% | 1% | 4% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 20 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 7% | 8% | 3% | 15% | 10% | 4% | 1% | 15% | 14% | 0% | 2% | 7% | 6% | 1% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 21 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 5% | 7% | 2% | 10% | 8% | 4% | 1% | 12% | 8% | 4% | 7% | 6% | 10% | 3% | 2% | 1% | 1% | 2% | 2% | 0% | 0% | 0% | 0% | 0% | 0% |
| 22 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 6% | 7% | 3% | 11% | 7% | 3% | 1% | 10% | 8% | 0% | 12% | 7% | 12% | 3% | 1% | 1% | 1% | 2% | 2% | 0% | 0% | 0% | 0% | 0% | 0% |
| 23 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 7% | 12% | 6% | 17% | 6% | 2% | 0% | 7% | 4% | 0% | 2% | 22% | 9% | 1% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 24 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 6% | 10% | 4% | 13% | 5% | 2% | 0% | 7% | 4% | 0% | 3% | 11% | 23% | 3% | 1% | 1% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 25 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 6% | 8% | 3% | 12% | 5% | 2% | 0% | 6% | 4% | 0% | 4% | 8% | 14% | 13% | 2% | 1% | 1% | 3% | 3% | 0% | 0% | 0% | 0% | 0% | 0% |
| 26 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 4% | 5% | 2% | 6% | 3% | 1% | 0% | 4% | 2% | 0% | 2% | 4% | 6% | 2% | 23% | 5% | 5% | 13% | 10% | 2% | 0% | 0% | 0% | 0% | 0% |
| 27 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 4% | 5% | 2% | 7% | 4% | 1% | 0% | 4% | 3% | 0% | 3% | 4% | 7% | 3% | 12% | 13% | 4% | 11% | 9% | 1% | 0% | 0% | 0% | 0% | 0% |
| 28 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 2% | 3% | 1% | 4% | 2% | 1% | 0% | 2% | 1% | 0% | 1% | 2% | 3% | 1% | 11% | 3% | 17% | 24% | 17% | 2% | 0% | 0% | 0% | 0% | 0% |
| 29 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 2% | 1% | 2% | 1% | 0% | 0% | 1% | 1% | 0% | 1% | 1% | 2% | 1% | 4% | 1% | 4% | 46% | 28% | 3% | 0% | 0% | 0% | 0% | 0% |
| 30 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 1% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 1% | 1% | 0% | 2% | 1% | 2% | 21% | 60% | 5% | 1% | 0% | 0% | 0% | 0% |
| 31 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 2% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 1% | 1% | 0% | 2% | 1% | 2% | 13% | 35% | 33% | 3% | 0% | 0% | 0% | 0% |
| 32 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 2% | 1% | 2% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 1% | 1% | 0% | 2% | 1% | 2% | 11% | 25% | 17% | 28% | 1% | 0% | 0% | 0% |
| 33 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 2% | 3% | 1% | 3% | 2% | 1% | 0% | 2% | 1% | 0% | 1% | 1% | 2% | 1% | 2% | 1% | 2% | 11% | 24% | 14% | 14% | 12% | 0% | 0% | 0% |
| 34 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 5% | 6% | 2% | 8% | 5% | 2% | 0% | 6% | 4% | 0% | 4% | 5% | 7% | 3% | 8% | 4% | 3% | 10% | 8% | 1% | 0% | 0% | 5% | 1% | 0% |
| 35 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 5% | 6% | 2% | 8% | 5% | 2% | 0% | 6% | 4% | 0% | 5% | 5% | 8% | 3% | 8% | 4% | 3% | 10% | 8% | 1% | 0% | 0% | 0% | 2% | 0% |
| 36 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

