WFRC & MAG Transportation Model Documentation

2005 Base Year Model

Version 6.0

May, 2007

Prepared by:
Resource Systems Group
White River Junction, VT

WASATCH FRONT REGIONAL COUNCIL

MOUNTAINLAND Association of Governments

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

ACKNOWLEDGEMENTS

The WFRC/MAG transportation model is a relatively advanced tool capable of analyzing complex urban dynamics and travel patterns. The model has evolved over the years under the oversight and as a result of hard work by many people. The current MPO staff directly responsible for the transportation model include Chad Worthen of MAG, and Ned Hacker, Muhammad Farhan and Andy Li of WFRC. Current staff overseeing socioeconomic forecasts include Shawn Eliot of MAG, and Scott Festin and Wayne Bennion of WFRC.

John Lobb of Resource Systems Group, Mike Brown of Wilbur Smith Associates, and Mick Crandall of the Utah Transit Authority are all former WFRC modelers that continue to participate in a significant way in the development and maintenance of the model. In addition, an active user community exists that provides meaningful insight and occasional enhancements, including staff of the Utah DOT, and consultants with Parsons Brinkerhoff, Fehr & Peers, Horrocks Engineering, InterPlan and others.

ABOUT WFRC AND MAG

The Wasatch Front Regional Council (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.

A primary planning process of WFRC and MAG involves their capacity as MPOs (Metropolitan Planning Organizations). As such, in the four urban counties the agencies are responsible for development of the five 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.

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 a estimates of VMT derived from a network-based travel model meeting certain minimal modeling requirements. Second, FTA's new start 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, and moreover, the practice has evolved sufficiently, particularly over the last 15 years, 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.

TABLE OF CONTENTS

1 INTRODUCTION **9**

2 MODEL OVERVIEW **10**

2.1 MODEL COVERAGE 10
2.2 MODEL STRUCTURE 11
2.3 MODEL COMPONENTS 11
2.4 TAZ STRUCTURE 13
2.5 NETWORK STRUCTURE 13
2.6 MODEL CALIBRATION AND VALIDATION 14

3 BASE YEAR (2005) LAND USE DATA **15**

3.1 BASE YEAR HOUSING 15
3.2 BASE YEAR EMPLOYMENT 16
3.3 ZONAL HOUSEHOLD DATA SYNTHESIS 17

4 FUTURE YEAR LAND USE PROJECTIONS **21**

4.1 PROJECTIONS PROCESS OVERVIEW 21
4.1.1 Historical Growth Factors by Density (MSID) *21*
4.1.2 UrbanSim *22*

5 ROADWAY AND TRANSIT NETWORKS **25**

5.1 ROAD NETWORK 25
5.1.1 Master Road Network *25*
5.1.2 Free-Flow Speeds and Capacity Definitions *25*
5.2 TRANSIT NETWORK 28
5.2.1 Transit Access Links *28*
5.2.2 Percentage of TAZ within walking distance of transit *30*

6 SURVEY DATASETS USED FOR MODEL DEVELOPMENT **31**

6.1 HOUSEHOLD TRIP DIARY SURVEY (1993) 31
6.2 ON-BOARD TRANSIT SURVEY (2002/2006) 32
6.2.1 2006 On-Board Survey Data Collection Details *32*
6.3 NATIONAL HOUSEHOLD TRAVEL SURVEY (2001) 33
6.4 CENSUS TRANSPORTATION PLANNING PACKAGE (2000) 33

7 AUTO OWNERSHIP **34**

8 TRIP PURPOSES **37**

9 TRIP GENERATION **38**

9.1 TRIP GENERATION MODEL STRUCTURE 38
9.2 ESTIMATING TRIP GENERATION 39
9.2.1 Trip Production Rates *39*

9.2.2 Trip Attraction Rates *41*
9.3 SPECIAL GENERATORS 42
9.4 BALANCING ATTRACTIONS TO PRODUCTIONS 42
9.5 EXTERNAL TRIPS 42

10 TRIP DISTRIBUTION 45

10.1 GRAVITY MODEL 45
10.2 DATA SOURCES AND PARAMETER ESTIMATION 45
10.4 IX-XI DISTRIBUTION 46
10.3 ASSERTED TRIP TABLES 46
10.4 HBW DESTINATION CHOICE MODEL 47
10.4.1 Destination Choice Model Mathematics *48*
10.4.2 Destination Choice Model Parameters *49*

11 NETWORK SKIMMING 53

11.1 AUTO PATHS 53
11.1.1 Skims for trip distribution *53*
11.1.2 Intrazonal Times *53*
11.1.3 Terminal Times *53*
11.2 TRANSIT PATHS 54
11.2.1 Bus Speeds *54*
11.2.2 Transit Path Finding Parameters *55*

12 MODE CHOICE 56

13 MANAGED LANES FORECASTING 62

14 TIME OF DAY DISTRIBUTION 64

15 TRAFFIC ASSIGNMENT 66

16 MODEL CALIBRATION AND VALIDATION 68

16.1 TRAFFIC ASSIGNMENT CALIBRATION 68
16.1.1 Modeled Traffic Volumes compared to Traffic Counts *68*
16.1.2 Modeled Traffic Speeds compared to Observed Speeds *73*
16.1.3 Modeled VMT compared to HPMS VMT *74*
16.2 AUTO OWNERSHIP CALIBRATION 75
16.3 TRIP DISTRIBUTION CALIBRATION 77
16.4 TRANSIT CALIBRATION 79
16.4.1 Bus Speeds *79*
16.4.2 Bus and Rail Boardings *79*
16.4.3 Trips by Mode *80*
16.4.4 Transfer Rates *81*
16.5 HOV CALIBRATION 83

17 USING THE MODEL 84

17.1 MODEL ORGANIZATION 84
17.2 MODEL SCRIPTS AND STEPS 85
17.3 POST-PROCESSORS AND DATA EXTRACTION 87
17.3.1 Highway/link based processes 87
17.3.2 Highway, district based processes 92
17.3.3 Transit / Mode Choice processes 94

18 NETWORK CODING 97

18.1 HOW TO CODE MANAGED LANES AND TOLLWAYS 97
18.1.1 Coding Dedicated Tollway Facilities 97
18.1.2 Coding Mixed Facilities (HOV lanes/HOT lanes) 97
18.2 TRANSIT NETWORK CODING 100
18.2.1 General Overview 100
18.2.2 Run the "TransitRouteTester.s" Script 100
18.2.3 Modify or create the routes defining the scenario 101
18.2.4 Design each transit scenario to the appropriate magnitude 101
18.2.5 Develop a rail operating plan 102
18.2.6 Additional Considerations when Adding a Rail Line 102
18.2.7 Add Support Links 102
18.2.8 Rail Speed Calculator 103

19 RUNNING SUMMIT 104

20 MODEL HISTORY 108

20.1 PRIOR TO 1999 108
20.2 MODEL VERSION 1 & 2 108
20.3 MODEL VERSION 3 109
20.4 MODEL VERSION 4 110
20.5 MODEL VERSION 5 110
20.6 MODEL VERSION 6 111

21 MODEL VALIDATION STUDIES 112

21.1 SPEED VALIDATION STUDY 112
21.2 STUDY OF THE MODEL'S SENSITIVITY TO INDUCED DEMAND 116

22 FORMAL PEER REVIEWS 118

22.1 MAY 18 - 19, 1999 PEER REVIEW 118
Comments and Recommendations (May, 1999) 118
22.2 JANUARY 2002 PEER REVIEW 123
Comments and Recommendations (January, 2002) 124

LIST OF FIGURES

FIGURE 1: CONCEPTUAL OVERVIEW OF THE WFRC/MAG MODEL 11
FIGURE 2: MODEL GEOGRAPHY & TAZ STRUCTURE 13
FIGURE 3: STREET NETWORK IN MODEL (PROVO AND OREM) 14
FIGURE 4: HOUSEHOLD SIZE MARGINAL DISTRIBUTION LOOKUP TABLE 18
FIGURE 5: HOUSEHOLD INCOME QUARTILE MARGINAL DISTRIBUTION LOOKUP TABLE 19
FIGURE 6: LAND-USE MARKET MODELED IN URBANSIM 23
FIGURE 7: CONCEPTUAL OVERVIEW OF INTEGRATED MODEL STRUCTURE (WHEN RUNNING URBANSIM) 24
FIGURE 8: AUTO OWNERSHIP MODEL INFORMATION FLOW 34
FIGURE 9: TRIP GENERATION INFORMATION FLOW 38
FIGURE 10: FRICTION FACTORS BY TRIP PURPOSE 46
FIGURE 11: MODEL FLOW DIAGRAM WITH DESTINATION CHOICE 48
FIGURE 12: HBW DIURNAL DISTRIBUTION 64
FIGURE 13: HBO DIURNAL DISTRIBUTION 65
FIGURE 14: NHB DIURNAL DISTRIBUTION 65
FIGURE 15: VOLUME-DELAY FUNCTIONS 67
FIGURE 16: MODELED VOLUMES VS. OBSERVED COUNTS (AWDT 2-WAY) 70
FIGURE 17: % OF HOUSEHOLDS WITH 0 VEHICLES (MODEL VS. ’00 CENSUS) 75
FIGURE 18: % OF HOUSEHOLDS WITH 1 VEHICLE (MODEL VS. ’00 CENSUS) 75
FIGURE 19: % OF HOUSEHOLDS WITH 2+ VEHICLES (MODEL VS. ’00 CENSUS) 76
FIGURE 20: HOME-BASED WORK TRIP DISTANCE COMPARISON 77
FIGURE 21: HOME-BASED OTHER TRIP DISTANCE COMPARISON 78
FIGURE 22: NON-HOME-BASED TRIP DISTANCE COMPARISON 78
FIGURE 23: 2001 MODELED VS. OBSERVED BUS TIMES (END TO END) 79
FIGURE 24: MODELED VS. OBSERVED BUS BOARDINGS (SPRING, 2006) 80
FIGURE 25: 2006 MODELED VS. OBSERVED BUS RIDERSHIP 80
FIGURE 26: 2006 MODELED VS. OBSERVED TRAX RIDERSHIP 81
FIGURE 27: 2006 MODELED VS. OBSERVED TRANSFER RATES (BUS TRIPS) 81
FIGURE 28: 2006 MODELED VS. OBSERVED TRANSFER RATES (TRAX TRIPS) 82
FIGURE 29: 2006 MODELED VS. OBSERVED TRANSFER RATES BETWEEN BUS AND TRAX 82
FIGURE 30: VALIDATION OF THE RAIL SPEED CALCULATOR 103
FIGURE 31: 6-9 AM SPEED COMPARISON FROM 2003 SPEED STUDY 113
FIGURE 32: 3-6 PM SPEED COMPARISON FROM 2003 SPEED STUDY 114
FIGURE 33: 9 AM - 3 PM SPEED COMPARISON FROM 2003 SPEED STUDY 115

LIST OF EQUATIONS

EQUATION 1: AUTO OWNERSHIP MODEL UTILITY EQUATIONS 35
EQUATION 2: TRIP ATTRACTION EQUATIONS 41
EQUATION 3: DOUBLY- CONSTRAINED GRAVITY MODEL EQUATIONS 45
EQUATION 4: LOGIT MODEL FORMULATION 49
EQUATION 5: UTILITY OF EACH DESTINATION 49
EQUATION 6: SIMPLIFIED MODE CHOICE MODEL FUNCTIONAL FORM 56
EQUATION 7: COEFFICIENT OF CORRELATION 68
EQUATION 8: PERCENT ROOT MEAN SQUARED ERROR 69

EQUATION 9: ABSOLUTE ERROR 69
EQUATION 10: SUM OF DIFFERENCES (OR % DIFFERENCE) 69

LIST OF TABLES

TABLE 1: 2005 POPULATION AND HOUSEHOLDS BY COUNTY 16
TABLE 2: 2005 EMPLOYMENT BY COUNTY 17
TABLE 3: EMPLOYMENT SECTOR EQUIVALENCY TABLE 17
TABLE 4: PROBABILITY OF LABOR FORCE PARTICIPATION BY HH SIZE AND INCOME 20
TABLE 5: MSID POPULATION & EMPLOYMENT GROWTH RATES 22
TABLE 6: CAPACITY LOOKUP TABLE 26
TABLE 7: FF SPEED LOOKUP TABLE 27
TABLE 8: TRIP PURPOSES IN TRIP GENERATION MODEL 39
TABLE 9: HBW TRIP PRODUCTION RATES 41
TABLE 10: NHB TRIP PRODUCTION RATES 41
TABLE 11: HBO TRIP PRODUCTION RATES 42
TABLE 12: EXTERNAL VOLUMES AND % OF XX/IXXI TRIPS 43
TABLE 13: IX TRIP RATES BY LARGE DISTRICT 44
TABLE 14: HBW DESTINATION CHOICE MODEL ESTIMATION RESULTS 51
TABLE 15: MISCELLANEOUS TRANSIT PATH BUILDING PARAMETERS 55
TABLE 16: TRANSIT MODE HIERARCHY AND TRANSFER RESTRICTIONS 55
TABLE 17: WEIGHT APPLIED TO SECONDARY TRANSIT MODES 55
TABLE 18: MODE CHOICE MODEL NESTING STRUCTURE 57
TABLE 19: MODE CHOICE MODEL COEFFICIENTS 58
TABLE 20: HBW MODE CHOICE MODEL CALIBRATED CONSTANTS 59
TABLE 21: HBO MODE CHOICE MODEL CALIBRATED CONSTANTS 60
TABLE 22: NHB MODE CHOICE MODEL CALIBRATED CONSTANTS 61
TABLE 23: HBC MODE CHOICE MODEL CALIBRATED CONSTANTS 61
TABLE 24: FHWA GUIDELINES FOR VEHICLE ASSIGNMENT CALIBRATION 70
TABLE 25: ASSIGNMENT LINK-LEVEL CALIBRATION STATISTICS (REGION-WIDE) 71
TABLE 26: ASSIGNMENT LINK-LEVEL CALIBRATION STATISTICS (BY COUNTY) 72
TABLE 27: AM PEAK PERIOD SPEED COMPARISON (WFRC MODEL AREA ONLY) 73
TABLE 28: MODELED VS. HPMS WEEKDAY VMT ESTIMATES BY COUNTY AND FACILITY TYPE 74
TABLE 29: MODELED VS. OBSERVED HOV VOLUMES ON I-15 83
TABLE 30: MAY 1999 PEER REVIEW RECOMMENDATIONS 120

1 INTRODUCTION

The WFRC/MAG Travel Demand Model ("the model") is an integrated land-use and transportation model covering Weber, Davis, Salt Lake and Utah Counties. 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.

The model is complex system of several models used to forecast travel demand along the Wasatch Front. These models estimate the travel patterns of people, based on their demographic characteristics, where they and work, as well as on the transportation facilities available to them. The models forecast where and by what mode (e.g. single occupant autos, local bus, light rail, etc.) people are likely to travel and assigns these trips onto facilities that represent the 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 identify and assess projects that meet the travel demand, and to analyze the air quality impacts of the transportation system.

The model estimates the movement of people and vehicles within the region during an average weekday in 2005. The model is implemented within the CUBE/Voyager modeling software package, with the application written in TP+ scripting. The model includes 1,296 internal Transportation Analysis Zones (TAZs) within the 4-county region and external traffic entering and exiting the region does so through 24 external zones.

Transportation planners can use the model to perform comprehensive regional transportation analyses, and 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 land use regulation.

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 is written to provide a technical description of the procedures and parameters used by WFRC and MAG to model travel demand. As such, it will be written in the language of travel models and with the assumption that the reader has a background in travel models.

2 MODEL OVERVIEW

The WFRC/MAG model is an integrated land-use, transportation, and air quality model designed to perform a wide range of analyses. The model includes several advanced features that place it on the cutting edge of improved modeling methods required to meet the needs of 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) and the Clean Air Act Amendments of 1990. 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.

Some of the most useful model outputs include:

- Origin-Destination flows,
- Directional link vehicle volumes,
- Vehicular travel times and speeds, and
- Transit ridership numbers.

The model produces forecasts for four times of day:

- AM Peak: 6-8:59 AM
- Midday: 9 AM – 2:59 PM
- PM Peak: 3-5:59 PM
- Evening/Off-peak: 6 PM – 5:59 AM

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 coverage has expanded over the years to the point that all of the developable area of Utah, Salt Lake, Davis and Weber counties is covered by the models, with the exception of the canyons and the 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 relatively small and is separated from the urban area by some distance. The upper or eastern portion of Weber County represents a significant percentage of the 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.

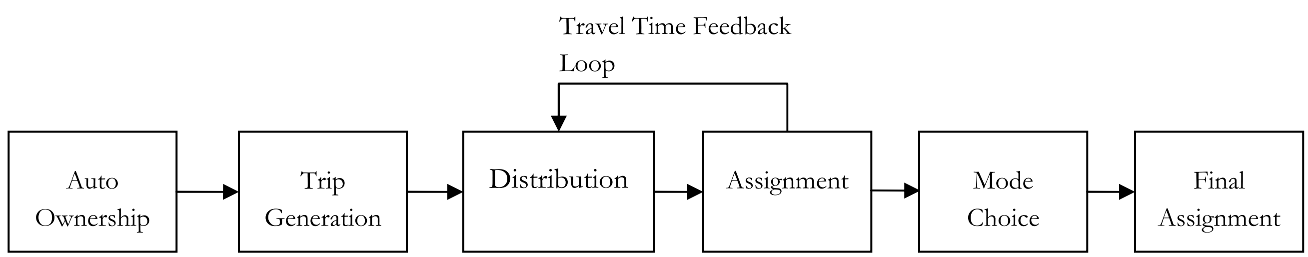
There is significant commuting from both Summit County (Park City) and Tooele County from the perspective of the populations of each of these outlying counties. The population of Summit County was approximately 32,000 in 2002 and Tooele County was approximately 46,000. In both cases the population centers are separated by distances of more than 15 miles from the urban portions of Salt Lake County. The issue of how to treat these growing travel flows may need to be dealt with in the future. At this time the commuting levels are not of a magnitude that treating the flows as an external-internal flow compromises the urban models to a significant degree.

2.2 MODEL STRUCTURE

System-wide transportation planning models are typically based on a four-step modeling process: trip generation, trip distribution, mode split, and trip assignment. The WFRC/MAG model incorporates these steps and adds an auto ownership model that is sensitive to urban design variables.

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 are also an *outcome* of trip assignment. Travel time, or more generally speaking *accessibility*, is calculated based on outputs from the assignment model, but also is an important determinant of trip distribution and mode split. Therefore it is customary to iterate these models in order to reach a convergent solution.

Figure 1: Conceptual Overview of the WFRC/MAG Model



At the start of a full model run, the auto ownership model estimates household auto ownership levels and then the trip generation model uses land use data and auto ownership to calculate trip ends at the transportation analysis zone (TAZ) level. These trip ends are then paired into origins and destinations in the distribution model. In the mode split model, a mode of travel is selected for each trip. Vehicle trips are assigned to the highway network in the assignment model. The travel time feedback loop in the model is accomplished prior to mode choice by converting person trips to vehicle trips based on observed data.

2.3 MODEL COMPONENTS

Although considered a five-step process as stated above, the model is actually comprised of several steps and each step is programmed or scripted separately. These steps include, but are not limited to:

- *Land use allocation model* allocates future land use (i.e. housing and jobs) based on accessibility, availability of land (through physical constraints and zoning), and location of existing land uses. This step saves a new land use file for the year being modeled. The land-use model is typically not run, but rather an adopted land-use forecast is input to the modeling system. However, it is possible to perform a complete and integrated model run by also running the UrbanSim land-use model (more on this below).

- *Auto ownership model* estimates the likelihood of each household in the region owning 0, 1, 2, 3+ cars. Auto ownership is a function of characteristics of the household and where the household lives. 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 and 2001. The number of trips to and from a place is a function of the amount and types of land-use activity within the zone.
- *Trip distribution model* pairs the origins and destinations for each zone for each of the trip purposes. Trip generation estimates the number of trips to or from each TAZ, and trip distribution completes the trip by describing which trip origins are linked with which trip destinations. The result of this is a person trip matrix for each trip type. Trip distribution links trip-ends of the same type based primarily on the spatial separation of different land-uses and observed sensitivities to trip length. One output of trip distribution is the person trip table for home to work that can be compared to the "Journey-to-Work" data provided by the Bureau of the Census.
- *Highway/transit skim builder* finds the best available travel path via each of the travel modes explicitly modeled. Several modes are explicitly modeled, including auto, transit modes (local bus, bus rapid transit, light rail, commuter rail) and non-motorized modes. Skims are reasonable 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.
- *Mode split model* calculates which mode the person trips are likely to take based on availability and mode-specific parameters (e.g. time, cost, transit frequency). Mode split 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. Important outputs of this module include 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 single link in either direction (select link analysis) or all the vehicle trips that originate or are destined for a zone (select zone analysis).
- *Transit assignment* uses the transit trip table output from mode split and assigns person trips using transit to the appropriate transit route. 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, MOBILE6 emissions model inputs, and calibration statistics.

2.4 TAZ STRUCTURE

The WFRC/MAG model is a zonal-based forecasting tool, modeling travel between aggregate transportation analysis zones (TAZ). Figure 2 shows an example of the transportation analysis zone (TAZ) structure. TAZs are mutually exclusive (i.e. they don't overlap) and collectively exhaustive (they cover the entire model region).

There are 1,296 internal TAZs and 24 external TAZs in the regional model. Land-use and socioeconomic data are summarized within this spatial framework and travel is estimated between the TAZs.

2.5 NETWORK STRUCTURE

For modeling purposes, the road network includes all facilities functionally designated as collector or above. There are approximately 19,000 road links in the network. Figure 3 shows a portion of the Voyager network covering Provo and Orem.