**Table 29: HBW Trip Distribution (Home-to-Work Row %), 2000 Census**

| Dist. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24% | 1% | 12% | 30% | 12% | 5% | 3% | 2% | 2% | 1% | 1% | 1% | 1% | 0% | 1% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2 | 19% | 8% | 13% | 27% | 13% | 6% | 3% | 2% | 2% | 0% | 1% | 1% | 0% | 0% | 0% | 1% | 1% | 0% | 1% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 3 | 7% | 1% | 23% | 18% | 11% | 13% | 6% | 4% | 2% | 1% | 2% | 2% | 2% | 0% | 1% | 2% | 1% | 0% | 1% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 4 | 12% | 1% | 12% | 35% | 16% | 5% | 5% | 2% | 2% | 1% | 1% | 2% | 1% | 0% | 0% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 5 | 7% | 0% | 10% | 25% | 27% | 8% | 4% | 3% | 2% | 1% | 2% | 2% | 1% | 0% | 1% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 6 | 2% | 0% | 4% | 8% | 8% | 34% | 7% | 6% | 10% | 2% | 4% | 3% | 3% | 1% | 2% | 3% | 1% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 7 | 4% | 0% | 8% | 10% | 7% | 13% | 20% | 9% | 6% | 3% | 4% | 3% | 2% | 0% | 1% | 3% | 1% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 8 | 1% | 0% | 4% | 7% | 3% | 13% | 10% | 14% | 12% | 4% | 9% | 6% | 4% | 0% | 2% | 4% | 2% | 0% | 2% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 9 | 2% | 0% | 3% | 5% | 4% | 10% | 7% | 9% | 18% | 5% | 7% | 8% | 6% | 1% | 3% | 5% | 1% | 0% | 3% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 10 | 0% | 0% | 1% | 1% | 1% | 2% | 2% | 2% | 4% | 16% | 23% | 14% | 9% | 1% | 4% | 9% | 2% | 0% | 4% | 0% | 0% | 0% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 11 | 0% | 0% | 0% | 0% | 1% | 1% | 1% | 1% | 1% | 5% | 34% | 15% | 11% | 2% | 6% | 7% | 3% | 0% | 6% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 12 | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 2% | 36% | 26% | 4% | 9% | 8% | 2% | 0% | 5% | 1% | 0% | 0% | 3% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 13 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 21% | 40% | 5% | 9% | 7% | 2% | 0% | 5% | 1% | 0% | 0% | 3% | 2% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 14 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 14% | 23% | 17% | 14% | 7% | 2% | 0% | 8% | 2% | 0% | 1% | 6% | 3% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 15 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 12% | 16% | 7% | 25% | 9% | 2% | 1% | 10% | 3% | 0% | 1% | 6% | 4% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 16 | 0% | 0% | 0% | 1% | 0% | 1% | 0% | 0% | 0% | 1% | 2% | 17% | 18% | 2% | 10% | 23% | 5% | 1% | 9% | 2% | 0% | 1% | 3% | 2% | 1% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 17 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 55% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 45% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 18 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 9% | 13% | 3% | 13% | 12% | 4% | 10% | 21% | 4% | 0% | 1% | 3% | 3% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 19 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 9% | 11% | 3% | 13% | 14% | 4% | 2% | 25% | 5% | 0% | 1% | 5% | 3% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 20 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 9% | 9% | 4% | 15% | 10% | 3% | 1% | 15% | 13% | 0% | 2% | 7% | 5% | 1% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 21 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 8% | 9% | 3% | 11% | 6% | 3% | 2% | 10% | 8% | 3% | 7% | 7% | 12% | 3% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 22 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 8% | 8% | 3% | 11% | 8% | 2% | 2% | 10% | 9% | 1% | 11% | 8% | 10% | 3% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 23 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 11% | 13% | 6% | 13% | 8% | 2% | 1% | 8% | 3% | 0% | 1% | 19% | 8% | 1% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 24 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 9% | 9% | 5% | 13% | 7% | 2% | 1% | 8% | 4% | 0% | 2% | 12% | 20% | 4% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 25 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 8% | 7% | 4% | 11% | 7% | 2% | 1% | 7% | 4% | 0% | 3% | 10% | 15% | 15% | 0% | 0% | 0% | 2% | 3% | 1% | 0% | 0% | 0% | 0% | 0% |
| 26 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 3% | 1% | 2% | 3% | 1% | 0% | 2% | 1% | 0% | 1% | 2% | 3% | 2% | 28% | 5% | 7% | 16% | 13% | 3% | 1% | 0% | 0% | 0% | 0% |
| 27 | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 2% | 1% | 4% | 4% | 1% | 0% | 4% | 1% | 0% | 2% | 3% | 5% | 4% | 19% | 13% | 6% | 13% | 9% | 2% | 1% | 0% | 0% | 0% | 0% |
| 28 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 2% | 0% | 2% | 2% | 1% | 1% | 2% | 0% | 0% | 1% | 2% | 1% | 1% | 14% | 2% | 18% | 25% | 20% | 4% | 1% | 0% | 0% | 0% | 0% |
| 29 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 1% | 1% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 1% | 1% | 1% | 5% | 2% | 5% | 40% | 31% | 5% | 1% | 0% | 0% | 0% | 0% |
| 30 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 2% | 1% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 1% | 0% | 3% | 1% | 2% | 18% | 57% | 6% | 2% | 0% | 0% | 0% | 0% |
| 31 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 1% | 1% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 1% | 2% | 15% | 30% | 37% | 4% | 0% | 0% | 0% | 0% |
| 32 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% | 1% | 0% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 1% | 2% | 13% | 23% | 24% | 28% | 1% | 0% | 0% | 0% |
| 33 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 1% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 0% | 1% | 2% | 2% | 1% | 13% | 18% | 18% | 22% | 15% | 0% | 0% | 0% |
| 34 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 5% | 1% | 5% | 0% | 0% | 0% | 6% | 1% | 0% | 0% | 4% | 6% | 1% | 18% | 11% | 2% | 18% | 9% | 2% | 0% | 0% | 4% | 0% | 0% |
| 35 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 6% | 4% | 2% | 8% | 4% | 2% | 0% | 12% | 0% | 0% | 1% | 8% | 1% | 3% | 5% | 5% | 3% | 12% | 15% | 2% | 3% | 0% | 0% | 3% | 0% |
| 36 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