Figure 2: Model Geography & TAZ Structure

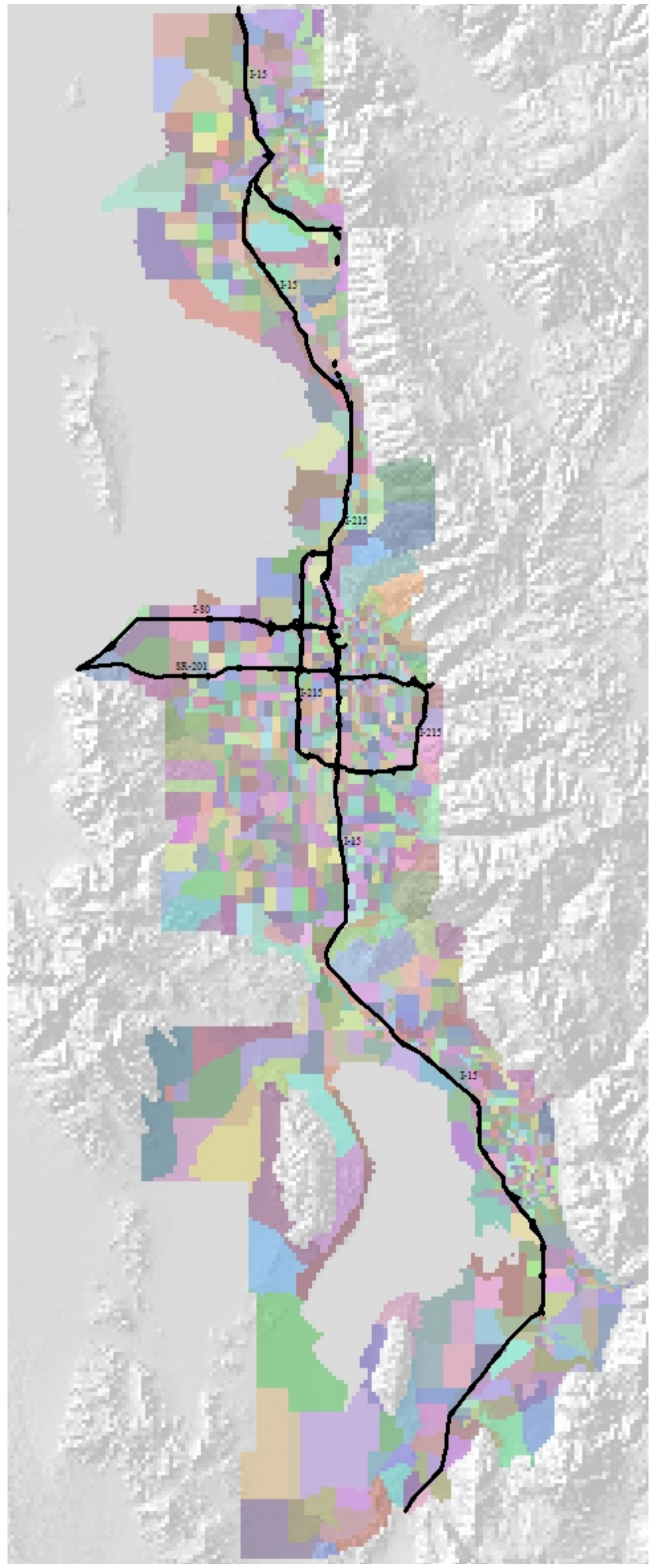
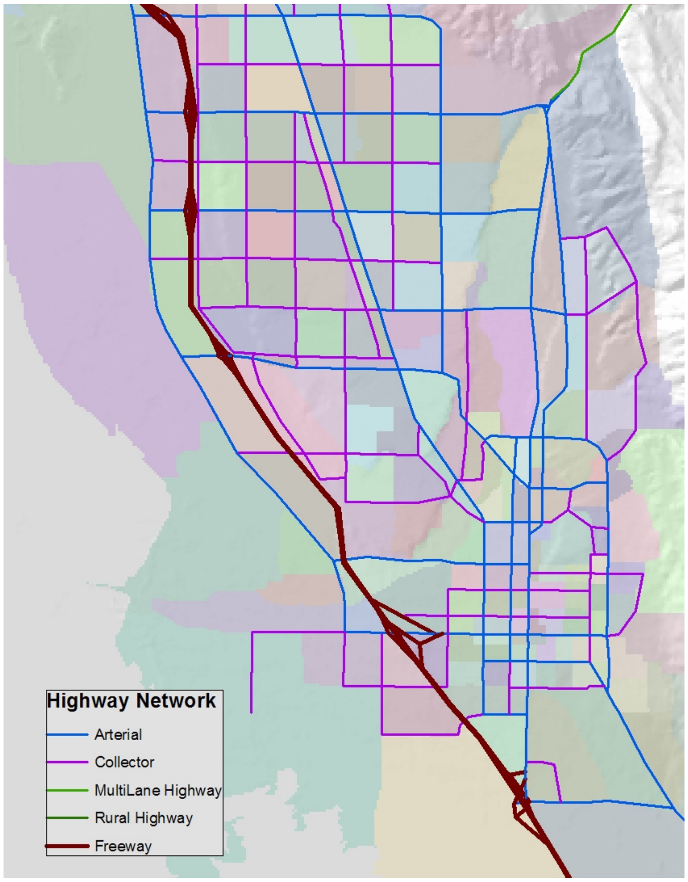


Figure 3: Street Network in Model (Provo and Orem)



2.6 MODEL CALIBRATION AND VALIDATION

The model is calibrated to reasonably represent 2005 “base year” travel conditions and patterns by adjusting parameters in the equations so that intermediate and final outputs more closely match observed data. Model output is also checked or "validated" against real-world data. Trip rates, transit ridership and highway volumes are examples of type of model outputs that are validated. When the model results do not match the base-year values within an acceptable tolerance, parameters are adjusted until the model is acceptable. For future forecast years, the model output is reviewed for "reasonableness" to validate model results and model sensitivities can be assessed.

3 BASE YEAR (2005) LAND USE DATA

Travel demand 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. As a consequence one of the initial steps in travel demand modeling is to gather current conditions and forecast how socioeconomic characteristics and locations are expected to change over time.

The WFRC/MAG travel model is calibrated to 2005 conditions. Land-use and socio-economic data for the base year model comes from the following sources:

- the 2000 Census and Census Transportation Planning Package
  - housing units and vacancy
  - household size & auto ownership
  - median income
- the 2000 Census Public-Use Micro-sample
  - detailed characteristics of households (UrbanSim)
- Annual buildings permits by TAZ
- 2005 county-level population and household totals and average household size (GOPB)
- 2005 parcel data for each county
- 2003 establishment-level employment categorized by employment sector (Department of Workforce Services)
- 2005 county-level employment estimates by sector (GOPB)

3.1 BASE YEAR HOUSING

The 2005 base year housing 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 using GIS software and checked with parcel data and aerial photography. It is assumed that building permits issued between Oct 1999 and Oct 2004 represent the housing units constructed from 2000 to 2005. It is also assumed that each housing unit built represents a household. The total households in each county are then summed and compared to the 2005 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 2005 TAZ households generated in the previous step and the 2000 Census, TAZ-level average household size. The TAZ population are then summed by county and compared with the GOPB, 2005 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 were 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, 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, but not those away at school or on LDS missions.

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

In preparation to run the UrbanSim model, 2005 parcel data (i.e. tax assessor data) is used to identify the location of residential dwelling units or the housing stock in 5 ½ acre grid cells covering the 4-county model area. In all counties except Utah County, 2003 tax assessor data was factored up to match the 2005 county-level data. Block-level vacancy rates from the 2000 Census are used to identify units that are occupied by households and that are free in the base year. A process similar to the one identified above is also used to check the household totals at the TAZ level and for quality assurance. Household characteristics were then assigned to each household based on data from the 2000 Census (CTPP & PUMS).

A total of 620,000 households and nearly 1.9 million people were within the model region in 2005.

Table 1: 2005 Population and Households by County

County	Population	Households	Average HH Size
Weber	209,600	72,900	2.87
Davis	272,400	85,900	3.17
Salt Lake	955,500	329,500	2.90
Utah	444,900	132,100	3.37
Total	*1,882,400*	*620,400*	*3.03*

3.2 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 software and the employers address to obtain a discrete point representing a number of employees as of July 1. A significant effort was undertaken to make sure that the number of employees in a given area was consistent with the building square footage available in the parcel data. Each job is assigned to the TAZ (or grid cell in the case of UrbanSim input) in which the point resides. The points are then factored by the total employment for each NAICS classification to account for the employment address that could not be successfully geocoded.

The DWS data is then converted to GOPB employment definitions using the cross-walk 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. The employment data is then grouped into the classifications used by the model and UrbanSim as outlined in Table 3.

For UrbanSim, employment square footage is also used. This is derived from the parcel data or, where parcels are missing the employment square foot data, it is estimated from the geocoded employment points.

Table 2 shows the base year employment across all TAZs by employment type.

Table 2: 2005 Employment by County

County	Retail Employment	Industrial Employment	Other Employment	Total Employment	Jobs/HH
Weber	21,400	17,600	61,100	100,100	1.37
Davis	23,400	19,100	76,500	119,000	1.39
Salt Lake	112,700	112,800	390,900	616,400	1.87
Utah	39,100	28,900	131,600	199,600	1.51
Total	*196,600*	*178,400*	*660,100*	*1,035,100*	*1.67*

Table 3 shows the sector definition and equivalency table across multiple datasets.

Table 3: Employment Sector Equivalency Table

GOPB ID	Name	DWS NAICS & Ownership ID	Travel Model Sector	Proposed UrbanSim Sector	% Home-Based Jobs
0	Forestry, Fishing	113,114 and 111421, 111422	*removed*	**Resources**	**0%**
1	Mining	21	*removed*	**Resources**	**0%**
2	Utilities	22	industrial	**Industrial**	**1%**
3	Construction	23	*removed*	**Construction**	**1%**
4	Manufacturing	31-33	industrial	**Industrial**	**1%**
5	Wholesale Trade	42	industrial	**Industrial**	**1%**
6	Retail Trade	44-45	retail	**Retail**	**3%**
7	Transp, Warehousing	48-49	industrial	**Industrial**	**1%**
8	Information	51	other	**Services**	**8%**
9	Finance, Insurance	52	other	**FIRE**	**3%**
10	Real Estate, Rental, Leasing	53	other	**FIRE**	**3%**
11	Profess, Tech Services	54	other	**Services**	**8%**
12	Mngmt of Co, Enter	55	other	**Services**	**8%**
13	Admin, Waste Services	56	other	**Services**	**8%**
14	Educational Services	61	other	**Services**	**8%**
15	Health Care, Social Asst	62	other	**Services**	**8%**
16	Arts, Enter, Rec	71	other	**Services**	**8%**
17	Accom, Food Services	72	other	**Retail**	**3%**
18	Other Services (excl Gov)	81	other	**Services**	**8%**
19-21	State & Local Gov, Fed Civilian & Military	92 and Ownership Code 10, 20 and 30 from all other categories	other	**Government**	**3%**
22	Farm	111-112,115 (minus 111421, 111422)	*removed*	**Resources**	**20%**

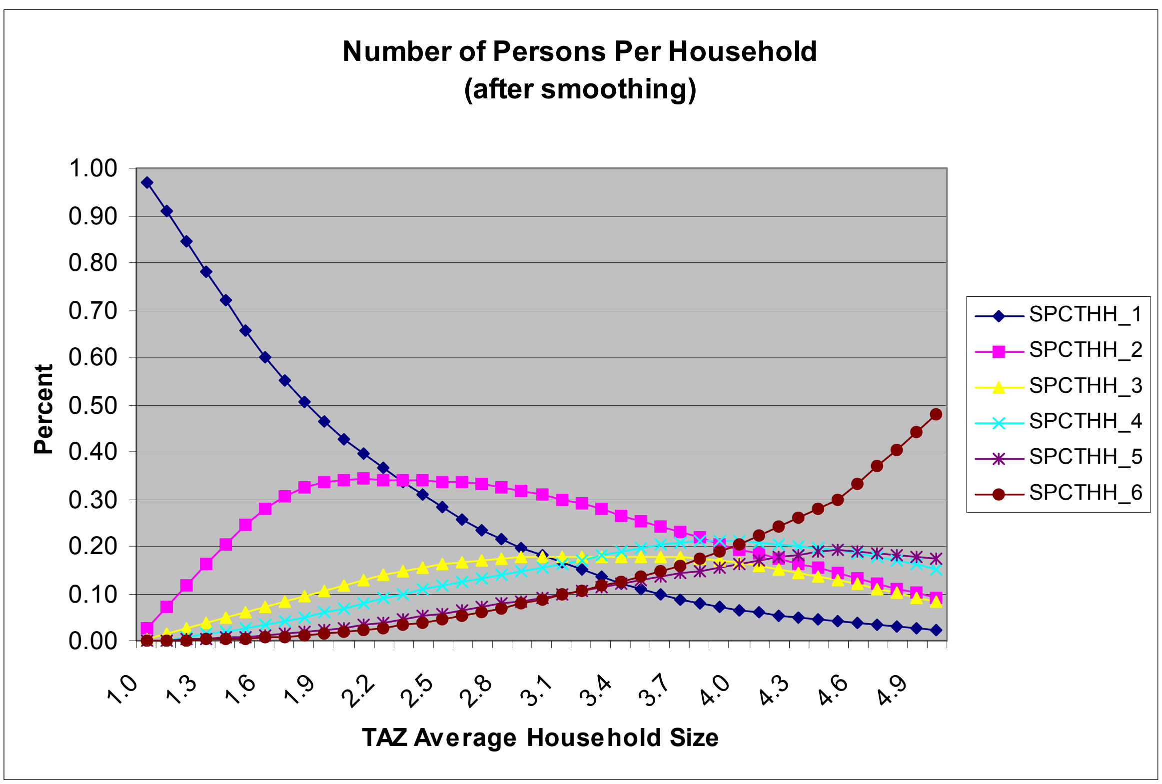
3.3 ZONAL HOUSEHOLD DATA SYNTHESIS

For advanced modeling, it is helpful to classify households by detailed market segment so that relevant characteristics of households can be used to forecast travel behavior. The 2000 Census provided an opportunity to classify households by size (# people in the household), income quartile, and workers per household. An off-model C++ program was written to apply Census curves 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 6 HH size categories (1 person to 6+ person), 4 worker categories (0 to 3+), and 4 income quartile categories. This then becomes basic 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.

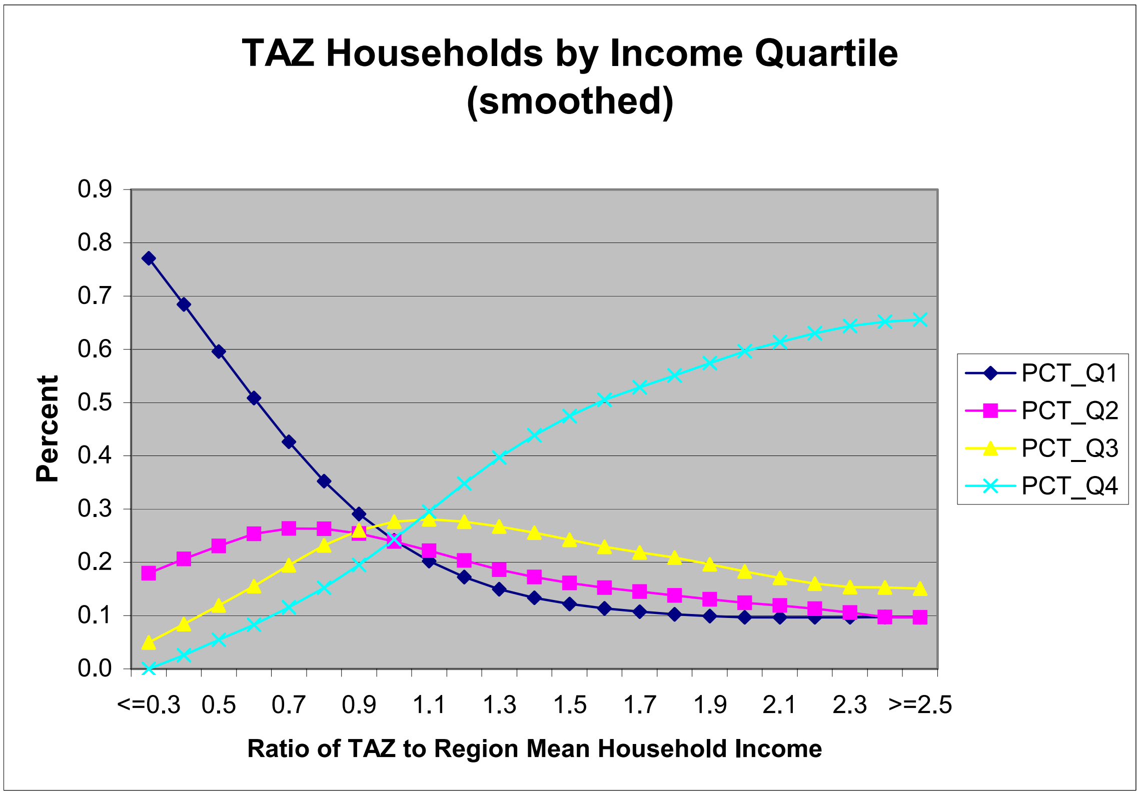
The segmentation process begins by projecting a household size distribution, based on zonal average household size. Essentially, the technique used is a lookup table, where given an average household size, an average distribution by size can be estimated. The lookup table was developed using 2000 Census data and was smoothed and calibrated to reproduce the marginal distribution at the region level. The lookup table is graphed in Figure 4.

Figure 4: Household Size Marginal Distribution Lookup Table



The second step in the segmentation process is to forecast the marginal distribution of households by income quartile. Again, the technique used is a lookup table. 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 graphed in Figure 5.

Figure 5: Household Income Quartile Marginal Distribution Lookup Table



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 simple 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 effective shares for each size/income category are presented in Table 4.

Table 4: Probability of Labor Force Participation by HH Size and Income

Probability Calculations

Size	Income Quartile	Workers 0	1	2	3+
1	1	0.431	0.569	-	-
1	2	0.181	0.819	-	-
1	3	0.105	0.895	-	-
1	4	0.061	0.939	-	-
2	1	0.307	0.318	0.375	-
2	2	0.217	0.300	0.482	-
2	3	0.116	0.303	0.580	-
2	4	0.046	0.217	0.737	-
3	1	0.004	0.360	0.422	0.213
3	2	0.003	0.221	0.562	0.214
3	3	0.001	0.171	0.517	0.311
3	4	0.000	0.071	0.384	0.545
4	1	0.004	0.360	0.422	0.213
4	2	0.002	0.137	0.728	0.133
4	3	0.001	0.087	0.753	0.159
4	4	0.000	0.044	0.619	0.337
5	1	0.002	0.081	0.906	0.011
5	2	0.001	0.098	0.806	0.095
5	3	0.001	0.118	0.665	0.216
5	4	0.000	0.071	0.384	0.545
6	1	0.006	0.121	0.580	0.294
6	2	0.003	0.221	0.562	0.214
6	3	0.001	0.171	0.517	0.311
6	4	0.000	0.071	0.384	0.545

4 FUTURE YEAR LAND USE PROJECTIONS

The socioeconomic forecasting process involves analytical models and local negotiation/review. The primary model used to allocate future demographic data differed for each MPO. WFRC used primarily UrbanSim to arrive at the 2005 calibrated travel model forecast; MAG used primarily MSID. Regardless of the analytical methods used to initially allocate population and job growth, the final projections are revised and agreeable to local governments. Regardless of the analytical methods used to initially allocate population and job growth, the final projections are revised and agreeable to local governments.

4.1 PROJECTIONS PROCESS OVERVIEW

1. The Utah Governor's Office of Planning and Budget (GOPB) provides county-level population and employment totals.
2. Working with cities, WFRC divides *population* into city-level control totals by assuming the growth rate of the past 20 years will continue until a city reaches 90% development, at which point the rate is cut in half each year until a minimum growth rate is reached. MAG population is controlled to county-level totals, not to city-level totals.
3. Estimate TAZ-level population, households and employment using two methods:
    a. Historical growth factors based on current density (a.k.a. MSID)
    b. UrbanSim (WFRC only)
4. If necessary, the process is iterative, considering the relative reasonableness of the different estimates.
5. Cities and planners review results, and their comments are implemented as applicable.

4.1.1 Historical Growth Factors by Density (MSID)

The MSID land use forecasting procedure is a trend-based model that allocates households, population and jobs to TAZs. MSID was developed locally and it is implemented in a spreadsheet, and it has recent enhancements to account for capacity constraints and planned developments. The MSID land use forecasting process relies on review and adjustment by the modeler and on comments from cities in the region.

For each TAZ the starting point for the forecast is the base year population, employment and zonal density. The densities are computed based on developable acres, and the acreage is segmented into residential and nonresidential by intersecting with a planned land use layer obtained from the city's most recently adopted General Plan land use.

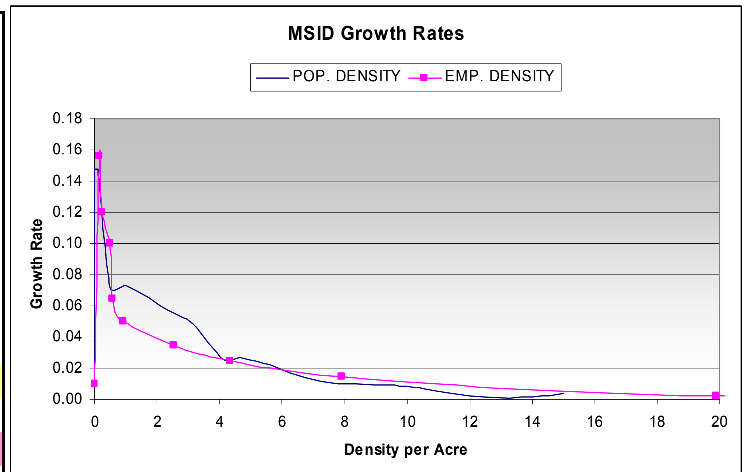
The growth rates in MSID were originally estimated from historical population and employment data from 1980, 1990 and 2000 with rates tending to decrease as density increases (Table 5). Rates were modified to exclude negative growth from occurring, which had been allowed in previous versions of MSID. The annual growth rates are applied for 5 years, at which point densities are recalculated using the projected population and employment, new growth rates are selected, and the process continues. This process in repeated until the horizon year (e.g. 2030) is reached.

MSID has evolved over years of use into a more flexible modeling tool, and now includes a variety of user-specified assumptions, including:

- The growth rate drops to essentially zero if the TAZ is estimated to be "built-out". Build-out is defined as the moment when the overall TAZ density exceeds the current density on developed land by 20% for residential and 100% for nonresidential land. That is, the currently undeveloped land is assumed to develop at no greater than 20% higher residential densities than the currently developed land in the TAZ. This assumes that future development in a TAZ will be relatively homogeneous in terms of density when compared to the existing development.
- To handle growth in zones with little to no population or employment today, zone seeding is used to help handle known development proposals and local planner's estimates of when and what type of development is likely to occur.
- GOPB estimates how they expect average household size to decrease by county over time. Once population is determined, total households are computed by assuming the same zonal household size as found today, adjusted by an annual negative growth rate as estimated by GOPB.