## 15.4.3 Screenline Comparisons

The trip distribution results from the model can also be assessed by evaluating the reasonableness of traffic flows across screenlines. Screenlines are used to compare modeled traffic flows to traffic counts via multiple roads that intersect with the screenline. Screenlines are useful to evaluate relatively large flows moving across multiple roads and indicate in general whether the model is moving enough traffic across a certain line in the region. The following comparison utilizes model version 7, compared to 2007 weekday traffic.

**Table 30: Regional Screenline Comparison**

| Screen | Model Vol | AWDT Count | Diff. | % Diff |
|---|---|---|---|---|
| 1 | 116,652 | 131,103 | (14,451) | -11.0% |
| 2 | 243,351 | 233,831 | 9,520 | 4.1% |
| 3 | 208,590 | 216,583 | (7,993) | -3.7% |
| 4 | 151,088 | 149,637 | 1,451 | 1.0% |
| 5 | 198,053 | 214,584 | (16,531) | -7.7% |
| 6 | 682,452 | 711,333 | (28,881) | -4.1% |
| 7 | 208,640 | 181,952 | 26,688 | 14.7% |
| 8 | 719,947 | 679,653 | 40,294 | 5.9% |
| 9 | 161,472 | 154,515 | 6,957 | 4.5% |
| 10 | 17,965 | 20,831 | (2,866) | -13.8% |
| 11 | 217,371 | 192,658 | 24,713 | 12.8% |
| 12 | 190,707 | 168,887 | 21,820 | 12.9% |
| 13 | 206,654 | 197,884 | 8,770 | 4.4% |
| 14 | 104,342 | 112,972 | (8,630) | -7.6% |
| 15 | 123,177 | 145,745 | (22,568) | -15.5% |
| 16 | 112,839 | 146,167 | (33,328) | -22.8% |

**Figure 40: Regional Screenlines**

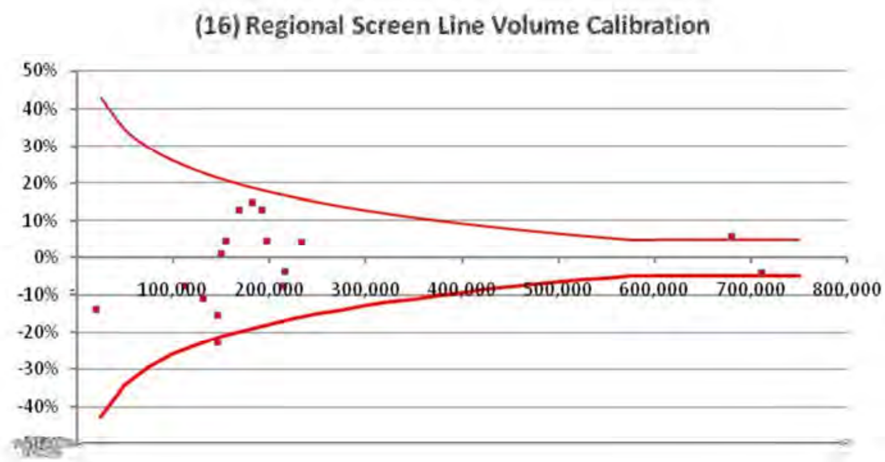



**Figure 41: Screenline Validation against Targets (Regional Screenlines)**

As the observed traffic count across a screenline goes up, the acceptable error goes down. The red error targets in these figures are recommended in NCHRP 255, and referenced throughout the modeling literature. The model does an excellent job with this validation measure, with all but one regional screenline comparison within +/- 20% and the majority within +/-10%. The regional screenlines are developed from the "large" screenlines that are on the model network, and the validation for the large screenlines is shown below.