Table 5: MSID Population & Employment Growth Rates

Population Density	Growth Rate	Employment Density	Growth Rate
0.000	0.0100	0.000	0.0100
0.001	0.1472	0.141	0.1560
0.100	0.1472	0.238	0.1200
0.510	0.0716	0.480	0.1000
1.000	0.0731	0.586	0.0650
2.451	0.0559	0.929	0.0500
3.150	0.0487	2.541	0.0350
4.130	0.0251	4.347	0.0250
4.630	0.0269	7.890	0.0150
5.400	0.0230	19.886	0.0025
7.240	0.0118	58.306	0.0025
9.400	0.0090		
10.500	0.0068		
12.420	0.0014		
14.000	0.0012		
15.000	0.0037		



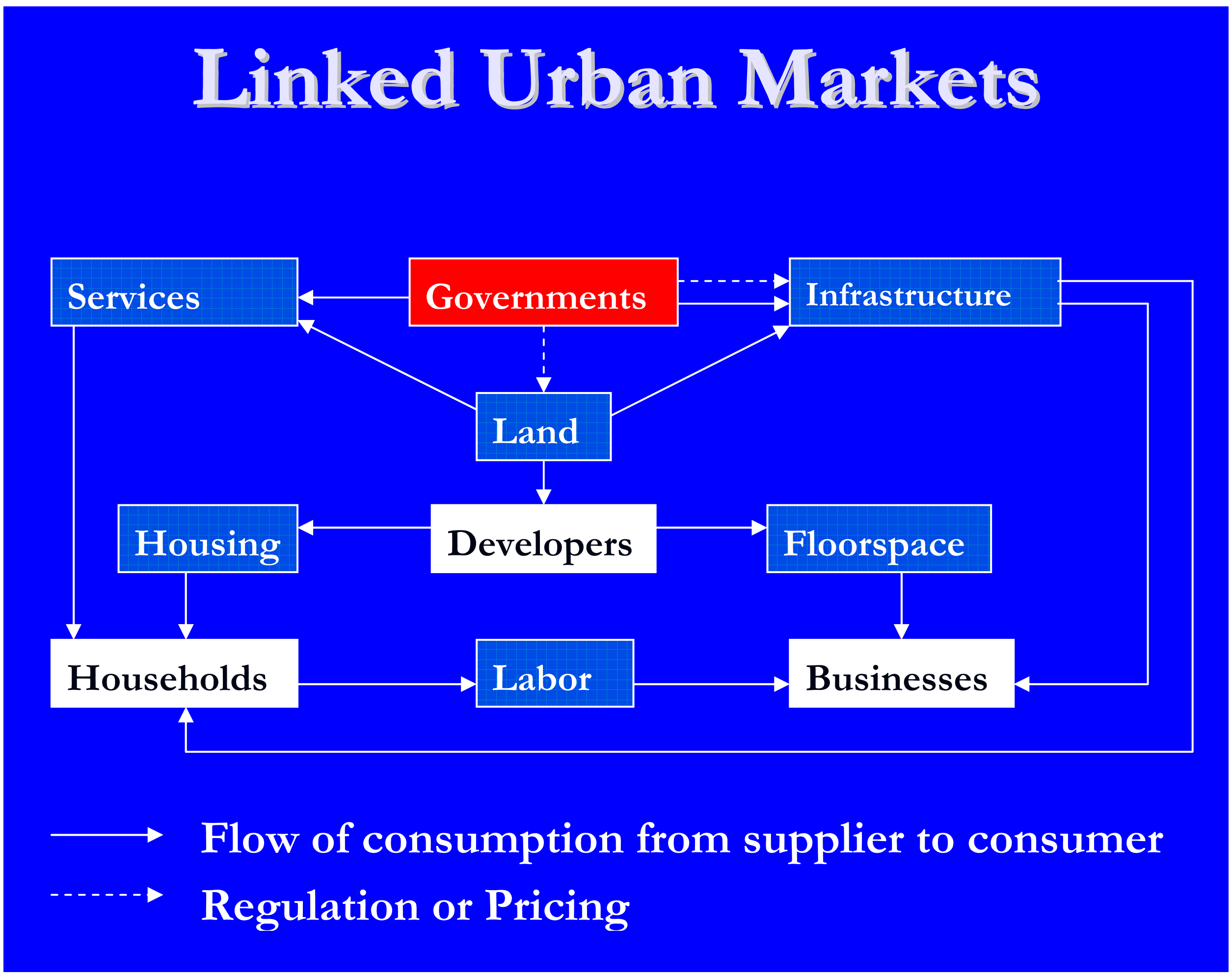
build out density for infill candidate
build out density

4.1.2 UrbanSim

UrbanSim is a state-of-the-art approach to forecasting future land-use growth, relying on a set of statistical models that pick up patterns in the way the region has grown. Critical inputs to the modeling system include jurisdictional master plans, environmental constraints and the proposed future transportation system. WFRC is one of a handful of MPOs across the country currently working with UrbanSim.

UrbanSim is designed to support metropolitan planning and policy analysis in a much more scientifically rigorous manner than MSID, and one important advantage is that growth forecasts are influenced by the quality of the proposed transportation system. By coupling UrbanSim with the regional travel demand model system, a range of land use and transportation policy interventions can be combined into policy 'scenarios', and the systematic effects of these intervention strategies can be explored on urban development outcomes and the quality of the transportation system. The objective of the UrbanSim project is to make available a set of analytical tools to support informed strategic planning to improve decisions about transportation, land use and the environment that affect the sustainability and quality of life in communities. UrbanSim documentation can be found at www.urbamsim.org.

Figure 6: Land-use Market Modeled in UrbanSim



The complexity of the UrbanSim model makes it far more challenging to implement. WFRC staff have recently completed a 2005 UrbanSim base year database and have successfully implemented UrbanSim during a regional visioning effort, and have used UrbanSim as input to the long-range socioeconomic forecasting effort.

By integrating a land use allocation model before trip generation, the model adds an important step to the traditional four-step model. The addition of the land use allocation model enables development of consistent and realistic land-use and transportation scenarios. It also enables better analyses of transit improvements and trip reduction measures.

Figure 7: Conceptual Overview of Integrated Model Structure (when running UrbanSim)

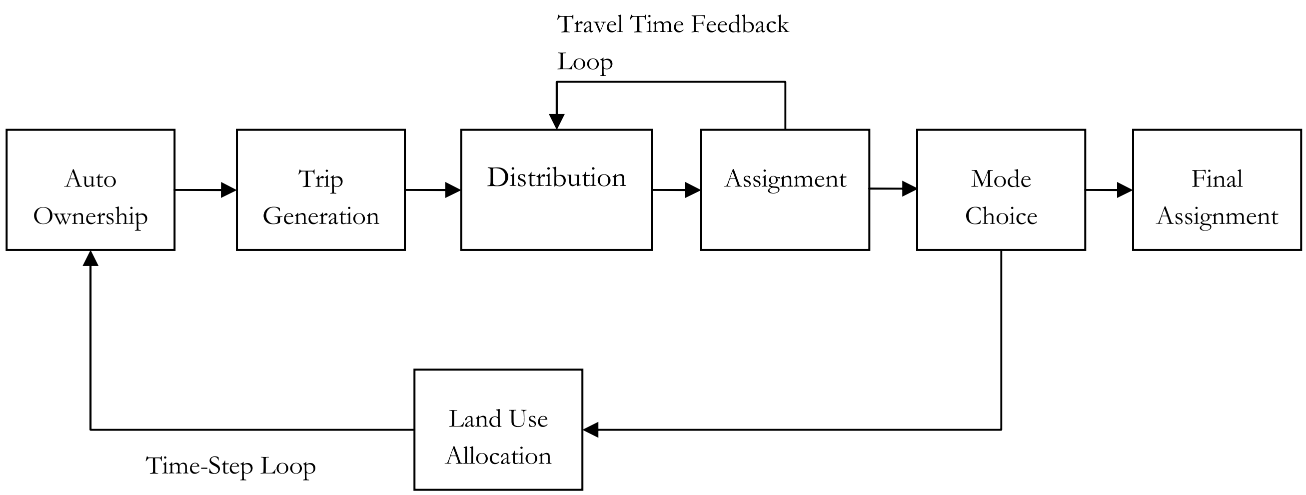


Figure 7 shows the feedback loop in which accessibility affects land use allocation, which in turn, works through the various modeling stages, to further affect accessibility. In addition, the model has another important feedback loop. The iteration loop between distribution and assignment occurs within a simulation year, because distribution and mode split adjust quickly to changes in service levels. Land use allocation adjusts much more slowly. Therefore, the land use allocation module allocates land use for the next time period based on accessibility in the previous time period. In general, we use time steps of 5 years that imply an average lag of 2 1/2 years. We consider this period to be a reasonable approximation of true time lags present in land use construction decision making.

The model output from UrbanSim is post-processed using both GOPB county-level projections and professional judgment. An additional reasonableness check for the 2005 model was to compare UrbanSim output with projections generated by the MSID process. Further adjustments were made to the projections based on review by local governments.

5 ROADWAY AND TRANSIT NETWORKS

The transportation system is represented in the travel models by abstract networks which represent the highway and transit systems. While the networks will always be an abstraction of the actual system, they attempt to represent the system in a manner which is consistent and as realistic as possible. The key parameters of the highway networks are travel speed and capacity. While the transit system is somewhat more complex because of the choices available, travel time and its components (access time, waiting time etc.) are the key.

5.1 ROAD NETWORK

The highway networks include links defining all freeways, principal and minor arterials and much of the collector system in each of the urbanized areas. TAZs are connected into the highway network by centroid connectors. The data that defines a highway link includes:

- 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 generalized free-flow speeds and capacity values to highway links. Area type is computed by the model, but lanes and functional type are user-specified.

5.1.1 Master Road Network

The MPOs have created a master network for the region. This network has the lanes and FT for the various years that need to be modeled. A TP+ script is used to extract the correct number of lanes and lane characteristics for the year 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.

5.1.2 Free-Flow Speeds and Capacity Definitions

Free-flow speeds and link capacities are assigned based on functional type using a lookup table. The current default values for capacity and FF speed are shown in Table 6 and Table 7, respectively.

Methodologies in NCHRP 357 and HCM 2001 are used to estimate FF speeds and capacities. Speeds are estimated first by assuming an unsignalized speed (stratified by functional type and area type), then factoring speeds down based on 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.

Capacities are estimated by factoring a saturation flow rate by the percentages of heavy vehicles, bus blockages, lane utilization, and green time. Specific links known to have unusually high or low "friction" are flagged and adjusted accordingly.

Table 6: Capacity Lookup Table

FT, Funclass	Friction type	# lanes	LOS E, in vphpl (Cap1hr1ln)	Sat. Flow Rate	Heavy Vehicle Fhv	Bus Block Fbb	Lane Utilization Flu	Friction Type (non-HCM)	g/C (estimated)
Centroid	All	7	10000						
2 Principle Arterial	1 High Friction	1	794	1900	0.96	0.98	1	0.8075	0.55
2 Principle Arterial	1 High Friction	2	772	1900	0.96	0.99	0.95	0.9	0.5
2 Principle Arterial	1 High Friction	3+	767	1900	0.96	0.99	0.91	0.933	0.5
2 Principle Arterial	2 Med. Friction	1	887	1900	0.96	0.98	1	0.9025	0.55
2 Principle Arterial	2 Med. Friction	2	815	1900	0.96	0.99	0.95	0.95	0.5
2 Principle Arterial	2 Med. Friction	3+	795	1900	0.96	0.99	0.91	0.967	0.5
2 Principle Arterial	3 Low Friction	1	983	1900	0.96	0.98	1	1	0.55
2 Principle Arterial	3 Low Friction	2	858	1900	0.96	0.99	0.95	1	0.5
2 Principle Arterial	3 Low Friction	3+	822	1900	0.96	0.99	0.91	1	0.5
3 Minor Arterial	1 High Friction	1	650	1900	0.96	0.98	1	0.8075	0.45
3 Minor Arterial	1 High Friction	2	695	1900	0.96	0.99	0.95	0.9	0.45
3 Minor Arterial	1 High Friction	3+	619	1900	0.96	1	0.91	0.933	0.4
3 Minor Arterial	2 Med. Friction	1	733	1900	0.96	0.99	1	0.9025	0.45
3 Minor Arterial	2 Med. Friction	2	733	1900	0.96	0.99	0.95	0.95	0.45
3 Minor Arterial	2 Med. Friction	3+	642	1900	0.96	1	0.91	0.967	0.4
3 Minor Arterial	3 Low Friction	1	813	1900	0.96	0.99	1	1	0.45
3 Minor Arterial	3 Low Friction	2	686	1900	0.96	0.99	0.95	1	0.4
3 Minor Arterial	3 Low Friction	3+	664	1900	0.96	1	0.91	1	0.4
4,5,6 Collectors	1 High Friction	1	526	1900	0.98	1	1	0.8075	0.35
4,5,6 Collectors	1 High Friction	2	557	1900	0.98	1	0.95	0.9	0.35
4,5,6 Collectors	1 High Friction	3+	474	1900	0.98	1	0.91	0.933	0.3
4,5,6 Collectors	2 Med. Friction	1	588	1900	0.98	1	1	0.9025	0.35
4,5,6 Collectors	2 Med. Friction	2	588	1900	0.98	1	0.95	0.95	0.35
4,5,6 Collectors	2 Med. Friction	3+	492	1900	0.98	1	0.91	0.967	0.3
4,5,6 Collectors	3 Low Friction	1	652	1900	0.98	1	1	1	0.35
4,5,6 Collectors	3 Low Friction	2	619	1900	0.98	1	0.95	1	0.35
4,5,6 Collectors	3 Low Friction	3+	508	1900	0.98	1	0.91	1	0.3
9 Non-Fwy Urban interchange, cross-street		N/A	1094	1900	0.96	1	1	1	0.6
10 Non-Fwy Urban interchange, major street		N/A	1550	1900	0.96	1	1	1	0.85
11, 12 Multilane Hwy (P,M)	N/A	N/A	912	1900	0.96	1	1	1	0.5
21-23 Rural Hwy (P,M,C)	N/A	N/A	994	1800	0.92	1	1	1	0.6
31 Fwy: lower capacity	N/A	N/A	2016	2100	0.96	1	1	1	1
32 Fwy: higher capacity	N/A	N/A	2208	2300	0.96	1	1	1	1
33 Fwy: CD roads	N/A	N/A	2016	2100	0.96	1	1	1	1
34 Fwy: HOV lanes	N/A	N/A	2208	2100	0.96	1	1	1	1
35 Fwy: Rural/High spd	N/A	N/A	1932	2100	0.92	1	1	1	1
36 Fwy: On/Off ramp	N/A	1	912	1600	0.95	1	1	1	0.6
36 Fwy: On/Off ramp	N/A	2	638	1600	0.95	1	0.7	1	0.6
37 Fwy: Loop ramp	N/A	N/A	1368	1600	0.95	1	1	1	0.9
38 Fwy: Managed Ln access	N/A	N/A	2208	2300	0.96	1	1	1	1
39 Fwy: Toll lanes	N/A	N/A	2208	2300	0.96	1	1	1	1
40 Fwy: HOT lanes	N/A	N/A	2208	2300	0.96	1	1	1	1

* FT is a numeric code for FUNCLASS. FT, AreaType, and lanes are fields that we maintain by hand, and are used to auto-generate spd/capclass.

"High Friction" = lack of turn pockets, shoulders, high driveways/mi, use of dual left turns, no two-way-left-turn lane, etc
"Low Friction" = Opposite low, generally good traffic engineering provided at intersections and access management appropriate to functional classification of road

* Note: All capacities are multiplied by .90 if in CBD-like conditions (HCM)

Table 7: FF Speed Lookup Table

FT, Functional Type	AT, Area Type	Free-flow speed (SFF)	Base Speed (NCHRP 387)	Signal/Stop Density (Estimated)	Uncongested Delay per Stop (LOS B-C)
1 Centroid / Local	5 CBD	13.4	22.0	7.0	15.0
1 Centroid / Local	4 Urban	16.2	25.0	6.0	13.0
1 Centroid / Local	3 Suburban	21.2	30.0	5.0	10.0
1 Centroid / Local	1-2 Rur/Transition	23.2	30.0	3.5	10.0
2 Principle Arterial	5 CBD	28.2	42.0	2.8	15.0
2 Principle Arterial	4 Urban	32.8	45.0	2.3	13.0
2 Principle Arterial	3 Suburban	39.6	50.0	1.9	10.0
2 Principle Arterial	1-2 Rur/Transition	44.7	55.0	1.5	10.0
3 Minor Arterial	5 CBD	27.5	42.0	3.0	15.0
3 Minor Arterial	4 Urban	30.6	45.0	2.9	13.0
3 Minor Arterial	3 Suburban	36.4	50.0	2.7	10.0
3 Minor Arterial	1-2 Rur/Transition	42.1	55.0	2.0	10.0
4,5,6 Collectors	5 CBD	22.9	37.0	4.0	15.0
4,5,6 Collectors	4 Urban	27.1	40.0	3.3	13.0
4,5,6 Collectors	3 Suburban	32.4	45.0	3.1	10.0
4,5,6 Collectors	1-2 Rur/Transition	32.7	45.0	3.0	10.0
31 Fwy: lower capacity	N/A	67.0	67.0		
32 Fwy: higher capacity	N/A	67.0	67.0		
33 Fwy: CD roads	N/A	55.0	55.0		
34 Fwy: HOV lanes	N/A	67.0	67.0		
35 Fwy: Rural/High spd	N/A	75.0	75.0		
36 Fwy: On/Off ramp	N/A	22.9	25.0	1	13.0
37 Fwy: loop ramp	N/A	30.0	30.0		
38 Fwy: Managed Ln access	N/A	67.5	67.5		
39 Fwy: Toll lanes	N/A	67.5	67.5		
40 Fwy: HOT lanes	N/A	77.5	67.5		
9 Non-Fwy Urban interchange, cross-street		38.0	38.0	0	
10 Non-Fwy Urban interchange, major street		50.0	50.0	0	
11-12 Multilane Hwy (P,M)	N/A	50.0	60.0	0.8	15.0
21-23 Rural Hwy (P,M,C)	N/A	51.4	60.0	1	10.0

* FT is a numeric code for functional type (class)
* Speeds assume more than 1 lane per direction. If just one lane, speeds are lowered by 1 mph to account for inability to pass.
* SFF = 1 / ((1 / unsignalized speed) + (Num stops per mile * Uncongested delay per V / 3600))
* Any spacially unique SPDEXCEPT's found in the network are applied (if FT < 31)

Required stops/mile due to signals or stop signs

	CBD	Urban	Suburban	Transition
P.Art	2.8	2.3	1.9	1.5
M.Art	3.0	2.9	2.7	2.0
Coll	4.0	3.3	3.1	3.0
Local	7.0	6.0	5.0	3.5

Unsignalized Speed

	CBD	Urban	Suburban	Transition
P.Art	42.0	45.0	50.0	55.0
M.Art	42.0	45.0	50.0	55.0
Coll	37.0	40.0	45.0	45.0
Local	22.0	25.0	30.0	30.0

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

	CBD	Urban	Suburban	Transition
All types	15.0	13.0	10.0	10.0

5.2 TRANSIT NETWORK

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 the Utah Transit Authority (UTA). Transit networks include local buses, express buses, bus rapid transit routes, light rail lines, and commuter rail lines.

Transit coding can be complicated, and this section is not intended to be a user's guide to network coding. 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 (4)
  - Bus rapid transit (5)
  - Express bus (6)
  - Light rail (7)
  - Commuter rail (8)
- Route stops
- Speed (fixed guideway only)
- Peak/Off-peak period headway

5.2.1 Transit Access Links

Access and egress links are necessary in TP+ so that trips can get from the 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 and egress, transferring and park-and-ride access. The model has an automated process to generate each of these types of links.

- <u>Walk access/egress:</u> Directional 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).
- <u>Drive access:</u> These directional links provide a connection from TAZ centroids to park-and-ride (PNR) nodes on the roadway network (modes 40, 50, 60, 70, 80).
- <u>Transfer links</u>: Two direction walk link to facilitate transfers between pairs of stop nodes that are nearby (mode 20 for auto-generated links, mode 21 for user-specified links).

5.2.1.1 Walk Access and Egress Links

Walk access and egress links are directional links between zone centroids and transit stop nodes. The maximum link length varies because significant effort is made to ensure transit access even in fringe area with large zones. Typically, the maximum walk length is ½ mile (over the network) for walk to/from bus, 3/4 mile max for walk to/from rail. These are auto-generated based on the distance from the centroid to the transit stop (mode 11 links). Where the centroid connection would require more walking than is truly required, access/egress links can be added manually (mode 12 links).

The algorithm to determine walk-access times for zones within walking distance of transit makes a concerted effort to trace at least one walk path to a transit stop for all zones within walking distance of transit. This is done by tracing a series of access paths, increasing the maximum path length over the network.

The maximum access/egress link length is quite long for zones in the outer suburbs (where TAZs are large and the network is sparse) because significant effort was made to ensure transit access even in fringe area with large zones. Typically, the maximum walk length is ½ mile (over the network) for walk to/from bus, 3/4 mile max for walk to/from rail. These are typically auto-generated based on the distance from the centroid to the transit stop (mode 11 links). Where the centroid connection would require more walking than is truly required, access/egress links can be added manually (mode 12 links).

5.2.1.2 Transfer Links

As with walk access and egress links, network links are necessary to connect nearby bus stops and allow transfers. An automated process has been developed that searches for bus and rail stops that are within ¼ mile of each other, and generates a transfer link. Transfer links are not necessary if two or more routes share the same stop node. The coding convention in the model is for automatically generated transfer links to be mode 20 and for manually coded transfer links to be mode 21.

5.2.1.3 Park and Ride Lots/Links

As with walk access links, in order to access transit by car a drive access link is necessary. Drive access trips can utilize a park-and-ride lot, or not (where a passenger gets 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 (typically a park and ride lot). Separate mode numbers are used for drive access locations that serve different modes. 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:

1. <u>Code PNR lots on roadway network</u>: All PNR lots or drive access locations are coded as node attributes on the master network.
2. <u>Confirm that lot coincides with routes for scenario</u>: First, the script identifies all transit stops by node and mode. The script then writes out a list of nodes where the node was identified as an existing/potential PNR lot for that mode and that mode actually stops at that node.
3. <u>Write PNR access code for most logical access point</u>: The nearest confirmed lots to a given zone are identified, and a TP+ format PNR record is recorded for that path. For commuter rail, only the nearest 2 lots are recorded. For light rail, BRT, and express bus, it's the nearest 3 lots that are identified from each TAZ.

5.2.2 Percentage of TAZ within walking distance of transit

GIS is used to estimate the percentage of each TAZ's area that is within walk distance of transit. GIS is used to create a 4/10 mile buffer around bus lines, and around express bus, BRT and rail stops. This buffer is then intersected with the TAZs to estimate the number of people and jobs within the walk access to transit buffer.

6 SURVEY DATASETS USED FOR MODEL DEVELOPMENT

There are a few important 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.

6.1 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 vehicle 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 City: 1200 households
- Ogden: 900 households
- Provo-Orem: 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 car ownership, household size and geographic area. Car 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 car-ownership and household size.

6.2 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 make adjustment to transit path-building parameters and assumptions.

6.2.1 2006 On-Board Survey Data Collection Details

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 5,583 questionnaires.

Routes were surveyed with a single assignment of approximately five hours. Within each route's assignment, trips were surveyed in each direction during both Peak and Non-Peak periods of travel. Peak hours were defined as either 6 AM – 8:59 AM or 3 PM – 5:59 PM. Non-Peak hours fell outside of the Peak designation. Once the number of trips for each route was decided, a sample plan incorporating each route's ridership was constructed to approximate the number of expected completed questionnaires. Sampled trips were clustered by block (i.e., consecutive trips a vehicle makes for a specified duration) for the purpose of efficient use of surveyor labor. The surveyor boarded the vehicle at the start of its trip and stayed on that vehicle to survey all of the sampled trips in the cluster. This minimized surveyor "down time". The use of clusters had the further advantage of de facto stratification by direction (i.e., most runs consist of bus trips alternately traveling inbound, outbound, inbound, etc.), as well as stratification by route and time of day.

Data were collected using a methodology that included the distribution of questionnaires to boarding passengers, simultaneously with the entry of boarding and alighting counts using Global Positioning System (GPS)-enhanced technology. Personal Digital Assistant (PDA) devices, equipped with GPS, recorded the location and time (arrival and departure) at each bus stop for each sampled trip. The process included entering the serial number ranges of surveys distributed at each stop to capture the boarding location of the respondent. Survey data were scanned and verified, corrected, and geo-coded concurrently during data collection.

6.3 NATIONAL HOUSEHOLD TRAVEL SURVEY (2001)

Conducted periodically since1969 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 2001 NHTS is the most recent available survey.1 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.

6.4 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 trends over time and whether or not they are changing.

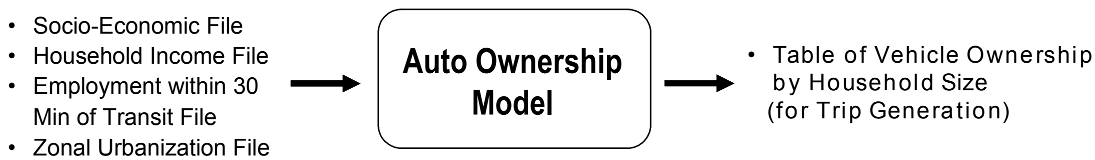
---

[1] http://nhts.ornl.gov/

7 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 8: Auto Ownership Model Information Flow



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.

Equation 1: Auto Ownership Model Utility Equations

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

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

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

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

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 5 zones (population/acres)
EMP30TRAN	= employment within 30 minutes of transit

All parameters in the utility equations are significant at .05 level, except the parameter for (pop. density for nearest 5 zones) for the 2-vehicle choice, which is significant at 0.10. Scatter plots are presented below.

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 vehicle 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.

8 TRIP PURPOSES

Trips are categorized by trip purpose, or trip type, in the following way:

- *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.
- *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.

9 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.

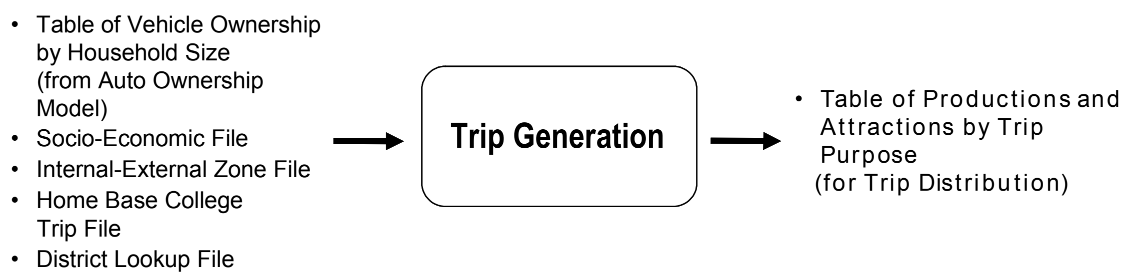
Trip generation is done in four steps:

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 vehicle 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 and are used in the trip distribution phase of the Model. The trip purposes include Home-Based Work (HBW), Home-Based Other (HBO), Non-Home-Based (NHB), Internal-External/External-Internal (IXXI), and Commercial.

Figure 9: Trip Generation Information Flow



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." Production ends occur at the trip maker's residence. 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.

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.

Productions and attractions are different than origins and destinations. 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, it is the destination (home) which is the production.

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.

Productions and attractions are calculated for eight purposes: 1) *home based work*, 2) *home based other*, 3) *home based school*, 4) *home based shopping*, 5) *home based personal business*, 6) *non-home based work*, 7) *non-home based non-work*, and 8) *commercial*. The eight purposes, purposes 2 through 5 are added together to form the *total home based other purpose* (9), and purposes 6 and 7 are added together to form the *non-home based purpose* (10). Purpose 11, *external trips*, is not calculated directly by trip generation. Rather it is read from a file to be processed later in the script. In the end, purposes 1, 8, 9, 10, and 11 are reported in the output.

Table 8: Trip Purposes in Trip Generation Model

1. Home-Based Work (HBW)		
2. Home-Based Other (HBO) 3. Home-Based School (HBSC) 4. Home-Based Shop (HBSH) 5. Home-Based Personal Business (HBPB)	⇨	9. Total Home-Based Other (HBO)
6. Non-Home-Based Work (NHBW) 7. Non-Home-Based Non-Work (NHBN)	⇨	10. Total Non-Home-Based (NHB)
8. Commercial (COMM)		
11. Internal-External (IX)		

Trip generation equations vary for productions and attractions as well as by purpose. The following paragraphs explain the more general differences between the production and attraction equations.

9.2 ESTIMATING TRIP GENERATION

9.2.1 Trip Production Rates

The WFRC/MAG Travel Demand Model uses a cross-classification approach to estimating trip productions. This approach is widely used in other regional network models.

Home-based productions (HBW and HBO) are estimated with trip rates that vary by household size and auto ownership. The person-trip rates for each class of households were estimated based on the 1993 Home Interview Survey.

For Non-home-based (NHB) trips and for commercial trips, the distinction between the production and attraction end of the trip is often not clear. Trips falling into the non-home based and commercial categories are often part of a series of trips, or a trip chain. This complicates the ability to think in terms of productions or attractions, making it much more complicated to model because the causal relationships are not as clear. Total non-home-based (NHB) trips are assumed to be a function of households in the region. The NHB trip rates on the following page apply to each household, and in the aggregate are used to scale total NHB trip-ends during trip-end balancing. However, NHB trips by definition do not have a trip-end at home and so NHB trip-end locations are estimated using linear regression models described in the trip attractions section.

Therefore, for a non-home based trip both trip-ends are considered attractions. The total attractions are then divided by two, splitting them equally among the production and attraction variables. A functionally similar approach is used in assigning commercial productions, although a separate but similar equation is used to calculate the productions.

Also a note on commercial trips: commercial trips were not surveyed as part of the 1993 Home Interview Survey. The commercial production and attraction equations were, however, updated in 1992 from the equations developed in the late 1960s. The update included replacing commercial acres with retail employment and residential acres with dwelling units.

Table 9: HBW Trip Production Rates

HB Work	VEH0	VEH1	VEH2	VEH3+
HH1	0.32	0.70	1.07	1.14
HH2	1.04	1.23	1.52	1.92
HH3	1.47	1.54	1.79	2.38
HH4	1.77	1.76	1.97	2.70
HH5	2.01	1.93	2.12	2.95
HH6+	2.20	2.24	2.31	3.32

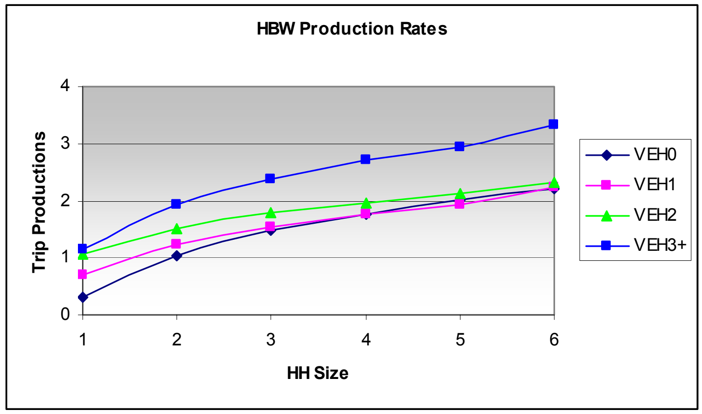


Table 10: NHB Trip Production Rates

NHB Work Related	VEH0	VEH1	VEH2	VEH3+
HH1	0.35	0.76	0.89	1.05
HH2	0.67	0.74	1.26	1.26
HH3	0.80	0.96	1.59	1.68
HH4	1.00	1.22	1.24	1.80
HH5	0.57	1.09	1.55	1.74
HH6+	0.57	0.97	1.40	1.81

NHB Non-work	VEH0	VEH1	VEH2	VEH3+
HH1	1.08	1.25	1.25	1.25
HH2	1.94	2.11	2.16	2.16
HH3	2.45	2.85	3.00	3.22
HH4	3.39	3.57	3.76	4.28
HH5	0.85	4.14	4.44	4.58
HH6+	0.85	5.12	5.30	5.60

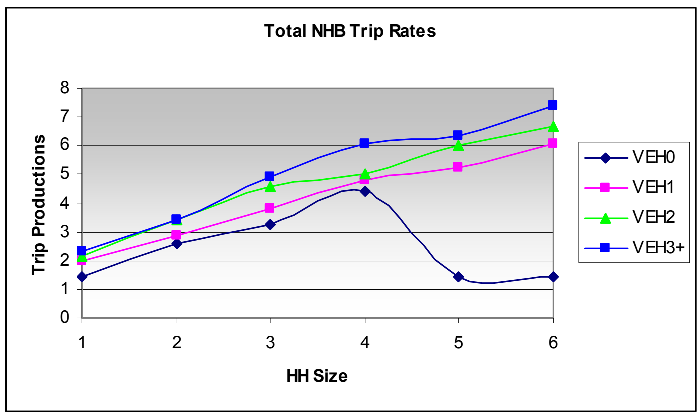


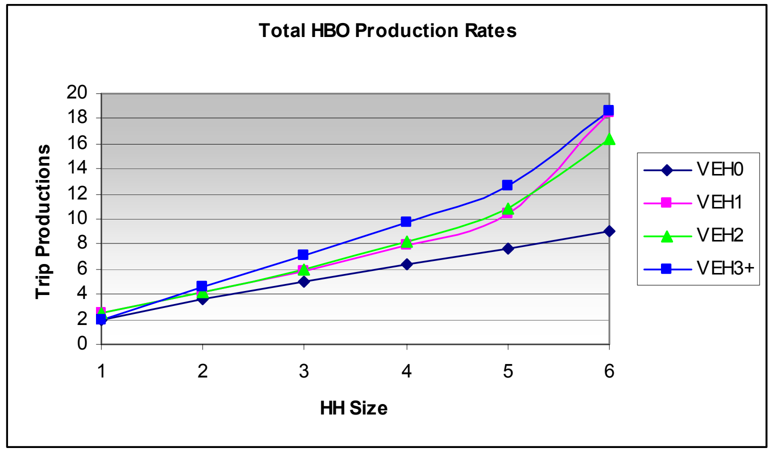
Table 11: HBO Trip Production Rates

HB School	VEH0	VEH1	VEH2	VEH3 +
HH1	0.01	0.17	0.14	0.00
HH2	0.41	0.45	0.24	0.30
HH3	0.90	0.89	0.64	0.95
HH4	1.47	1.48	1.33	1.77
HH5	2.11	2.23	2.32	2.74
HH6+	2.84	4.80	4.68	5.04

HB Shop	VEH0	VEH1	VEH2	VEH3+
HH1	0.49	0.42	0.51	0.31
HH2	1.01	0.97	0.99	1.05
HH3	1.32	1.30	1.27	1.49
HH4	1.53	1.52	1.47	1.80
HH5	1.70	1.70	1.63	2.04
HH6+	1.84	2.02	1.83	2.38

HB Pers. Bus.	VEH0	VEH1	VEH2	VEH3+
HH1	0.45	0.65	0.54	0.48
HH2	0.67	0.91	0.96	1.04
HH3	0.79	1.07	1.21	1.37
HH4	0.88	1.18	1.39	1.60
HH5	0.95	1.26	1.53	1.79
HH6+	1.01	1.42	1.71	2.05

HB Other	VEH0	VEH1	VEH2	VEH3+
HH1	1.04	1.27	1.26	1.12
HH2	1.53	1.80	1.95	2.13
HH3	2.00	2.64	2.86	3.29
HH4	2.45	3.78	4.00	4.60
HH5	2.87	5.23	5.37	6.05
HH6+	3.27	10.17	8.22	9.20



9.2.2 Trip Attraction Rates

Attraction ends are non-home land uses such as workplaces, shops, schools, hospitals, and other people's residences. For the model, attraction trip ends are primarily tied to employment, in some cases by category of employment. The number of trip ends each employment class attracts is estimated from a regression analysis which uses the 1993 trip diary survey responses as the estimation database. In this regression analysis, the attraction trip end type is the independent variable. Possible dependent variables include the employment classes and the number of housing units within the attraction end TAZ.

Trip attractions rates were estimated based on census tract aggregation of the 1993 Home Interview Survey. The following variables were determined to be the key variables in estimating attractions:

- Total Population (TOTPOP)
- Total Dwelling Units (TOTDWL)
- Total Employment (TOTEMP)
- Retail Employment (RETEMP)
- Other Employment (OTHEMP)

Equation 2: Trip Attraction Equations

HBW Attractions = TOTEMP*1.2167

HBO Attractions = TOTPOP*0.8460 + RETEMP*2.8497

HBSC Attractions = TOTPOP*0.4197

HBSH Attractions = RETEMP*1.6208 + TOTDWL*0.7221

HBPB Attractions = TOTDWL*0.6886 + RETEMP*0.9799 + OTHEMP*0.1913

NHBW Trip Ends = TOTEMP*1.2130 + TOTDWL*0.7246

NHBNW Trip Ends = TOTDWL*2.8188 + RETEMP*5.9869 + OTHEMP*0.6750

COMM Trip Ends = TOTEMP*0.5664 + TOTDWL*0.8 + RETEMP*.5216

For Non-home-based and commercial trips the equations above represent TOTAL trip-ends for a TAZ. The assumption is made in the model that half of the trip-ends are origins/productions and half are destinations (attractions).

9.3 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 facilities such as universities, large business parks, airports, regional shopping malls, high density urban zones (CBD), and sports complexes. Total trip-ends in special generator zones are predicted using linear regression models that were estimated for each special generator zone and are used to factor the estimated person trips predicted using the models described above (prior to extracting IX-XI trips and balancing productions and attractions).

In the Salt Lake Area, the special generators include the Salt Lake International Airport (Zone 425), Jordan Landing (785), the University of Utah and nearby medical campus (438, 449), the four existing regional shopping malls (682, 750, 766, 870), a proposed regional mall on 5600 W. (474), and several zones in the Salt Lake City CBD (456-460, 465-468, 485-488, 495, 496, 498, 499). In most cases the additional trips are estimated based on total employment in the zone. In the case of the zones with malls, retail employment is a factor.

In the Ogden Area, the special generators include Weber State University (141), Layton Hills Mall (242), and Newgate Mall (135). In the Provo area, the special generators are the University Mall (1191) and the Provo Mall (1079). Again, additional trips are estimated based on total and retail employment.

9.4 BALANCING ATTRACTIONS TO PRODUCTIONS

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.

After all productions and attractions have been calculated, total attractions are adjusted to equal total productions by purpose. The productions and attractions for the HBSC, HBSH, HBPB, and HBO purposes are combined into a single HBO purpose since the trip distribution process distributes trips for a single HBO purpose. For non-home-based trips, the attractions are divided in two for each zone, with one-half of the attractions assumed to be destinations and the other half assumed to be origins.

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 in the trip generation spreadsheet. 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.

9.5 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 WFRC/MAG regions and the other trip-end inside the region. The second type of external trips are *external-external* trips (XX trips), which do not stop in the region.

Total external trips (IX-XI 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 IX-XI and XX trips, we assume that only major external stations (e.g. the interstates) serve XX trips, and the percentage of XX on these facilities is asserted to be 13%, which is consistent with surveys done in Phoenix and Reno.

Table 12: External Volumes and % of XX/IXXI Trips

External TAZ	Name	TUH AADT 2001	TUH AWDT 2005	XX %	IXXI %
194	N Ogden Pass	1,650	4,960	0	100
195	I-15 Box Elder/Weber	45,415	44,977	13	87
196	89 Box Elder/Weber	9,285	14,099	0	100
198	Ogden Canyon	8,305	7,395	0	100
199	I-84 East	14,145	16,536	13	87
991	I-80 at SR 201, Tooele	20,790	22,094	13	87
992	SR 201 at I-80, Tooele	13,385	14,960	0	100
995	Emigration Canyon	6,835	15,851	0	100
996	I-80 East Parley's	41,040	48,865	13	87
997	Millcreek Canyon	1,000	1,082	0	100
998	Big Cottonwood	4,225	4,145	0	100
999	Little Cottonwood	5,530	5,986	0	100
1480	I-15 Juab/Utah	22,548	27,035	13	87
1481	Goshen	1,300	1,389	0	100
1482	Payson Canyon	600	688	0	100
1483	SF Canyon (Hwy 6)	9,405	9,476	0	100
1484	Hobble Ck. Can (Spgville)	3,220	3,695	0	100
1485	Provo Canyon	16,705	17,077	0	100
1486	AF Canyon	2,415	2,645	0	100
1487	Tooele line near Cedar Fort	1,065	1,871	0	100

In the model, the internal trip-ends for IX-XI 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.

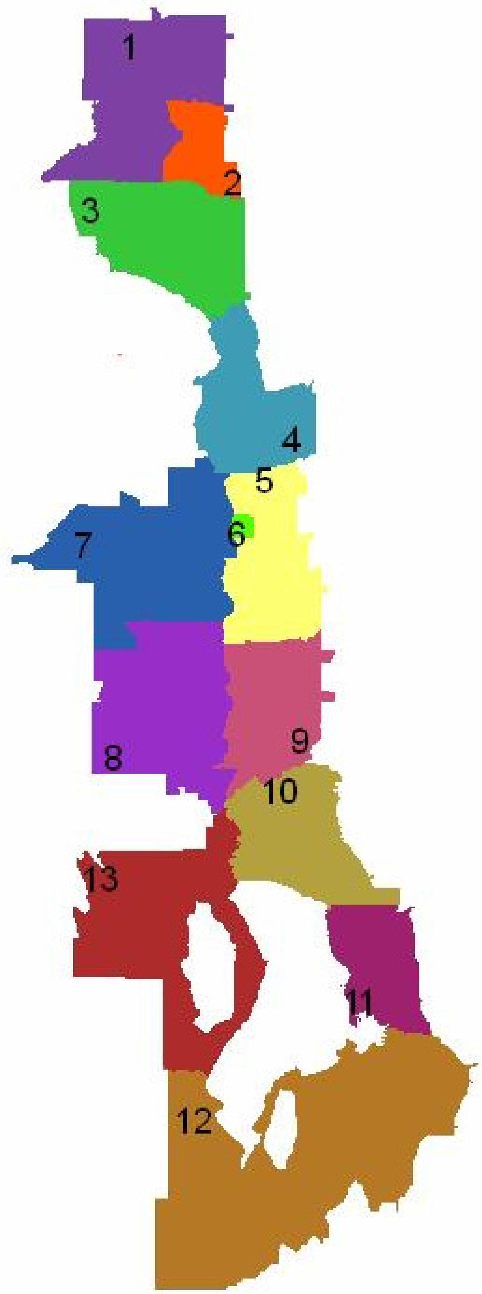
XI trips represent 75% of the total estimated IXXI counts estimated at each station, while IX trips are assumed to be 25%. The 75-25 split assumes that on an average weekday there are more people coming from outside the region to attractions within the region than there are people going from the region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

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 MPO large districts. The average IX-XI trip-end ratios are shown for each district in Table 13.

Table 13: IX Trip Rates by Large District

Large District	HBW IX	HBO IX	NHB IX
1	0.036	0.017	0.014
2	0.018	0.009	0.010
3	0.011	0.006	0.003
4	0.006	0.004	0.004
5	0.006	0.009	0.005
6	0.006	0.008	0.007
7	0.013	0.015	0.013
8	0.011	0.007	0.007
9	0.014	0.006	0.005
10	0.012	0.006	0.005
11	0.011	0.005	0.004
12	0.010	0.004	0.003
13	0.009	0.004	0.003

Map of Large Districts



10 TRIP DISTRIBUTION

Trip distribution is the pairing of origins and destinations to form complete trips. Paring is done separately within each trip type. For example, work-to-home origins from workplaces are paired with work-to-home destinations at residences.

10.1 GRAVITY MODEL

The trip distribution within a trip type is done initially 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. We have chosen to use 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. This function is applied separately for each of the trip purposes.