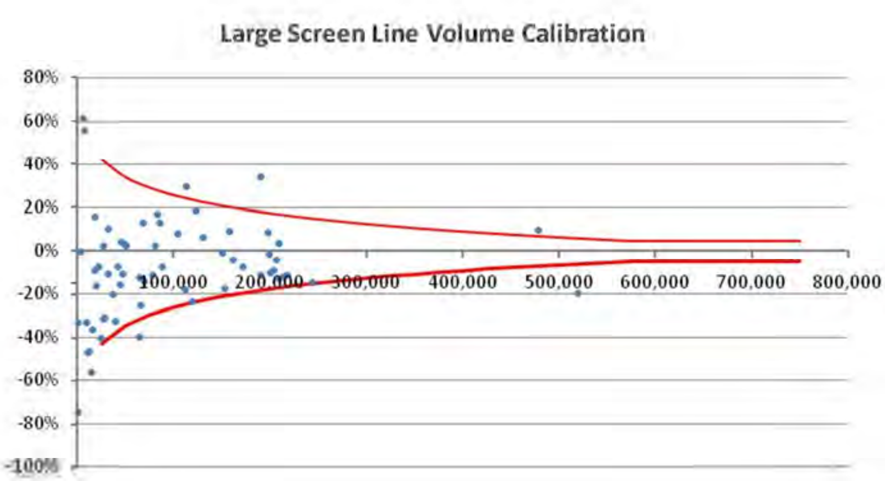
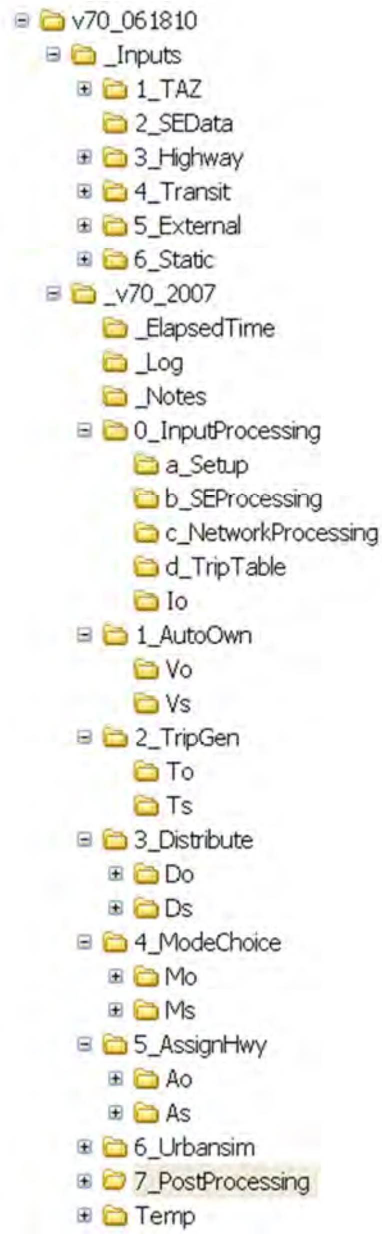



**Figure 42: Screenline Validation against Targets ("Large" Screenlines)**

# 16.0 Model Directory and Scripts

## 16.1 Model Directory Structure and Organization




A completed scenario includes over 1,500 files occupying approximately 5-6 Gigabytes of space on a hard disk. To manage this, the model is organized into a single root directory for a scenario with 12 second-level directories for distinct model steps. Within each process directory, there is usually an Output and a Script directory.

The model is run using a batch file (HailMary.bat). The model runs as a series of 20-30 separate scripts, and this batch file strings them together. The batch is organized as a "football game". If anything about the model stream is incorrect, the batch will "crash" and generate a "You got tackled at script …" message to indicate where the model run failed. The bulk of the files generated by the model are intermediate temporary files that are written to a temp directory to be isolated for easy removal when archiving or sharing a model run.