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:	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*

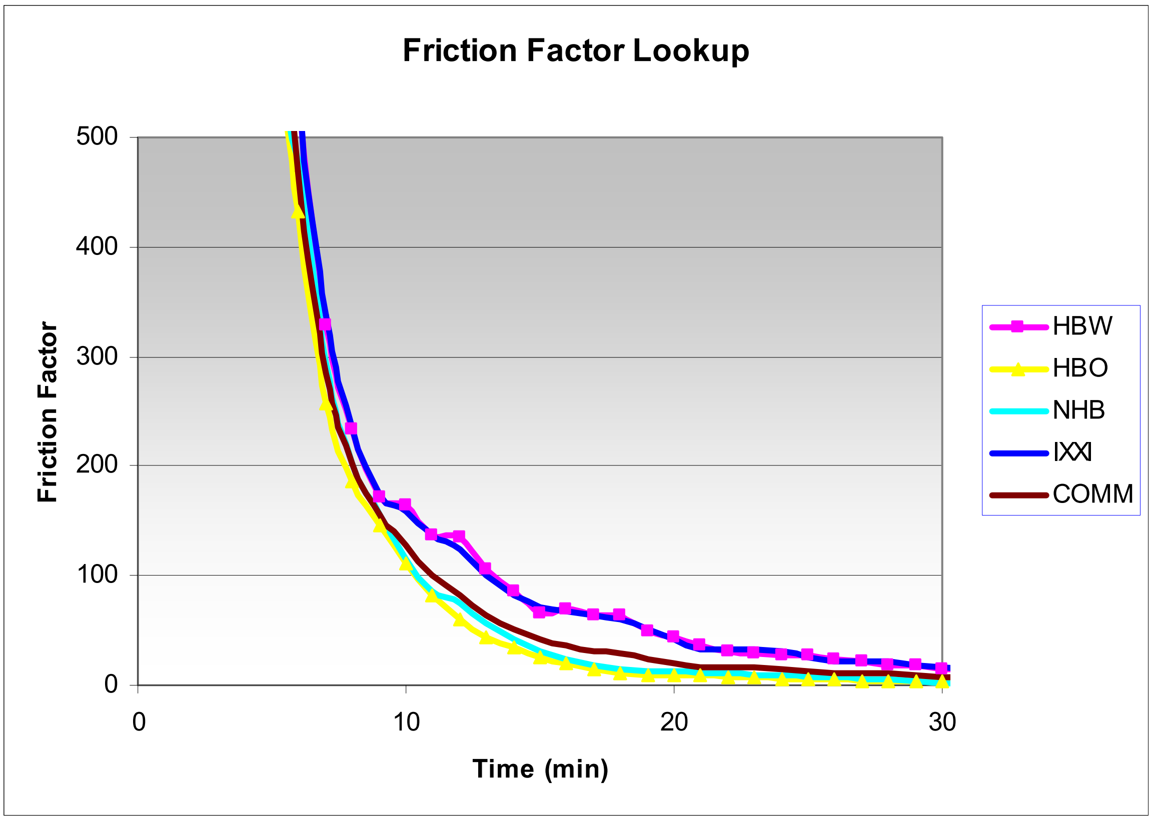
The inputs to trip distribution include the productions and attractions from trip generation and an impedance matrix. The impedance matrix includes auto travel times between zones, intrazonal times, and terminal times.

10.2 DATA SOURCES AND PARAMETER ESTIMATION

A TP+ script has been written that iteratively adjusts gravity model friction factors until an observed trip length distribution is matched by the model. The inputs to the calibration script are trip length distributions (by trip purpose) and modeled skims. 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.

Figure 10: Friction Factors by Trip Purpose



10.4 IX-XI DISTRIBUTION

XI trips are distributed by travel time from the external station, with the internal attractions weighted by the zonal employment. IX trips are distributed by travel time, but internal trip-ends are approximated by zonal population. IXXI friction factors are essentially identical to HBW friction factors.

10.3 ASSERTED TRIP TABLES

Many transit and roadway projects currently under review would serve major generators that have a distribution pattern that a gravity model would not adequately estimate on its own. The major universities in the region, the Salt lake International Airport, Lagoon Amusement Park, and Cabella's are all examples of destinations with obviously unique trip distribution patterns.

- **Colleges**: Home addresses of college students were obtained from each major college, which allowed creation of a distribution pattern for that college.

- **Airport**: An airport survey was also available that allowed distribution of airport patrons across the region, where the gravity model had previously allocated trips almost exclusively to neighborhoods nearest the airport.
- **Lagoon**: The Lagoon amusement park is another isolated zone for which total trips were available. The HBO purpose to Lagoon had an average trip length of slightly more than 10 minutes. This was thought unreasonable since this is the only major amusement park in Utah. HBO trips were thus extended further to draw from the whole region, but with emphasis on nearest zones.
- **Cabella's**: There has been some concern regarding the impacts of Cabella's being constructed in Lehi. It is said to be large enough and unique enough to draw trips from all over the region and even high numbers from outside the region. The regular gravity model will not model this well, considering it simply another retailer and sending trips to it primarily from within northern Utah County and southern SL County. To counteract this tendency, Cabella's trip generation and distribution is estimated in an off-model spreadsheet, and the resulting trip table is fed into the model.
- **External (XX) Trips**: The external through trips are estimated using a matrix balancing routine. The matrix balancing routine takes as input XX trip-ends by external station, as well as assumptions about the attractiveness between pairs of external stations and converges to a solution where the trip-ends are conserved.

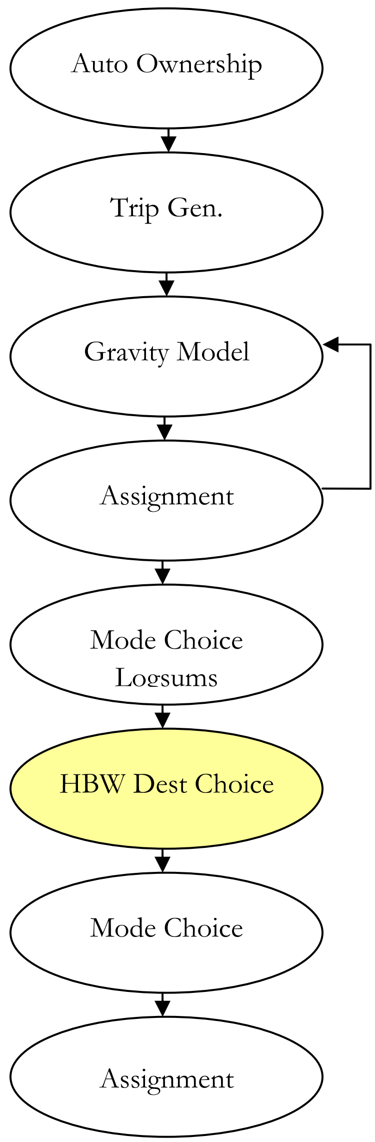
10.4 HBW DESTINATION CHOICE MODEL[1]

Destination choice models were estimated and implemented to model trip distribution for the Home Based Work (HBW) trip purpose. The destination choice model form has some advantages over the traditional gravity model. First, the destination choice models are disaggregate 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 measure of travel impedance. This makes the destination choice model consistent with and sensitive to all transportation modes in the mode choice model. 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 as such, 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 11.

[1] PB Consult estimated the HBW destination choice model and a more complete report documenting that work is available. The excerpts below are more-or-less taken directly from that report.

Figure 11: Model Flow Diagram with Destination Choice



10.4.1 Destination Choice Model Mathematics

Discrete choice models compute the probability of selecting an alternative amongst an enumerated list of all possible alternatives. Given a list of possible choices, a discrete choice model computes the probability of selecting each alternative. 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. 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 k, given production zone i,

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

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

The equation states that given 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 for a selecting 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, a Home Based Work 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.

10.4.2 Destination Choice Model Parameters

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 a 2002 universe. 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.

Table 14: HBW Destination Choice Model Estimation Results

	Run 63	
Measure	**Coeff**	**T-Stat**
Logsum - 0 Auto	0.311	5.530
Logsum - 1 Auto, Low Income	0.212	4.595
Logsum - 1 Auto, High Income	0.212	4.595
Logsum - 2 Auto, Low Income	0.399	6.003
Logsum - 2 Auto, High Income	0.428	7.195
Highway Distance	-0.089	-35.750
Retail Ratio - 0 Auto	0.458	2.330
Retail Ratio - 1 Auto, High Income	-0.524	-3.371
Retail Ratio - 2 Auto, High Income	-0.718	-8.856
Industrial Ratio - 1 Auto, Low Income	-1.269	-5.011
Industrial Ratio - 1 Auto, High Income	-0.921	-5.880
Industrial Ratio - 2 Auto, High Income	-0.459	-6.275
Likelihood with zero coefficients	-20816.857	
Likelihood with constants only	0.000	
Initial likelihood	-25595.798	
Final likelihood	-20106.188	
ρ^2 w.r.t. zero	0.034	
ρ^2 w.r.t. constants	0.000	

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.

11 NETWORK SKIMMING

11.1 AUTO PATHS

Auto skims are inputs to the trip distribution and mode choice models. The shortest auto paths are determined based on minimum travel time, and are computed separately for peak and off-peak conditions. The skimming process is relatively straight-forward, but there are a few wrinkles that are worth mentioning.

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).

When the toll modeling capability was implemented, it quickly became apparent that it was necessary to consider the reality that trip distribution patterns may be quite different whether a major facility had tolls or not. To account for this, separate skims are produced for toll paths and for non-toll paths, by time of day. The impedance in the gravity model trip distribution is then the geometric mean of the toll time and the non-toll time. The weights used during averaging are the toll and non-toll shares, which the user inputs from a previous model run. This formulation has the distinct advantage that toll skims and non-toll skims are explicitly represented, but in application it does require the user to have a reasonable estimate of toll and non-toll shares, so the process may be iterative.

11.1.2 Intrazonal Times

Even though the typical TAZ is not a perfect square, for the purposes of computing an approximate average internal distance we assume that the average internal distance is ½ of the square root of the TAZ area. Intra-zonal travel times are then 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 TRANSIT PATHS

Separate transit skims are developed for each linehaul mode in the transit network (i.e. local bus, BRT, express bus, light rail, and commuter rail), for each access mode (i.e. walk and drive to each of the linehaul modes). For these 10 access-to-linehaul modes, skims are developed for both a peak period and an off-peak period. The TRNBUILD path-builder in TP+ is used for transit skimming, relying on relative path weights to find the shortest time path for each mode (if a reasonable path exists).

11.2.1 Bus Speeds

Bus speeds are estimated inside the model, based on the auto speeds. In 2003 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 aren't 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 90% 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. In 2003 there was no BRT in operation and yet the model needs to estimate BRT speeds in an internally consistent manner. In general, the following logic was used to determine speed rules for BRT routes:

- BRTs would travel faster than local buses due to fewer stops, ITS enhancements, and possibly different vehicles
- BRTs would not travel faster than autos in mixed traffic
- If BRTs travel on exclusive right of way, this ROW should be coded explicitly on the network and the speed set accordingly
- There are potentially a range of services that might fall under the BRT label and any default assumption needs to be somewhat conservative but reasonably applicable on average

The speed rules for BRT operating in mixed traffic are:

- Freeways – BRTs travel at 95% of auto speeds
- Principal arterials – BRTs travel at 80% of auto speeds
- Minor arterials – BRTs travel at 80% of auto speeds
- Collectors – BRTs travel at 80% of auto speeds

11.2.2 Transit Path Finding Parameters

The following parameters and assumptions are used to define transit paths specific to each mode. These parameters 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.

Table 15: Miscellaneous Transit Path Building Parameters

Transfer Penalty	12 minutes
Walk Speed	2.5 MPH
Minimum Wait (local bus)	3 minutes
Initial Wait Time	Weighted by factor of 2
Transfer Weight Time	Weighted by factor of 3

Table 16: Transit Mode Hierarchy and Transfer Restrictions

		Mode Allowed?				
		Local Bus	**BRT**	**Express Bus**	**Light Rail**	**Commuter Rail**
PATH Type	**Local Bus**	**YES**	no	no	no	no
	BRT	**YES**	**YES**	no	no	no
	Express Bus	**YES**	**YES**	**YES**	**YES**	no
	Light Rail	**YES**	**YES**	no	**YES**	no
	Commuter Rail	**YES**	**YES**	no	**YES**	**YES**

Table 17: Weight Applied to Secondary Transit Modes

		Weight Applied to Other Modes				
		Local Bus	**BRT**	**Express Bus**	**Light Rail**	**Commuter Rail**
PATH Type	**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	**2**	**1**

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.

12 MODE CHOICE

In a conventional urban transportation modeling system, the mode choice model estimates the fraction of person-trips between each origin and destination that use public transit vs. auto.

We use a "post-distribution" mode choice modeling approach, meaning that mode choice will be estimated for each origin-destination pair after the trip distribution model is run. A nested multinomial logit-form 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 logit model is shown in Equation 6.

Equation 6: Simplified Mode Choice Model Functional Form

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

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

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

The "utility functions" (Vs) in this equation can contain mode-specific travel time, cost and access variables as well as traveler-specific variables, each 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 substantially 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.

The nesting structure and model parameters are shown below. 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.

Table 18: Mode Choice Model Nesting Structure

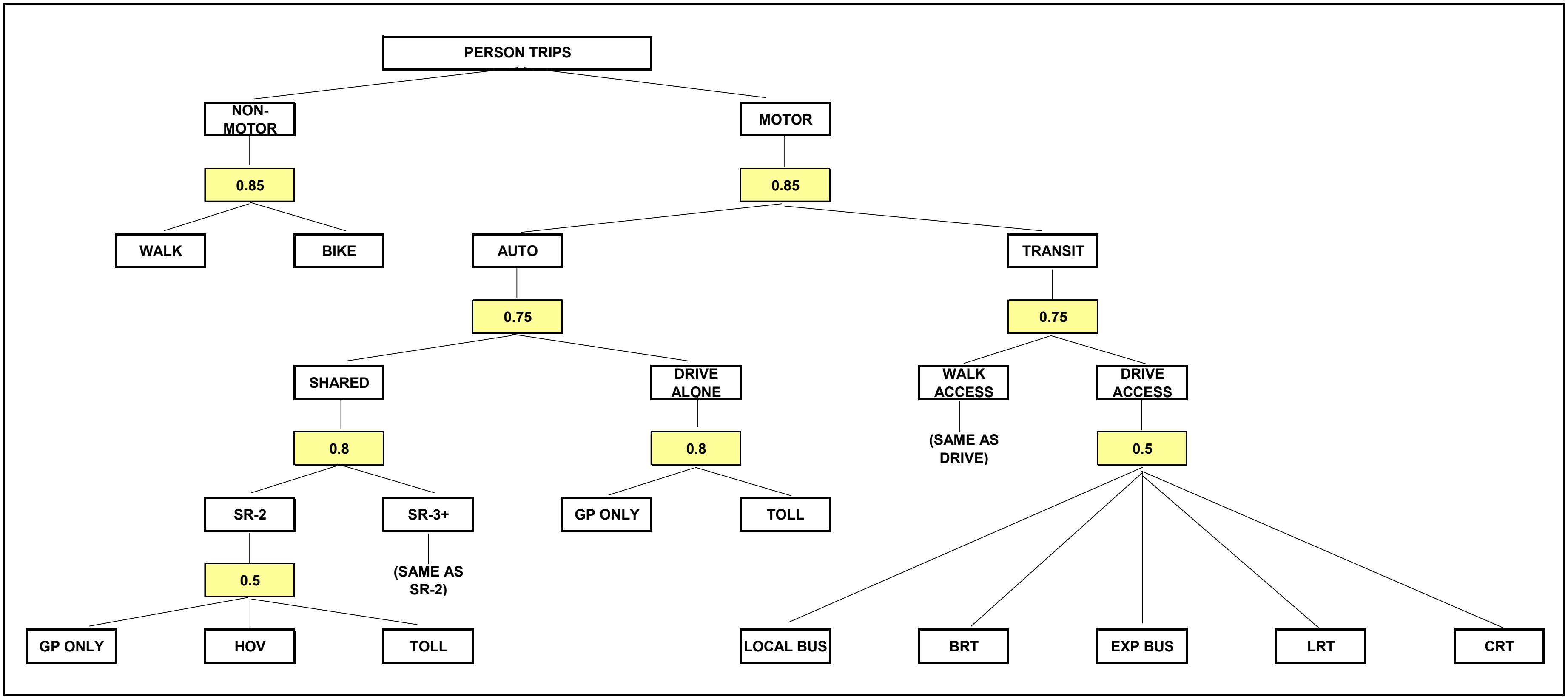


Table 19: Mode Choice Model Coefficients

	HBW	HBO	NHB	HBC	
ivt	-0.0221	-0.0160	-0.0233	-0.0221	IN-VEHICLE TIME
initwait	-0.0427	-0.0320	-0.0442	-0.0427	FIRST TRANSIT WAIT TIME
xferwait	-0.0500	-0.0480	-0.0663	-0.0500	TRANSIT TRANSFER WAIT TIME
walk_1	-0.0462	-0.0320	-0.0425	-0.0462	FIRST MILE OF WALK/OUT-OF-VEHICLE TIME
walk_gt_1	-0.0850	-0.0480	-0.0425	-0.0850	OVER 1 MILE WALK/OUT-OF-VEHICLE TIME
drive	-0.0541	-0.0320	-0.0583	-0.0541	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	-0.0099	-0.0120	-0.0025	-0.0030	TOLL COST (LOW INCOME - IF APPLICABLE)
tollcost_highinc	-0.0012	-0.0040			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	0.3300	0.2400	0.3500	0.3300	WALK DIRECTLY TO EXPRESS DUMMY
rail direct walk	0.3300	0.2400	0.3500	0.3300	WALK DIRECTLY TO RAIL DUMMY
drive_time_to_ivt	0	0	0	0	DRIVE TO TRANSIT ACCESS TIME DIVIDED BY IVT
drive_dist_to_xy	0	0	0	0	DRIVE TO TRANSIT ACCESS DISTANCE DIVIDED BY XY
transfers - walk	-0.332	-0.320	-0.200	-0.221	TRANSIT TRANSFERS - WALK ACCESS TRIPS
transfers - drive	-0.221	-0.320	-0.200	-0.221	TRANSIT TRANSFERS - DRIVE ACCESS TRIPS
1/distance on rail - walk	-1	-1	-1	-0.5	WALK-RAIL DISTANCE COEFFICIENT TO MATCH TLF
1/distance on rail - drive	-4	-4	-4	-4	DRIVE-RAIL DISTANCE COEFFICIENT TO MATCH TLF
CBD_dummy_transit	0.2210	0.3200	0.2330	0	TRANSIT BIAS - CBD DUMMY
CBD_dummy_walk			0.4901	0	WALK BIAS - CBD DUMMY
zonal_urbanization	0.0030	0.0020	0	0	TRANSIT BIAS - ZONAL URBANIZATION DENSITY MEASURE (ATTRACTION ZONE)

ALL COEFFICIENTS ARE SHOWN AT THE MULTINOMIAL LEVEL.

Table 20: HBW Mode Choice Model Calibrated Constants

	HBW PEAK		
	0 CAR	**1 CAR**	**2 CAR**
DRIVE ALONE (GP)	0	0	0
DRIVE ALONE (TOLL)	0.11	0.11	0.11
SHARED RIDE 2 (GP)	-1.08	-1.08	-1.08
SHARED RIDE 2 (HOV)	-1.02	-1.02	-1.02
SHARED RIDE 2 (TOLL)	-0.97	-0.97	-0.97
SHARED RIDE 3 (GP)	-1.70	-1.70	-1.70
SHARED RIDE 3 (HOV)	-1.64	-1.64	-1.64
SHARED RIDE 3 (TOLL)	-1.59	-1.59	-1.59
WALK-LOCAL	0.96	-0.38	-1.28
WALK-LOCAL-EXPRESS*	0.96	-0.38	-1.28
WALK-EXPRESS	1.29	-0.05	-0.95
WALK-LOCAL-RAIL*	1.61	0.28	-0.63
WALK-RAIL	1.94	0.61	-0.30
DRIVE-LOCAL	n/a	-1.59	-1.90
DRIVE-EXPRESS	n/a	-1.59	-1.90
DRIVE-RAIL	n/a	-0.45	-0.76
WALK	-1.58	-0.68	-1.58
BIKE	-3.78	-2.88	-3.78

	HBW OFF-PEAK		
	0 CAR	**1 CAR**	**2 CAR**
DRIVE ALONE (GP)	0	0	0
DRIVE ALONE (TOLL)	0.00	0.00	0.00
SHARED RIDE 2 (GP)	-1.25	-1.25	-1.25
SHARED RIDE 2 (HOV)	-1.31	-1.31	-1.31
SHARED RIDE 2 (TOLL)	-1.25	-1.25	-1.25
SHARED RIDE 3 (GP)	-1.72	-1.72	-1.72
SHARED RIDE 3 (HOV)	-1.78	-1.78	-1.78
SHARED RIDE 3 (TOLL)	-1.72	-1.72	-1.72
WALK-LOCAL	3.61	-0.10	-1.30
WALK-LOCAL-EXPRESS*	3.61	-0.10	-1.30
WALK-EXPRESS	3.94	0.23	-0.97
WALK-LOCAL-RAIL*	4.03	0.32	-0.88
WALK-RAIL	4.36	0.65	-0.55
DRIVE-LOCAL	n/a	-2.00	-2.48
DRIVE-EXPRESS	n/a	-2.00	-2.48
DRIVE-RAIL	n/a	-0.86	-1.34
WALK	0.50	-0.43	-1.15
BIKE	-2.87	-3.81	-4.53

*** A Transfer penalty also applies, which is not shown here.**

Table 21: HBO Mode Choice Model Calibrated Constants

	HBO PEAK		
	0 CAR	1 CAR	2 CAR
DRIVE ALONE (GP)	0	0	0
DRIVE ALONE (TOLL)	0.03	0.03	0.03
SHARED RIDE 2 (GP)	-0.01	-0.01	-0.01
SHARED RIDE 2 (HOV)	-0.31	-0.31	-0.31
SHARED RIDE 2 (TOLL)	0.02	0.02	0.02
SHARED RIDE 3 (GP)	0.03	0.03	0.03
SHARED RIDE 3 (HOV)	-0.27	-0.27	-0.27
SHARED RIDE 3 (TOLL)	0.06	0.06	0.06
WALK-LOCAL	-0.10	-1.62	-2.69
WALK-LOCAL-EXPRESS*	-0.10	-1.62	-2.69
WALK-EXPRESS	0.01	-1.51	-2.58
WALK-LOCAL-RAIL*	0.49	-1.03	-2.10
WALK-RAIL	0.60	-0.92	-1.99
DRIVE-LOCAL	n/a	-3.67	-4.35
DRIVE-EXPRESS	n/a	-3.67	-4.35
DRIVE-RAIL	n/a	-1.86	-2.54
WALK	0.51	0.53	0.34
BIKE	-2.05	-2.04	-2.22

	HBO OFF-PEAK		
	0 CAR	1 CAR	2 CAR
DRIVE ALONE (GP)	0	0	0
DRIVE ALONE (TOLL)	0.00	0.00	0.00
SHARED RIDE 2 (GP)	-0.07	-0.07	-0.07
SHARED RIDE 2 (HOV)	-0.27	-0.27	-0.27
SHARED RIDE 2 (TOLL)	-0.07	-0.07	-0.07
SHARED RIDE 3 (GP)	-0.10	-0.10	-0.10
SHARED RIDE 3 (HOV)	-0.30	-0.30	-0.30
SHARED RIDE 3 (TOLL)	-0.10	-0.10	-0.10
WALK-LOCAL	0.32	-1.62	-2.54
WALK-LOCAL-EXPRESS*	0.32	-1.62	-2.54
WALK-EXPRESS	0.43	-1.51	-2.43
WALK-LOCAL-RAIL*	1.08	-0.86	-1.78
WALK-RAIL	1.19	-0.75	-1.67
DRIVE-LOCAL	n/a	-3.97	-4.57
DRIVE-EXPRESS	n/a	-3.97	-4.57
DRIVE-RAIL	n/a	-1.09	-1.70
WALK	-0.40	-0.47	-0.68
BIKE	-2.95	-3.03	-3.24

*** A Transfer penalty also applies, which is not shown here.**

Table 22: NHB Mode Choice Model Calibrated Constants

	NHB	
	PEAK	OFF_PEAK
DRIVE ALONE (GP)	0	0
DRIVE ALONE (TOLL)	0.12	0.00
SHARED RIDE 2 (GP)	-0.34	-0.22
SHARED RIDE 2 (HOV)	-0.69	-0.57
SHARED RIDE 2 (TOLL)	-0.22	-0.22
SHARED RIDE 3 (GP)	-0.42	-0.36
SHARED RIDE 3 (HOV)	-0.77	-0.71
SHARED RIDE 3 (TOLL)	-0.30	-0.36
WALK-LOCAL	-2.39	-2.09
WALK-LOCAL-EXPRESS*	-2.39	-2.09
WALK-EXPRESS	-1.92	-1.62
WALK-LOCAL-RAIL*	-1.87	-1.93
WALK-RAIL	-1.40	-1.46
DRIVE-LOCAL	-3.30	-3.25
DRIVE-EXPRESS	-3.30	-3.25
DRIVE-RAIL	-2.29	-2.52
WALK	-1.51	-1.22
BIKE	-4.05	-4.39

*** A Transfer penalty also applies, which is not shown here.**

Table 23: HBC Mode Choice Model Calibrated Constants

	HBC
	DAILY
DRIVE ALONE (GP)	0
DRIVE ALONE (TOLL)	0.11
SHARED RIDE 2 (GP)	-0.60
SHARED RIDE 2 (HOV)	-0.85
SHARED RIDE 2 (TOLL)	-0.49
SHARED RIDE 3 (GP)	-1.08
SHARED RIDE 3 (HOV)	-1.33
SHARED RIDE 3 (TOLL)	-0.97
WALK-LOCAL	-0.63
WALK-LOCAL-EXPRESS*	-0.63
WALK-EXPRESS	-0.38
WALK-LOCAL-RAIL*	-0.37
WALK-RAIL	-0.12
DRIVE-LOCAL	-1.67
DRIVE-EXPRESS	-1.67
DRIVE-RAIL	-0.23
WALK	0.39
BIKE	-3.29

*** A Transfer penalty also applies, which is not shown here.**

13 MANAGED LANES FORECASTING

WFRC's and MAG's regional travel demand models are designed to analyze High-Occupancy Vehicle (HOV), High-Occupancy Toll (HOT), and dedicated toll-way demand in the Wasatch Front region. The model system was enhanced to allow explicit representation of HOV and toll trips. 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 structure allows the mode choice model to explicitly trade-off the time and costs associated with each of the highway paths (HOV versus toll versus general purpose lane travel). The model is segmented by household income, reflecting different cost sensitivities by income group, time period (peak versus off-peak), and by trip purpose, reflecting that travelers tend to have a higher value of time when making work trips than trips for other purposes. The model captures trade-offs between highway and transit modes, while recognizing higher bus operating speeds due to the availability of HOV lanes. Trips for each mode are assigned to a network representation and analyzed to determine facility operating characteristics (volume, volume/capacity ratio, congested speed).

The model is flexible enough to test a fairly broad range of policies, including HOV lanes, HOT lanes (where HOVs pay no toll or a smaller toll), and tollway lanes (where every user pays). The model can analyze a distance-based toll policy, and the toll rate can vary by time period. Daily toll revenue can be estimated by analyzing toll demand and average toll paid on each facility by time period. Different toll rates can be applied to HOT lanes or tollway lanes, but all HOT lanes must have the same toll rate, and all tollway lanes must have the same toll rate. HOV users of HOT lanes can be charged a lower toll, or zero toll.

The new managed lane alternatives are nested under the drive-alone, shared-ride 2 and shared-ride 3+ auto alternatives. The new alternatives are:

- Drive-Alone Non-Toll
- Drive-Alone Toll
- Shared Ride 2, Non-Toll, Non-HOV (general purpose only)
- Shared Ride 2, Non-Toll, HOV
- Shared-Ride 2, Toll
- Shared Ride 3+, Non-Toll, Non-HOV (general purpose only)
- Shared Ride 3+, Non-Toll, HOV
- Shared-Ride 3+, Toll

This structure allows the mode choice model to explicitly trade-off the time and costs associated with each of the highway paths. The model is segmented by household income; thus, low-income travelers are more sensitive to cost, while high-income travelers are less sensitive to cost and therefore more willing to pay to use toll facilities. The model estimates the number of trips that can use each mode. Each mode's trips are then assigned to the highway network, with the appropriate highway links available (for example, drive-alone non-toll trips are prohibited from using toll lanes).

The peak period auto utility equations rely on the AM travel time differences to determine relative mode shares. While the decision to use a managed lane can certainly vary by time period (i.e. one could easily use a toll lane in one period and not another), it is assumed that relying on AM travel time differences to forecast demand for both peak periods will result in a conservative toll forecast, which is critical for reliable toll feasibility studies. It is reasonable to assume, however, that the PM peak managed lane demand will be higher than the AM peak demand, due to increased congestion. To account for this explicitly for work trips, the diurnal distribution of HBW managed lane trips assumes that 40% of the total peak HBW managed lane trips are in the AM peak and 60% are in the PM peak.

The mode choice model contains a function that discourages short managed lane trips. This disutility function is applied to all trips that utilize the managed lane for less than 2 miles, effectively lowering the managed lane share to reflect the reality that merging into an HOV lane or paying a toll is inconvenient for a short trip. The model also includes a toll bias constant for the peak period that slightly increases the toll share, all else equal due to increased reliability. This toll bias increases with increasing time savings, providing a higher bias as time savings increases, up to a maximum benefit of 5 minutes of in-vehicle time for HBW/NHB/HBC trips and 2.5 minutes for HBO trips.

To build managed lane paths for mode choice model skims, the managed lane speeds are assumed to be 68 mph. This assumption implies an operating policy whereby the operator will assure this operating speed. It is important to keep this assumption in mind when looking at loaded assignment networks. If the loaded network has significant congestion on the managed lane then the 68 mph assumption is not reasonable and the toll rate must be increased or the mode choice model managed lane speeds decreased.

Toll paths are built by minimizing a function of time and cost. Toll cost is converted to time assuming a $30 value of time. This value of time was chosen via a series of sensitivity tests and reviewing paths and is intentionally higher than a reasonable average value of time because the intention is to only exclude completely illogical toll paths.

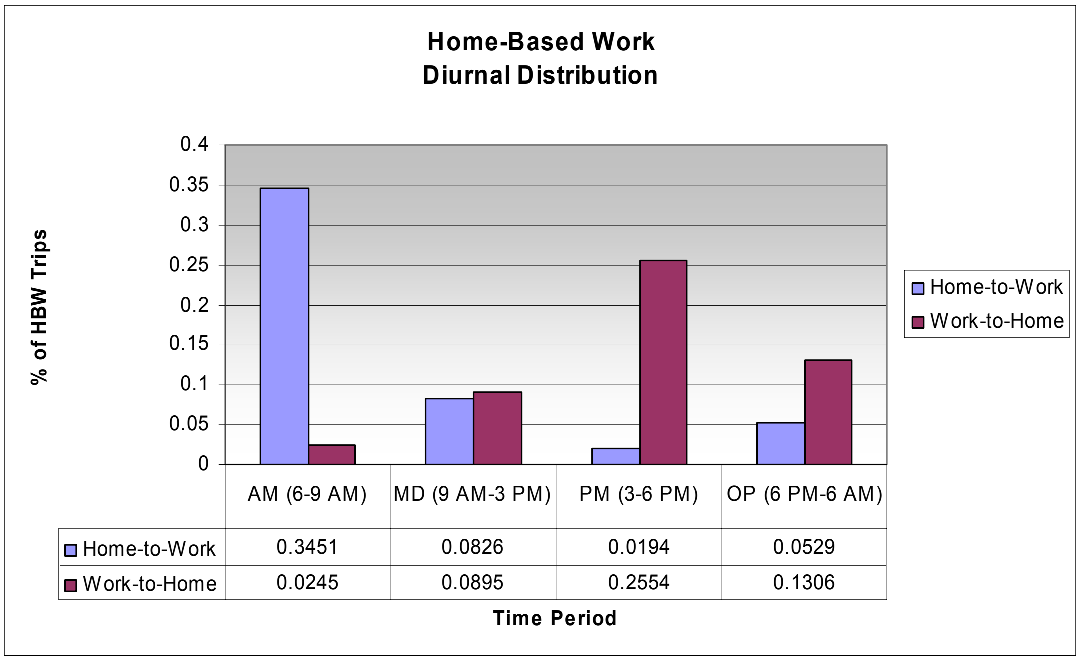
The managed lane model enhancements have not been extensively calibrated to existing data in the WFRC/MAG region, due to no toll facilities existing in the region and limited data from the existing HOV lanes.

14 TIME OF DAY DISTRIBUTION

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 4 time periods (AM peak, Mid-day, PM peak and night/off-peak).

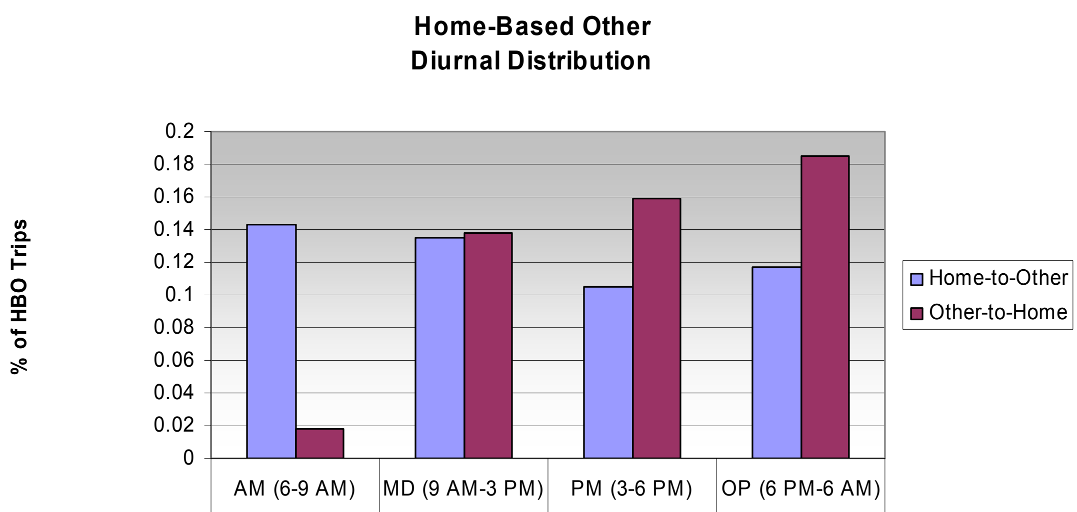
The estimate of trips by time of day comes from the 1993 home interview survey and is presented below for the 3 primary trip purposes. For home-based trips, the diurnal distribution is unique by direction (e.g. home-to-work vs. work-to-home), but for NHB trips the directionality of the trip matrix does not vary by time of day.

Figure 12: HBW Diurnal Distribution



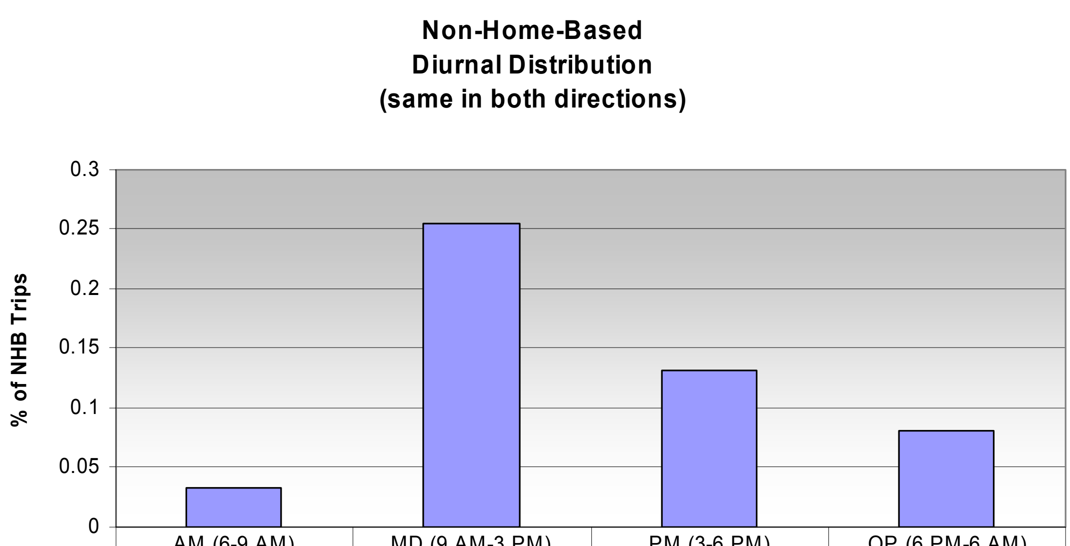
	AM (6-9 AM)	MD (9 AM-3 PM)	PM (3-6 PM)	OP (6 PM-6 AM)
Home-to-Work	0.3451	0.0826	0.0194	0.0529
Work-to-Home	0.0245	0.0895	0.2554	0.1306

Figure 13: HBO Diurnal Distribution



	AM (6-9 AM)	MD (9 AM-3 PM)	PM (3-6 PM)	OP (6 PM-6 AM)
Home-to-Other	0.1432	0.1349	0.1047	0.1172
Other-to-Home	0.0177	0.1384	0.1591	0.1848

Figure 14: NHB Diurnal Distribution



	AM (6-9 AM)	MD (9 AM-3 PM)	PM (3-6 PM)	OP (6 PM-6 AM)
NHB	0.0331	0.2543	0.1316	0.081

15 TRAFFIC ASSIGNMENT

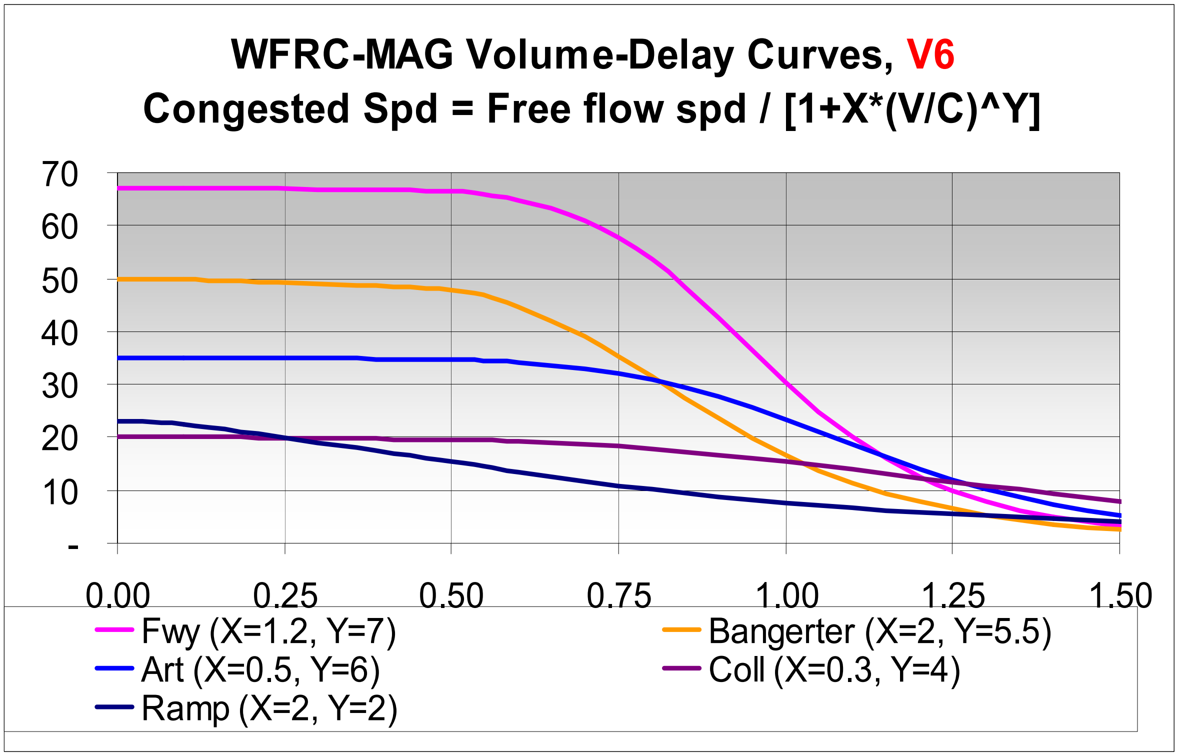
The purpose of the assignment model is to locate a specific route along links and through intersections for every vehicle trip. The vehicle trips calculated in the mode split model, which are in the form of an origin/destination matrix, are "assigned" to the network based on a user equilibrium model. The trip table is input to a user equilibrium model, which uses an iterative process to achieve a convergent solution in which no travelers can improve their travel times by switching to another route.

In order to develop and calibrate the model, a network including roadway (link) characteristics must be constructed. Once the network is complete, the model must be calibrated. The assignment calibration is assessed based on how accurately the model output link volumes match observed traffic counts.

In order to accommodate managed lanes forecasting capabilities and to utilize different cost functions for long trips versus short trips, 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. In addition, long and short vehicle trips are assigned to shortest paths using different cost functions. Short trips, currently specified as trips <10 miles, are assigned based on a function of time and distance, with the thinking being that the both time and distance are important when time savings are minimal. For trips over 10 miles, the shortest time path is used, so distance is not a factor.

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 (20 in the AM, 10 in the Midday, 30 in the PM and 10 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 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 significant. The current default max iterations are large enough that previous convergence criteria will be satisfied, but run-time will increase.

Figure 15: Volume-Delay Functions



16 MODEL CALIBRATION AND VALIDATION

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

16.1 TRAFFIC ASSIGNMENT CALIBRATION

The traffic assignment model is considered calibrated when the modeled traffic volumes and the modeled traffic speeds are consistent with base year observed traffic count and speed data. The Federal Highway Administration (FHWA) has developed guidelines for traffic volume calibration standards.[1] An additional validation check is to compare the vehicle miles traveled (VMT) estimated by the WFRC/MAG model to the VMT estimated using traffic counts collected for highway performance monitoring (HPMS).

16.1.1 Modeled Traffic Volumes compared to Traffic Counts

The following sections detail the calculation of the various statistics used to measure roadway link-level calibration. Individual link errors were calculated by subtracting the simulation volume from the ground count for that link.

Coefficient of Correlation

The coefficient of correlation, "r", is commonly used to measure the strength and direction between two sets of 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 correlation, and an r value of -1 would indicate a perfect inverse correlation. The value of r can be estimated using the following formula.

Equation 7: Coefficient of Correlation

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

FHWA recommends a minimum r value of 0.88, which corresponds to an r-squared value of .77 (correlation of .88).

Root Mean Squared Error

The root mean squared error (RMSE) is an average link error that weights the larger volume errors in a network. It should be noted that the RMSE is always higher than the actual average network error because of the weighting scheme. This is discussed in the following section on absolute error. RMSE is calculated as:

---

[1]Ismart, Dane. Calibration and Adjustment of System Planning Models. U.S. Department of Transportation, Federal Highway Administration Publication FHWA-ED-90-015. Washington, DC, December 1990.

Equation 8: Percent Root Mean Squared Error

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

where:

x = Ground count
y = Calibration volume
n = Number of observations

The RMSE is used to calculate the effectiveness of individual link and node modifications, as well as general changes in trip generation and distribution and assignment parameters. RMSE should generally be less than 40%.

Absolute Error

The absolute error is the absolute value of the average, unweighted error. It reflects the average link error in the network and is reflected in the following formula:

Equation 9: Absolute Error

$$\text{Absolute Error} = \frac{\sum|y-x|}{\sum x} \times 100\%$$

Sum of Differences

The sum of differences is the average error of the network. It is similar to FHWA's "percent error region-wide standard"[1]

Equation 10: Sum of Differences (or % Difference)

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

1 "Calibration and Adjustment of System Planning Models", December 1990, FHWA ED 90-015, page 35.

A comparison between the FHWA guidelines and the calibrated model is shown in Table 24. All measures of vehicle assignment performance exceed guidelines published by the FHWA.