The model contains very few repetitive, embedded parameters. If a file name or parameter is used more than once or is an important assumption affecting model results, it is usually removed from the script and placed in either the "control center" or "general parameters" files. Within the model scripts, these parameters are aliased with the @parameter@ syntax. This approach enhances robustness, functional utility, readability, and guarantees that when you change a parameter once, it is changed everywhere.

1. **Control Center (1ControlCenter.block)**: A single file in the root directory of the model that contains (most likely) all of the information that makes one scenario unique from another (file names, paths, and parameters).
2. **General Parameters (0GeneralParameters.block)**: This file is similar to the Control Center in that it contains parameters and variables that are referenced in the individual model scripts. The information in the General Parameters file is changed with far less frequency by the typical model user, so therefore it has been placed in a separate file.
3. ***.s files (scripts)**: The model scripts are stored in files with a *.s extension. These scripts are created using TP+/Voyager scripting, and the model includes dozens of individual scripts.
4. ***.block files (sub-routines to scripts)**: Some scripts are particularly complicated, and in certain instances, "block files" are used to make the code more readable. Block files often include sections of code that are called multiple times, or may include long sections of code that represented repetitious syntax that otherwise would clutter the script. Block files are called within scripts using syntax such as: "READ FILE = 4pd_assign.block".

## 16.2 Model Inputs Directory

A key change in version 7 of the model is that the model inputs are now stored outside of the model. This is done to reduce duplicate information (a little), and has made it easier to keep track of variations of key inputs.

The model is packaged with an "_Inputs" directory and a "blank scenario" directory (a model directory that has not been run). The _Inputs directory is a repository for model inputs that the user may edit in creating distinct scenarios. When running the model for a particular scenario, the model scripts reference specific files in the inputs directory, as specified by the user in the Control Center file (more on this below). Output from one process is used as input to another, but the input directory is used exclusively for files that are not generated directly by the model.

The inputs directory contains a sub-directory labeled "static" which contains a series of inputs that would not be changed by the typical model user. These files include external demand assumptions (IXXI, XX Tables), special generator control totals (College, Airport & Lagoon) and base year distributions, friction factors for trip distribution, lookup tables for the household demographic disaggregation process, and a roadway network that identifies geographic and physical barriers that people can't walk across (used in defining transit walk access).

## 16.3 Model Scripts

The following list provides a brief explanation (not thorough) of what each of the scripts in the Hail Mary batch file does.

1. **Input Processing**
    a. **1InputSetup.s:** This script checks to ensure that necessary files and data exist in the right place (as specified in the ControlCenter file). This helps quickly identify a few potential problems that can occur upon running the model. This script also creates a log file that is a record of the model run.
    **b.** **1DemographicAnalysis:** This script summarizes the input SE data by county and looks for potential errors/inconsistencies.
    c. **2UrbanizationTermTime.s:** This script defines a density-based area type for use in setting arterial speeds. The urbanization values are split into five ranges (rural, transition, suburban, urban, CBD).
    d. **1NetProcessor.s:** This script reads the Master network database and outputs a scenario network with the lane configuration and other attributes that are relevant to the scenario. It loads the Area Type onto the network, along with Pop/Emp for the base year and horizon year. Scenario speeds & capacities are computed from network attributes, and distance values are updated. A series of logic checks are applied and any outliers are flagged.
    e. **2FFSkim.s:** This script does a free-flow auto skim.
    f. **3TurnPenalty.s:** This script creates turn penalties to prevent trips from crossing directly from one TAZ centroid to another without using the network.
    g. **4TransitRouteTest_0xfer_Emp30.s:** This script reads scenario transit routes and crashes early if the link structure is not compatible with the highway structure. This script also does a best walk-to-transit skim for the purpose of identifying TAZ pairs connected by transit with 0 transfers, and computing employment within 30 minutes of transit.
    h. **1TripTable.s:** This script creates the trip tables for the airport, colleges and Lagoon.
2. **Auto Ownership**
    a. **1HHDisaggregation.s:** This script segments households by income quartile, num workers, and people per HH using Census derived marginal distributions.
    b. **2AutoOwnership.s:** This script applies a logit model that estimates auto ownership by household category.

3. **Trip Generation**

    a. **1TripGen.s:** This script applies the trip generation models to estimate trip productions and trip attractions. Adjustments for special generators and externals are made.

4. **Trip Distribution / Feedback Loop**

    a. **1Distribution.s:** This script applies a gravity model to estimate trip distribution for HBW, HBO, NHB, Commercial, and IXXI trips. Vehicle trips are estimated and then assigned to the roadway network. Distribution and assignment are iterated until convergence is reached (95% of the links are changing by less than 5%). Trip tables are averaged from one iteration to the next.

    b. **2SumToDistricts_Gravity.s:** This script post-processes the gravity model output to create district level trip tables.

    c. **3TLF_Distrib_PA.s:** The script produces trip length frequencies for the gravity model output.