Table 24: FHWA Guidelines for Vehicle Assignment Calibration

	FHWA Guideline	Model
Correlation Coefficient	0.88	0.92
Percent Error Region-Wide	5%	-1.7%
Sum of Differences By Functional Class		
Freeways	7%	2.2%
Principal Arterials	10%	3.8%
Minor Arterials	15%	-5.9%
Collectors	25%	-17.1%

Figure 16: Modeled Volumes vs. Observed Counts (AWDT 2-way)

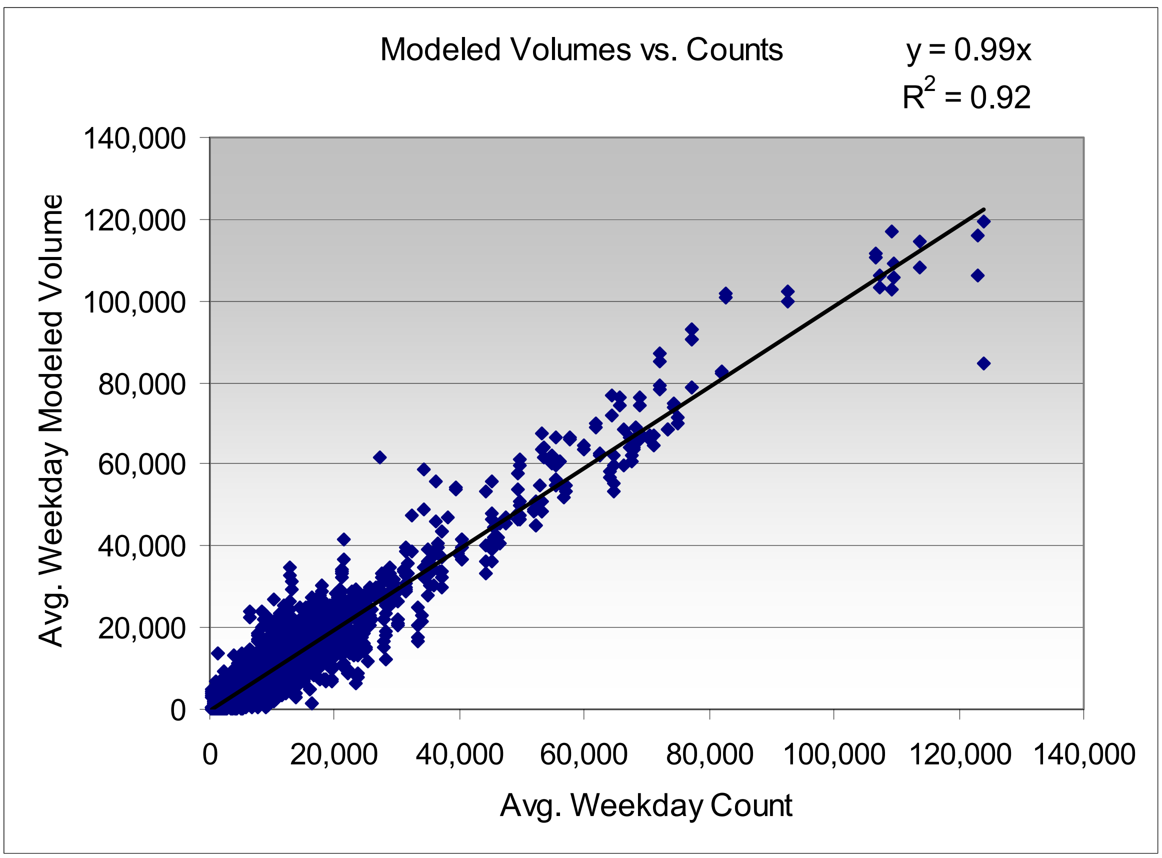


Table 25: Assignment Link-level Calibration Statistics (Region-wide)

		Entire Region
All Facility Types		
Total UDOT Counts	=	21,892,056
Total Estimated Volume	=	21,519,184
Total Difference (Est-Obs)	=	-372,872
Total Number of Segments	=	1,591
%RMSE	=	31.6
%Error (E-O/O)	=	-1.7
Freeways Only		
Total UDOT Counts	=	9,522,420
Total Estimated Volume	=	9,729,369
Total Difference (Est-Obs)	=	206,949
Total Number of Freeway Segments	=	195
%RMSE	=	16.3
%Error (E-O/O)	=	2.2
Collectors & Rural Highways		
Total UDOT Counts	=	2,420,002
Total Estimated Volume	=	2,006,294
Total Difference (Est-Obs)	=	-413,708
Total Number of Freeway Segments	=	557
%RMSE	=	55.7
%Error (E-O/O)	=	-17.1
Minor Arterials & Multi-Lane Highway		
Total UDOT Counts	=	5,429,197
Total Estimated Volume	=	5,107,899
Total Difference (Est-Obs)	=	-321,298
Total Number of M. Arterial Segments	=	567
%RMSE	=	41.1
%Error (E-O/O)	=	-5.9
Pr. Arterials		
Total UDOT Counts	=	4,528,274
Total Estimated Volume	=	4,699,763
Total Difference (Est-Obs)	=	171,489
Total Number of P.Arterial Segments	=	274
%RMSE	=	28.8
%Error (E-O/O)	=	3.8

Table 26: Assignment Link-level Calibration Statistics (by County)

	Weber County	Davis County	Salt Lake County	Utah County
All Facility Types				
Total UDOT Counts	2,247,764	3,216,401	13,004,315	3,423,576
Total Estimated Volume	2,153,846	3,022,108	13,137,589	3,205,642
Total Difference (Est-Obs	-93,918	-194,293	133,274	-217,934
Total Number of Segments	215	210	818	348
%RMSE	34	20	33	30
%Error (E-O/O)	-4	-6	1	-6
Freeways Only				
Total UDOT Counts	689,664	1,859,525	5,946,764	1,026,467
Total Estimated Volume	623,215	1,814,302	6,311,731	980,121
Total Difference (Est-Obs)	-66,449	-45,223	364,967	-46,346
Total Number of Freeway Segments	22	33	118	22
%RMSE	13	6	19	8
%Error (E-O/O)	-10	-2	6	-5
Collectors & Rural Highways				
Total UDOT Counts	260,912	244,005	1,374,510	540,575
Total Estimated Volume	213,155	173,108	1,153,289	466,742
Total Difference (Est-Obs)	-47,757	-70,897	-221,221	-73,833
Total Number of Freeway Segments	73	60	271	153
%RMSE	58	49	53	62
%Error (E-O/O)	-18	-29	-16	-14
Minor Arterials & Multi-Lane Highway				
Total UDOT Counts	647,081	816,723	3,194,977	770,416
Total Estimated Volume	581,586	738,785	3,071,475	716,054
Total Difference (Est-Obs)	-65,495	-77,938	-123,502	-54,362
Total Number of M. Arterial Segments	76	100	285	106
%RMSE	43	41	40	41
%Error (E-O/O)	-10	-10	-4	-7
Pr. Arterials				
Total UDOT Counts	650,107	301,755	2,488,064	1,088,348
Total Estimated Volume	735,890	299,298	2,608,822	1,055,753
Total Difference (Est-Obs)	85,783	-2,457	120,758	-32,595
Total Number of P.Arterial Segments	44	18	144	68
%RMSE	33	20	30	25
%Error (E-O/O)	13	-1	5	-3

16.1.2 Modeled Traffic Speeds compared to Observed Speeds

WFRC and UDOT have been collecting speed data since 2000 and these speed data have been invaluable in calibrating the traffic assignment model to both replicate observed traffic counts and traffic speeds. A model that replicates observed speeds will also do a good job estimating *both* trip length distributions and trip time distributions.

The following comparison is of modeled AM travel speeds compared to observed speeds for the AM time period, collected on a large sample of roadways (by direction).

Table 27: AM Peak Period Speed Comparison (WFRC model area only)

Facility Type	Area Type	Observed Speed	Model Speed	Segments
Freeways	Fringe	72	71	23
	Suburban	63	59	159
	Urban	60	59	106
Pr. Arterials	Fringe	39	41	38
	Suburban	35	35	160
	Urban	29	28	64
	CBD	28	24	43
M. Arterials	Fringe	39	39	64
	Suburban	32	32	290
	Urban	30	28	168
	CBD	26	25	98
Collectors	Fringe	32	34	19
	Suburban	30	30	112
	Urban	28	26	122
	CBD	22	21	44
Multi-Lane Hwys	All areas	45	40	83

16.1.3 Modeled VMT compared to HPMS VMT

Another overall indicator of the general reasonableness of the traffic assignment model is to compare modeled VMT to the VMT estimated by the HPMS traffic monitoring data. In general, since HPMS VMT is estimated from traffic counts, the comparison of VMT is similar to the traffic count comparisons above.

Table 28: Modeled vs. HPMS Weekday VMT Estimates by County and Facility Type

County		Fwy VMT	Art VMT	Fwy+Art	Local VMT
Weber	Modeled:	992,000	2,429,000	3,421,000	327,000
	UDOT:	1,070,000	2,582,000	3,652,000	880,000
	% Diff:	-7.3	-5.9	-6.3	-62.9
Davis	Modeled:	3,258,000	2,181,000	5,439,000	469,000
	UDOT:	3,369,000	2,271,000	5,640,000	1,287,000
	% Diff:	-3.3	-3.9	-3.6	-63.5
Salt Lake	Modeled:	10,094,000	11,132,000	21,225,000	1,620,000
	UDOT:	9,282,000	11,163,000	20,446,000	3,926,000
	% Diff:	8.7	-0.3	3.8	-58.7
Utah	Modeled:	3,764,000	4,469,000	8,234,000	774,000
	UDOT:	3,887,000	4,632,000	8,519,000	2,089,000
	% Diff:	-3.1	-3.5	-3.4	-63.0
Whole Region	Modeled:	18,135,000	20,241,000	38,376,000	3,239,000
	UDOT:	17,608,000	20,649,000	38,257,000	8,183,000
	% Diff:	3.0	-2.0	0.3	-60.4

16.2 AUTO OWNERSHIP CALIBRATION

Below is a comparison of modeled vs. observed auto ownership at the Census tract geography. The auto ownership model coefficients were estimated from the home interview survey, while the validation was done against Census data. While there are not standards for acceptable validation of an auto ownership model, the correlation coefficients between the model and the observed data are quite good.

Figure 17: % of Households with 0 Vehicles (Model vs. '00 Census)

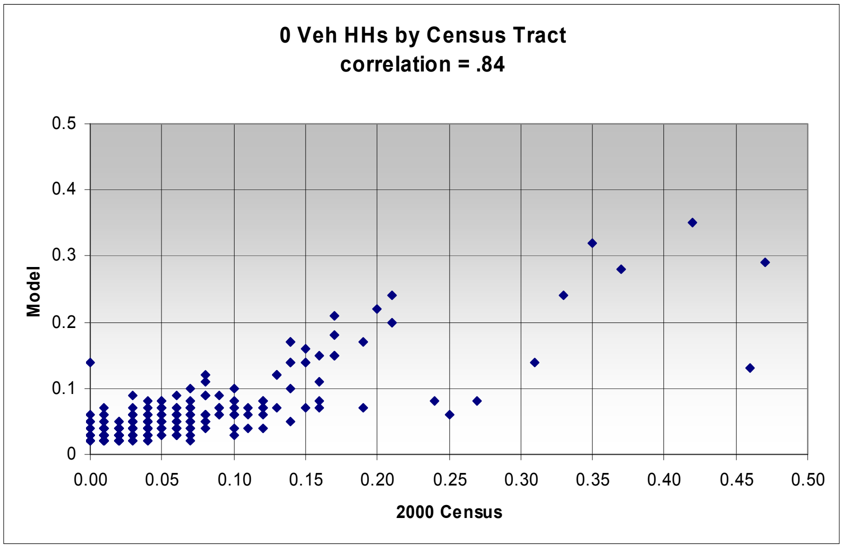


Figure 18: % of Households with 1 Vehicle (Model vs. '00 Census)

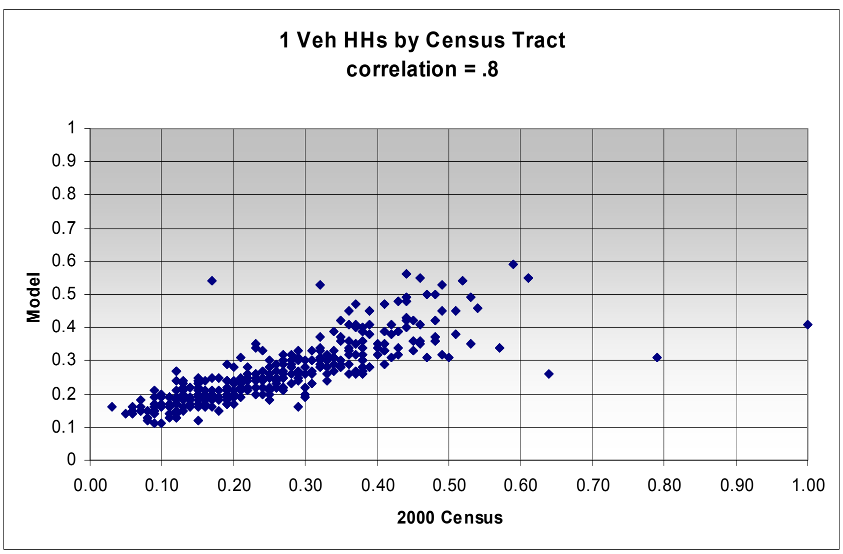
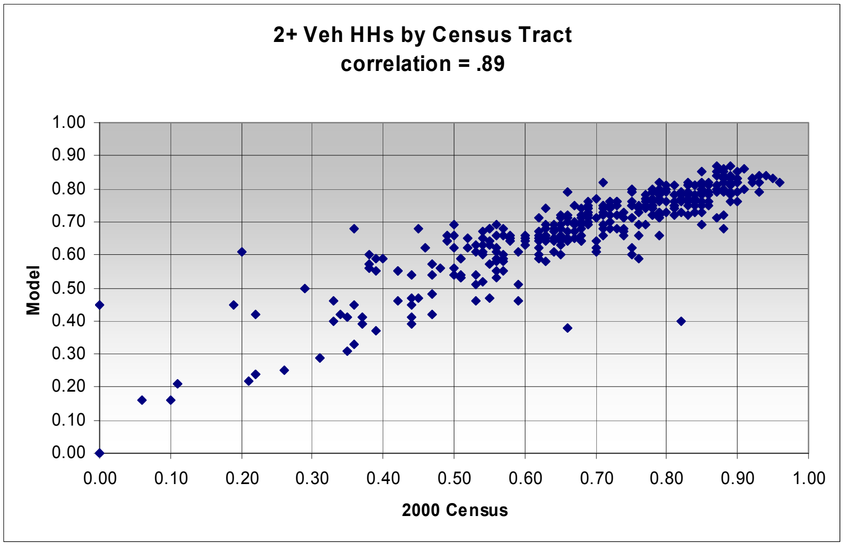


Figure 19: % of Households with 2+ Vehicles (Model vs. '00 Census)



16.3 TRIP DISTRIBUTION CALIBRATION

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 home interview survey, and then adjusted manually 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 home interview survey.

The NHTS data represent the smallest sample, but also the most current sample (2001). In general, the trip length frequency comparison is acceptable when the model trends generally similarly to each of the observed distributions. To reiterate, 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.

Figure 20: Home-based Work Trip Distance Comparison

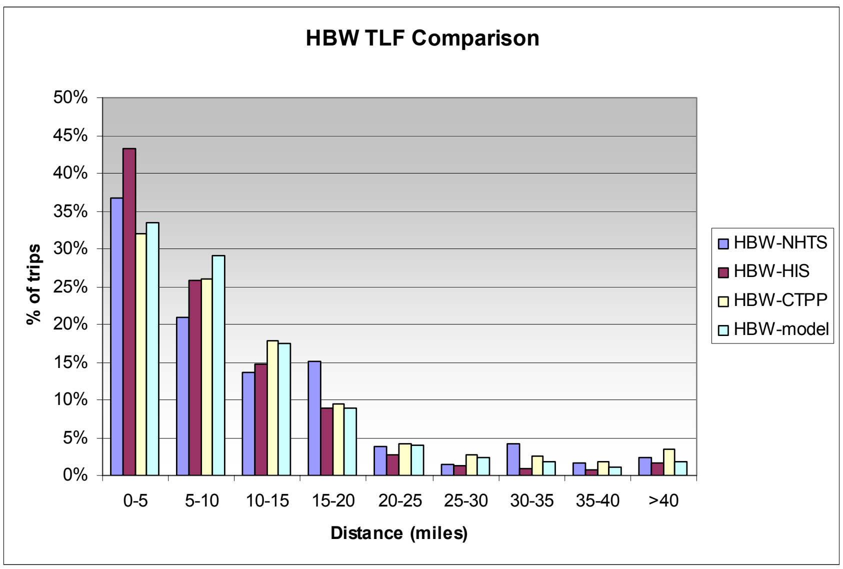


Figure 21: Home-based Other Trip Distance Comparison

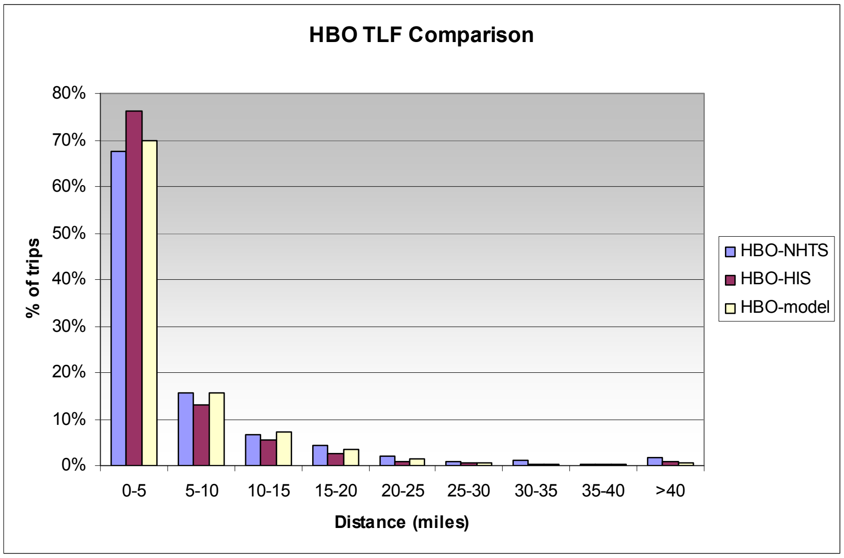
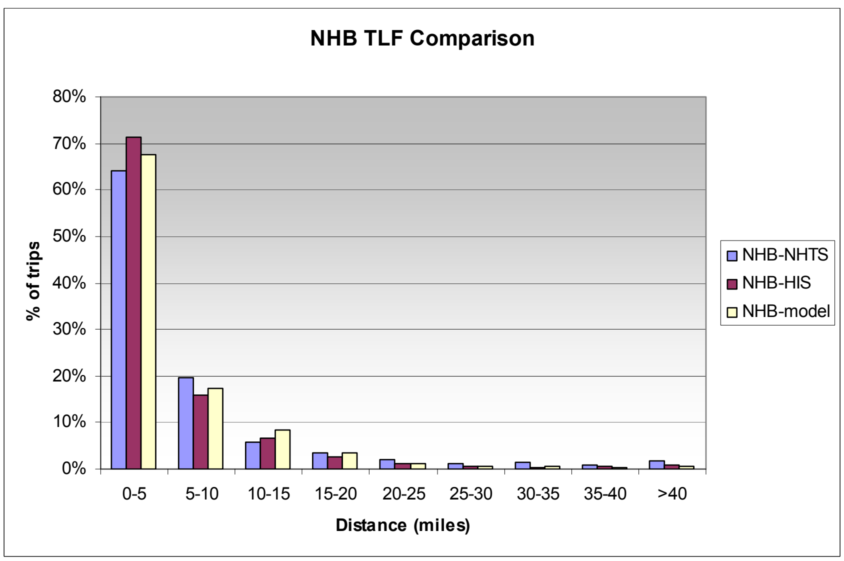


Figure 22: Non-home-based Trip Distance Comparison



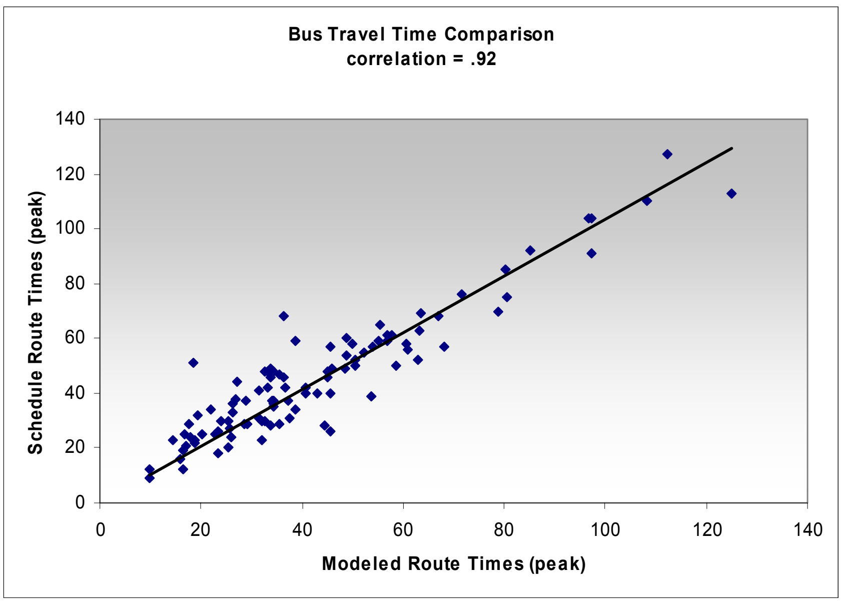
16.4 TRANSIT CALIBRATION

There are several ways to evaluate the reasonableness of the transit components in the regional model. Below are several different analyses comparing different aspects of the model to observed data.

16.4.1 Bus Speeds

The modeled bus speeds are a function of the congested auto speeds, assuring consistency between the modeled auto speeds and the modeled bus speeds. The relationship between bus speeds and auto speeds was developed by comparing bus schedule data to observed auto speeds. It is also useful to check the estimated travel times by route against the scheduled end-to-end travel times, and this comparison is presented in Figure 23. The modeled bus times are very consistent with the actual bus travel times at the route level.

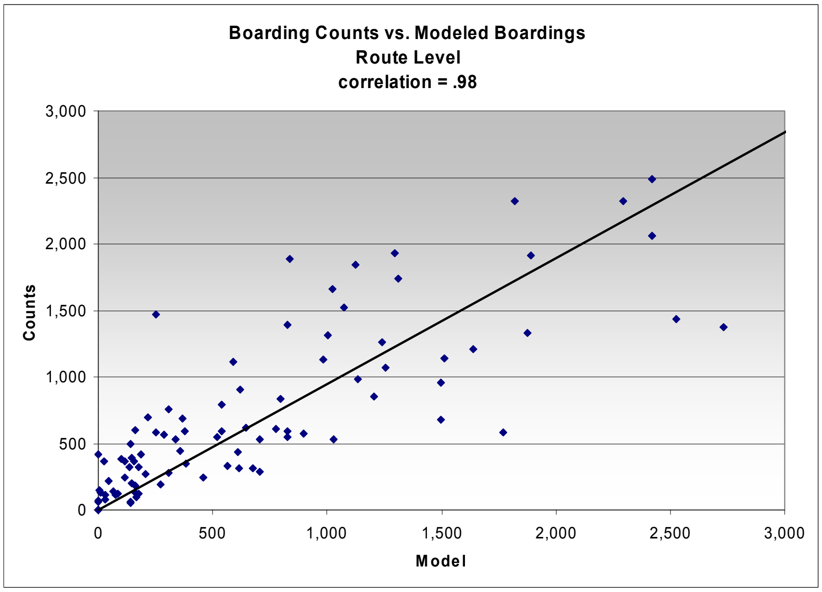
Figure 23: 2001 Modeled vs. Observed Bus Times (end to end)



16.4.2 Bus and Rail Boardings

One metric to measure the performance of the transit model is to compare modeled and observed boardings by route. Figure 24 displays a comparison of the modeled and observed boardings. In order to see the graphical data more clearly, the display is limited to routes with fewer than 3000 boardings, which excludes rail and a couple of bus routes, but the correlation coefficient is computed on all data, including rail lines.