5. **Mode Choice (and many other things)**

    **a. 1Segmnt_TripsByDetailed.s**:

    **b. 2Segmnt_TransitAccessMarkets.s:** This script uses transit walk access buffers to identify which portion of TAZs are walk accessible to transit (at production and attraction end).

    **c. 3Skim_auto.s:** This script creates auto skims for each TAZ pair, distinguishing paths using toll lanes, HOV lanes and GP lanes.

    **d. 4Skim_walk_PNR_access.s:** This script creates walk access/egress, drive access links, and walk transfer links for transit paths.

    **e. 5Skim_Tran.s:** This script skims the transit network and estimates the attributes for each transit option between TAZ pairs.

    **f. 6HBW_logsums.s:** This script computes HBW logsums for use in destination choice.

    **g. 7HBW_dest_choice.s:** This script applies a destination choice trip distribution model for HBW trips. The output from the destination choice model is used to overwrite the output from the gravity model for HBW trips only.

    **h. 8TripTablesByPeriod.s:** This script separates daily trips into peak and offpeak periods for mode choice model application.

    **i. 9Segmnt_PA_HBbyMC.s:** This script separates HBO and HBW trips by market segment.

    **j. 10ConvertSomeXI2HBW.s**: This script converts some external-internal trips to HBW trips based on Census data, so that some external trips can go through mode choice.

    **k. 11Mc_HBW_HBO.s**: This script applies a nested logit mode choice model for HBW and HBO trips. These models are segmented by auto ownership and income.

    **l. 12Mc_NHB_HBC.s**: This script applies a nested logit mode choice model for NHB and HBC trips. These models are not segmented by household characteristics.

    **m. 13DailyModeSplit.s:** This script post-processes the mode choice output to create trip tables by mode for the entire day.

    **n. 14AsnTran.s:** This script assigns the transit trip tables to the transit network to estimate boardings and alightings by route.

    **o. 15SharesReport.s:** This script writes out the “shares report” which is a summary of demand by mode for the region and user-specified geographies.

p. **16BoardingsReport.s:** This script summarizes the transit assignment output to create transit boarding summaries by station and route.

q. **17SumToDistricts_FinalTripTables.s**: This script creates district level trip tables by mode.

r. **17TLF_DestChoice_PA.s:** The script produces trip length frequencies for the HBW destination choice model output.

s. **18MCElapsedTime.s:** This script keeps track of the elapsed time required to run mode choice related scripts, which is by far the longest series of scripts in the model.

t. **_validate_managed_lane.s:** This script produces a variety of frequency distributions for toll and HOV trips, summarizing the demand by variables such as travel time savings and distance on the managed lanes.

u. **2TripsPerAcreAnalysis.s:** This script computes the trips per developable acre for each TAZ, by mode and trip purpose.

6. **Roadway Assignment**

   a. **4AssignHwy_ODtables_ManagedLanes.s:** This script factors the daily auto trip tables for 8 purposes into 4-periods using factors from the survey. Trips are converted to vehicle trips, and converted from production-attraction to origin-destination format.

   b. **4AssignHwy_ManagedLanes.s:** This script assigns auto trips to the road network (traffic assignment) using a multi-class user equilibrium assignment approach.

   c. **4AssignHwy_ScreenlineAdjuster.s:** This script applies techniques outlined in NCHRP to adjust model volumes based on a comparison of base year traffic assignment model output to traffic counts. Screenlines and traffic counts are used as the basis for assessing model fit. This script does not need to be run in most cases.

7. **UrbanSim**

   a. **HwyTimes_UrbanSim.s:** This script computes travel time/accessibility variables necessary to link the travel model with UrbanSim. This script does not need to be run unless using UrbanSim.

8. **Post Processing**

   a. **1HwyStats_county.s:** This script summarizes statistics and output indicators from the loaded roadway network, such as VMT, VHT and lane miles under congested and uncongested conditions at a county and regional level.

   b. **1HwyStats_city.s:** This script summarizes statistics and output indicators from the loaded roadway network, such as VMT, VHT and lane miles under congested and uncongested conditions at a city level.

   c. **9VMTprofile_2002.s:** This script prepares the inputs necessary to run MOBILE6.

   d. **1TLF_Purp.s:** This script prepares summaries of the trip length (distance and time) frequency distributions by trip purpose and county from trip distribution.

   e. **1TLF_transit.s:** This script prepares summaries of the trip length (distance and time) frequency distributions by trip purpose, county and transit mode.

The model is officially completed after running these scripts, and the batch file moves to a series of processors and data extraction routines.

## 16.4 History of Model Versions

### 16.4.1 PRIOR TO 1999

Travel models for the Salt Lake and Ogden areas began with extensive travel surveys conducted in 1960 for Salt Lake and 1962 for Ogden. Based on that information, travel models were developed to support the preparation of the initial long-range transportation plans for the two areas. The models that were developed were consistent with the state of the practice at the time. Trip generation, distribution and assignment were each done for auto trips only.

Around 1970 two changes were made to the models. The initial trip generation models for both areas consisted of linear regression equations with many variables, some of which were difficult to forecast. The first change to the models was to simplify the trip generation equations. The revisions were based on the 1960 data and did not change the auto trip basis of the equations. The second change was to adjust the friction factors used for trip distribution. Several sections of the interstate system had been constructed between the time that the travel survey had been done and 1970. The existing friction factors when combined with the faster speeds allowed by freeways resulted in travel patterns inconsistent with those being observed through traffic counting. As a result, friction factors were re-calibrated to improve the models' ability to match the travel patterns of the time.

During the early 1980's interest began to grow in analyzing major transit investments. Travel models that only included auto trips were not of much value. Two modifications were made. The first was to convert the trip generation equation from auto trips to person trips. In that process work trip generation was converted from a regression equation with auto as the independent variable to a zonal trip rate per household, which varied by average autos per household. The second change was to develop a mode choice model. The mode choice model was a multinomial logit model based on Census Journey-to-Work data and covered only the Salt Lake area.

In 1991 a transit on-board survey was conducted in the Salt Lake area and the mode choice model was converted to a nested logit form. The conversion used a combination of local coefficients and coefficients borrowed from other areas and re-estimated the constants to match the on-board survey. A mode choice model was developed for home-based college trips. The mode choice models continued to be calibrated entirely on data from the Salt Lake area.

In 1995, a comprehensive model update was conducted based on results from the home interview survey conducted in 1993. The trip generation process was completely revised to a cross-classification model with trip rates by household size and auto ownership, and new friction factors were developed for trip distribution. The survey revealed a shift of trips from work trips to home-based other and non-home-based trips and required revision of the constants in the mode choice model to match the on-board survey. A mode choice modeling procedure for home-based other and non-home-based trips was developed.

### 16.4.2 MODEL VERSION 1 & 2

Based on recommendations from travel model peer reviews that began in 1999, the WFRC and MAG made significant changes to travel models and travel model inputs. The zone structure was disaggregated to give the model more sensitivity to non-auto travel modes. An auto-ownership model was borrowed from Portland, OR and used to predict the number of households in each zone owning 0, 1, 2, 3+ automobiles, which is a critical input to trip generation. The trip distribution processes for the three urbanized areas were combined into a single process, effectively integrating travel modeling throughout the three areas. Feedback was introduced between trip distribution and assignment. Travel time penalties were instituted between urbanized areas to better model observed travel patterns. The mode choice modeling processes were upgraded and recalibrated for use in all three urbanized areas, and a procedure for modeling non-motorized trips was implemented. The traffic assignment procedure was modified from a daily assignment to assignments for four distinct periods (AM peak, midday, PM peak and evening/night). Separate BPR curves were developed for freeways and capacity assumptions were revised.

Model version 1 was provided by a consultant, and version 2 was a result of various refinements made in-house by WFRC and MAG staff to make the model more user-friendly (such as creating a folder structure for each step in the model). The methods and parameters in versions 1 and 2 were very similar.

### 16.4.3 MODEL VERSION 3

Beginning in 2002, through much of 2003, a significant model development effort began in advance of several critical major investment studies (e.g. commuter rail from Ogden to Salt Lake). The development effort focused on three things: (1) refining model inputs (networks, and socioeconomic forecasts); (2) refining the procedures to use these inputs (e.g. a "Master" network was developed, along with a script to extract a "scenario" network); and (3) refining and recalibrating all of the models in the modeling process based on local data:

- The "base year" for the model was changed from 1996 to 2001.
- Extensive revisions were made to the socioeconomic forecasting process, MSID.
- A routine was developed to estimate the joint distribution of households by size, number of workers and income quartile in order to incorporate market segmentation into the application of the auto ownership and mode choice models.
- A new auto ownership model was estimated based on local household survey data, and calibrated to the 2000 Census.
- Trip generation equations for the separate urbanized areas were combined into one set of equations for the entire model region.
- Irregularities in the trip production cross-classification rates were "smoothed" to produce trip production tables that are theoretically consistent.
- Trip distribution models were calibrated using local household survey data.
- Methods for modeling internal-external, external-internal travel were improved.
- Fixed trip tables were developed using survey data for both the major local universities and the Salt Lake International Airport.
- Speed data collected from 2001 to 2003 by WFRC was used to validate forecasted model speeds on both the highway and transit networks.
- Substantial revisions were made to the mode choice models in order to incorporate changes made to other steps of the modeling process (such as market segmentation).
- Nested Logit models were developed for Home-Based Other and Non-Home-Based trip purposes. Modifications were made to the mode choice model nesting structure and specification, and the models were calibrated using on-board survey data collected in 2002.
- Improvements were made to make volume-delay functions to better model observed speed data and the vehicle assignment cost function was made more sensitive to congestion effects.
- Significant refinements were made to transit and highway networks.

### 16.4.4 MODEL VERSION 4

In late 2003 and 2004, model version 4 was developed. The primary motivation for improvements in version 4 was the on-going Ogden-Salt Lake Commuter Rail study, and so most of the improvements new to the model in version 4 were related to mode choice.

- Mode choice model coefficients were estimated using local survey data (previously the coefficients had been asserted)
- The mode choice model was segmented by time of day (peak and off-peak)
- HBW distribution for 0-car households was done using an impedance that was a function of transit accessibility
- Refinements to walk and drive access to transit path building; the 2002 on-board survey was assigned
- Bus rapid transit (BRT) was split out as a separate mode
- Mode choice model calibration was refined
- Highway assignment was done separately for short trips and long trips (different user cost functions)

### 16.4.5 MODEL VERSION 5

- In early 2005, it became clear that two UDOT EISs (Mountain View Corridor and I-15 in Utah County) needed to assess the viability of managed lane alternatives. The distinguishing feature of version 5 is that a comprehensive toll and HOV forecasting methodology was built into the model.
- Added HOV and Toll modes to the mode choice model
- Developed separate skims for general purpose paths, HOV paths and HOT/toll paths
- Implemented a detailed multi-user, multi-class assignment procedure
- Fixed the number of assignment iterations (above and beyond what was necessary for acceptable convergence)
- Implemented a HBW destination choice model for trip distribution
- Sensitized the gravity model to toll and non-toll impedance using a geometric mean

### 16.4.6 MODEL VERSION 6

Mode version 6 is currently being finished up. Essentially, model version 6 is a more refined version of version 5, with one improvement of note, which is the incorporation of on-board transit survey data collected in 2006.

A version 6.1 of the model was produced as part of the Draper LRT extension study and for use in all UTA studies (including the Provo-Orem BRT and Ogden transitway). Version 6.1 included a refined calibration of the transit modeling components, including path-finding, transit access links, and mode choice model calibration.

### 16.4.7MODEL VERSION 7

Model version 7 was released in late 2010, and includes several enhancements. The notable enhancements are:

- 2007 base year, 2040 horizon year

- New TAZ structure with approximately 1000 more TAZs, and corresponding networks
- New socioeconomic projections
- Revised "front-end" to the model
    - General parameters file
    - Pulled the Inputs directory out of the model
    - Automated the creation of several inputs, such as the "Gliebe process" (the SE disaggregation process), the college/airport trip tables and the employment within 30 min of transit
- Revisions to roadway capacities to better reflect actual/observed traffic counts by facility type and number of lanes
- Minor revisions to trip generation, including changes to trip production rates, trip attraction rates and special generators
- Created a new impedance function for auto path-finding in trip distribution, mode choice and traffic assignment that is a function of time, distance and cost. This resulted in the need to recalibrate the gravity models based on the new definition of impedance (previously only time was used).
- Incorporated the transit changes made for version 6.1
    - New walk and drive access links
    - New buffering methodology
    - Rational mode specific constants
    - Consistent transit path weights and mode choice parameters
    - Revised mode choice coefficients for OVT and transfer penalties
- Revised the transit fare costs for all modes
- Revised time-of-day assumptions for auto assignment
- Recalibration to 2007 data