Figure 24: Modeled vs. Observed Bus Boardings (Spring, 2006)



16.4.3 Trips by Mode

The following two comparisons demonstrate that the regional model closely approximates total trips and boardings for both bus and TRAX modes.

Figure 25: 2006 Modeled vs. Observed Bus Ridership

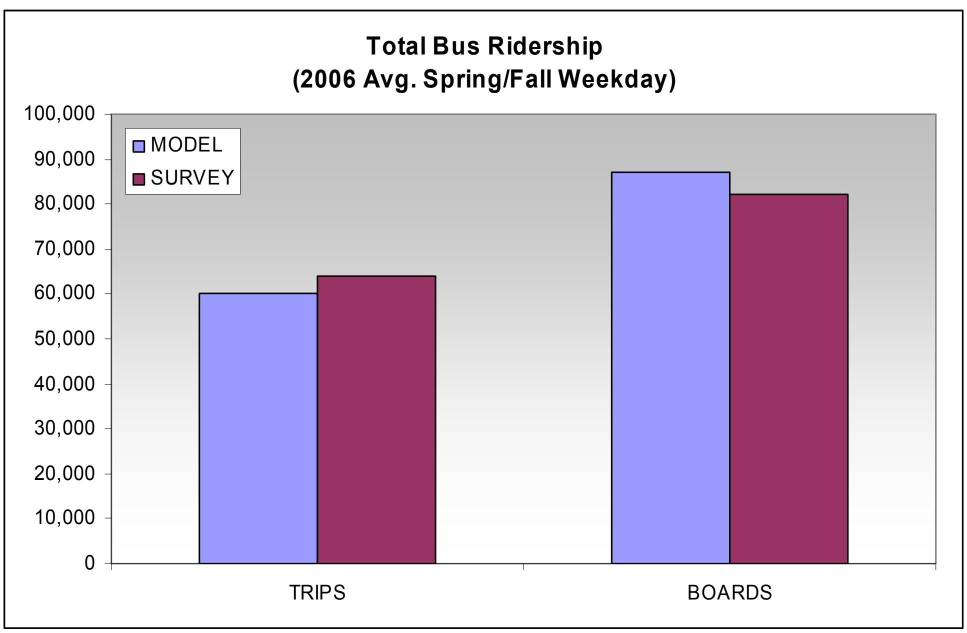
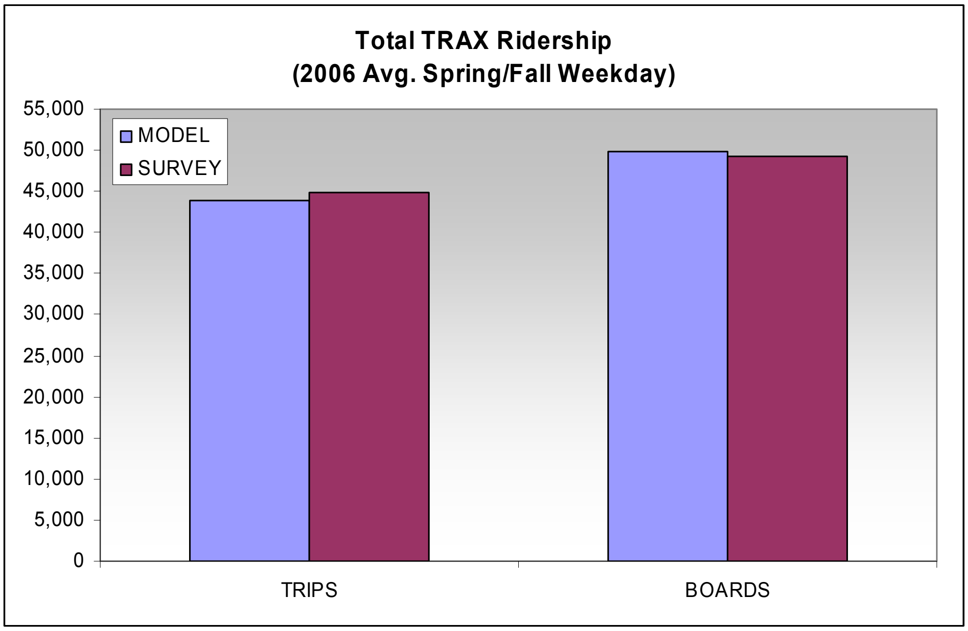


Figure 26: 2006 Modeled vs. Observed TRAX Ridership



16.4.4 Transfer Rates

Related to the previous charts, the following comparisons demonstrate that the regional model closely approximates transfer rates for both bus and TRAX modes, as well as the amount of transferring between buses and TRAX.

Figure 27: 2006 Modeled vs. Observed transfer rates (bus trips)

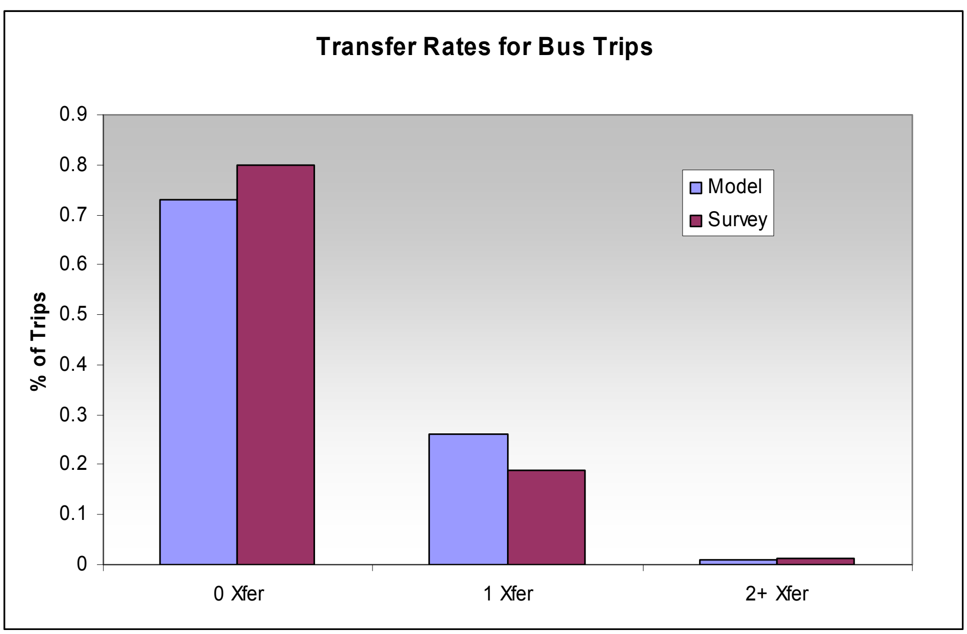


Figure 28: 2006 Modeled vs. Observed transfer rates (TRAX trips)

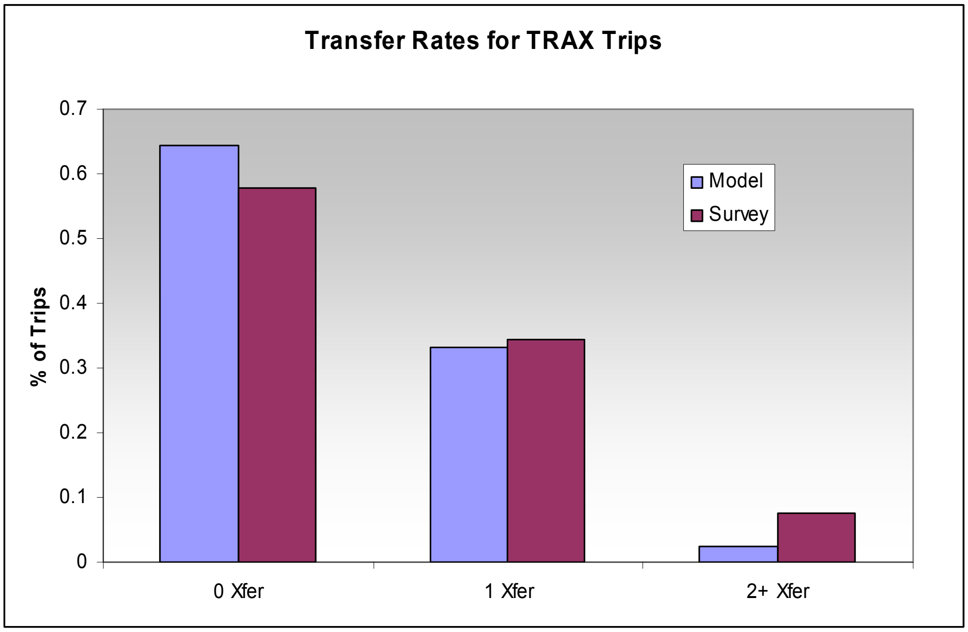
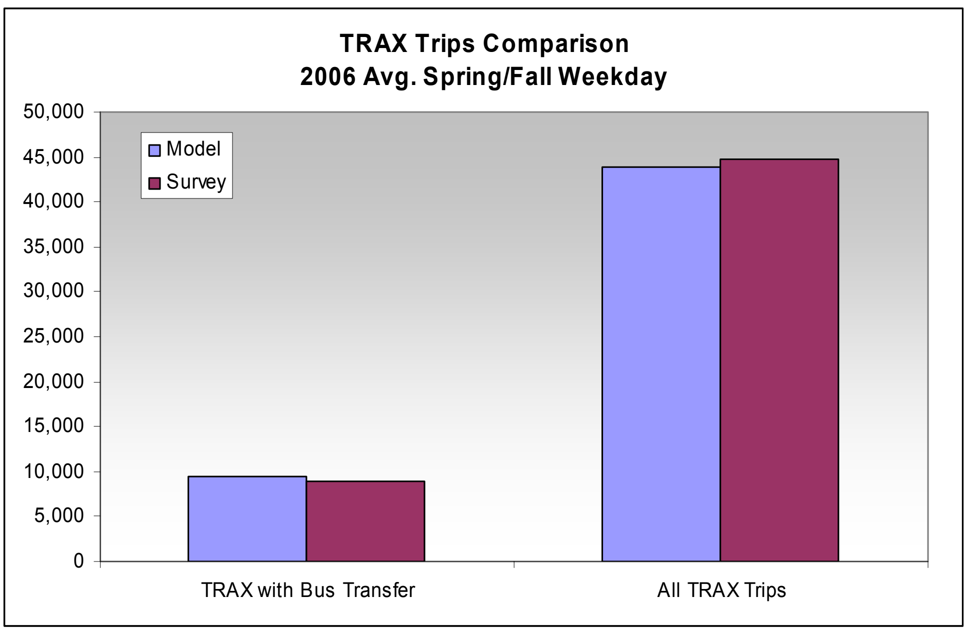


Figure 29: 2006 Modeled vs. Observed transfer rates between bus and TRAX



16.5 HOV CALIBRATION

High occupancy vehicle (HOV) lanes have been in operation on I-15 in Salt Lake County since 2002. More recently, the HOV lane has been extended into Utah County. In 2006, the decision was made to allow single-occupant vehicles (SOVs) to buy-in to the HOV lane with a monthly pass.

The 2005 base year model has the managed lanes on I-15 coded as HOV lanes. The following table shows a comparison of the base year HOV modeled volumes to observed traffic counts collected in 2006 before the policy change, at 4 locations. The comparison is stratified by time of day.

Table 29: Modeled vs. Observed HOV Volumes on I-15

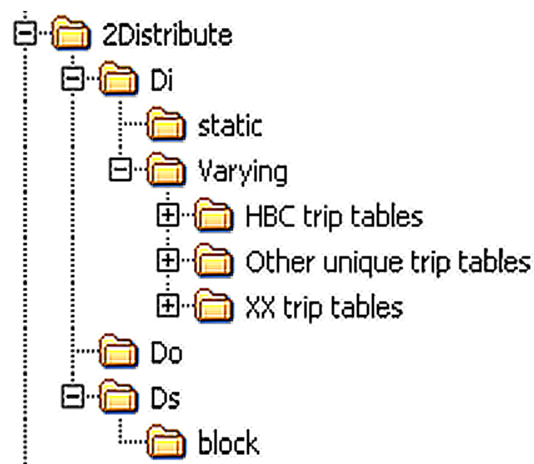
	Counted 2005 AWDT		Modeled 2005 AWDT	
	Southbound HOV	Northbound HOV	Southbound HOV	Northbound HOV
Andy Avenue				
AM	550	1,273	741	1,277
MD	1,769	2,044	1,922	1,770
PM	1,933	1,451	2,356	1,427
EV	1,910	1,650	1,550	1,249
Total	6,162	6,417	6,569	5,723
5800 South				
AM	552	1,640	811	1,855
MD	1,874	2,167	2,411	2,365
PM	2,821	1,612	3,307	1,693
EV	2,072	1,651	2,161	1,725
Total	7,319	7,071	8,690	7,638
9800 South				
AM	728	2,221	868	1,711
MD	1,984	2,647	2,258	2,254
PM	2,897	2,301	2,761	1,679
EV	2,316	2,093	1,971	1,700
Total	7,925	9,263	7,858	7,344
15600 South				
AM	691	1,593	728	1,164
MD	2,007	2,378	1,521	1,517
PM	1,885	1,644	1,927	1,319
EV	2,006	1,764	1,317	1,275
Total	6,589	7,378	5,493	5,275

The model does a very good job forecasting HOV volumes observed in 2005. The correlation between these counts and modeled volumes is .97.

17 USING THE MODEL

17.1 MODEL ORGANIZATION

1. **Control Center**: A single file that contains all the information to make one scenario unique from another (Files, paths, parameters). The model contains very few repetitive, embedded parameters. In other words, if a file name or parameter is used more than once, it is removed from the script to the control center, and aliased with the @parameter@ construction. This approach enhances robustness, functional utility, readability, and guarantees that when you change a parameter once, it is changed everywhere.
2. ***.block files**: Similar to the control center, when we find a need to repeat a section of code, we save that code block to a separate file then "READ FILE = 4pd_assign.block", using temporary variables to feed any flags or values to the block. This approach greatly simplifies the code, enhances our ability to understand "which file did what to whom", and ensures that changes to the block are accounted for everywhere.
3. **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.
4. **File management and directory structure**: A completed scenario includes about 1,500 files at approximately 2.5 Gigabytes. To manage this, we maintain a single root directory for the scenario and about 12 second level directories for distinct processes. Within each process we have an Input, Output, and Script directory. 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 bulk of the files are intermediate temp files that are written to a temp directory to be isolated for easy removal when packaging a run to CDs. A copy of the Master network is written to the scenario so that every file used in the scenario is contained within the root directory, making it simple to regenerate results even years later.



5. **Software & hardware packages**: The model runs on a single PC, but you are well served to get a good one. For example, in 2004 a great machine for the model had a 3.2 GHz, multi-thread processor with three 120 Gig hard drives linked together in a "Raid" configuration, which allows a single file to be written in thirds to each drive – tripling the write speed (a significant bottle-neck when working with such large data sets).

17.2 MODEL SCRIPTS AND STEPS

For a complete reference on all of the model scripts, including more information on executing the model, please refer to the model User's Guide, available from the MPOs.

1. **CheckForInputPresence.s**: This first script in the stream simply paths to all the inputs we can identify, attempts to read them simply to ensure their presence, and crashes the model if something is not present. "Crash early rather than later" is the idea.

2. **ComputeAreaTypeTermTime.s**: This script attempts to identify the type of area each zone is or is close to. Our arterial free-flow speed is a function of the cityscape the link is traversing, and we wanted these speeds to react to the demographics file. Urban value = pop/acre + 2*emp/acre averaged for the zone and its 4 nearest neighbors. The urban values are then split to 5 ranges (rural, transition, suburban, urban, CBD). Range breaks are somewhat arbitrary (we looked at a thematic map of the breaks, and set the values where they seemed to best describe our understanding of the city).

3. **NetProcessor.s**: This script reads the Master network database and outputs to a scenario network the lane configuration and other attributes that are relevant to the scenario. It loads the Area Type computed above first to all nodes, and from there it is migrated to all links. (All nodes must be identified as within a specific TAZ via GIS spatial join). Pop/Emp for the base year and horizon year are also loaded to centroids for informational purposes. Scenario speeds & capacities are computed from network attributes. Distance values are updated. A series of logic checks are applied (freeways with 1-lane, free-flow speeds above 65 mph or below 20, unusually long or short links, zone attributes outside expected ranges, unconnected centroids, reverse links that are not a mirror image, etc.). Any outliers are red-flagged to a file for checking. The master network includes all potential alignments and link/node attributes for any conceivable scenario. This ensures that while the attributes vary, the link/node skeleton structure is identical between scenarios (an essential element for maintaining transit compatibility across scenarios).

4. **TransitRouteTester.s**: Reads scenario transit routes and crashes early if the link structure is not compatible with the highway structure.

5. **AutoOwnership.s**: Logit construction which estimates auto ownership by household category. An off-line process divides households into income quartile, num workers, people per HH.

6. **TripGen.s**: This element is "plain vanilla". Productions per HH increase with HH size and autos owned. Attractions are based on zone population, total employment, retail, industrial, and other employment. Trips are generated for HB Work, HB School, HB Shopping, HB Personal Business, HB other, Commercial, NHB Work, and NHB Non-Work. There are adjustments for special generators. There is no feedback to this level.

7. **2DistributionFeedback.s:** We use gravity distribution for HBW, HBO, NHB, Commercial, and IXXI. HBW is doubly-constrained and based on AM peak speeds, and the others are singly constrained and based on mid-day speeds. We remove college trips from the HBO class, and create trip tables for major colleges, the airport, and an amusement park off-line. College distribution is based on 2001 student zip codes, adjusting for future growth within range of the college. We also assume that students closer to the college take more trips from home to college per day than those

further away. Airport trips come from a patron survey. Work trips to these destinations are treated regularly. Transit is sensitive to these attractors, which was the major motive for off-line trip tables. We iterate between four-period assignment and distribution until convergence defined as "95% of the links are changing by less than 5%". We do trip table averaging between iterations.

8. **Mode Choice:** We use a nested Logit structure separated for HBW, HB College, HBO, and NHB. The nests are motorized – non-motorized; auto-transit; 1,2,3+ occupant auto; Local bus-Express bus-Light rail-Commuter rail; walk-drive to each. The whole thing is complex-but-normal. Below describes only those elements that may be uncommon.

9. **Skim_AutoTran.s**: In addition to creating auto and transit travel times, we created what we think may be an innovative technique for creating walk support links to and from transit. We iterate between TRNBUILD and HWYNET to create support links that reach successively further. First we write support links in the SUPPORTO format for all stops that are "close" to zone centroids. Then we read the SUPPORTO format into HWYNET as a link record, effectively creating new centroids. Then we do the same for "far" zones. The objective is to capture large zones that may have a fraction close to the stop – not in itself a novel idea, but the idea of converting support links to centroids helps visualize who's got access and who doesn't.

10. **Network based automated Park-n-Ride creation**: TRNBUILD requires PNR lots have the syntax: "`PNR NODE= 3463 ZONES=1-1500".` We have identified a hierarchy of PNR lots on our Master network with a node attribute (Commuter rail lots at the top, bus-only lots at the bottom). An algorithm determines a zone's nearest 1-4 commuter rail stops, light rail stops, etc., then prints that zone as part of the PNR list in the above format. It filters by whether there actually is a stop at the PNR lot, and it allows lesser modes to have access to higher mode lots (i.e. Someone might drive to a light rail PNR lot to take the coincident bus). The result is an easy-to-view-and-maintain network based system for PNR lots that can take advantage of CUBE's display features to help us tell whether we've hooked up the PNR lots correctly.

11. **AssignHwy.s:** The 1,2,3+ person/auto trip tables for 8 purposes are divided into 4-periods using factors from the survey. They are converted to vehicle trips, and segregated as short or long trips (above 10 miles). 16 trip types (2 lengths, 8 purposes) are equilibrium-assigned to each period. Impedance for long trips is based 100% on time. Short trips are 33% time, 67% distance (dial settings required for calibration). See the chart for our VDF curves. We heavily penalize ramps when they approach capacity to simulate ramp-meters, and the general difficulty of moving from the arterial to the freeway (discourages short trips on freeway in peak). We write the 1st net as a "tempA", then read it back in for the next period and write a "tempB". We alternate between these, so at the end we have a single net with the results of all periods. We read the last temp in and rename all the "V1_1" type-fields to "AM_HBW_LONG" type-fields. We then write a final auto travel time matrix. There is no peak spreading method.

The model is officially completed at this point, and the batch file moves to a series of processors and data extraction routines.

17.3 POST-PROCESSORS AND DATA EXTRACTION

17.3.1 Highway/link based processes

- **HwyStats.s**: Summarizes VMT, VHT, speed, delay as shown below.

Stats by road type & period
Delay = VHT actual - VHT free flow
Vehicle Hours Traveled.
Average Speed
Vehicle Miles Traveled
% of links with V/C > 1.0 or 1.2
More detail on facility types
Detailed VMT
TotLane Miles & Tot State owned

RE calib 2001 MCpost _VOL

GROUP	DELAY(hr)	VHT	SPEED	VMT	PCTVC>1	PCTVC>1.2
Fwy_AM	3,754	55,156	61.3	3,383,773	2.4	0.1
Fwy_MD	212	74,577	65.4	4,878,299	0.0	0.0
Fwy_PM	8,090	72,876	58.4	4,257,818	5.2	0.8
Fwy_EV	0	53,919	65.8	3,550,019	0.0	0.0
Fwy_Tot	12,056	256,528	62.6	16,069,908	1048	
RMP_AM	2,423	6,704	18.6	124,658	6.7	0.4
RMP_MD	4,320	11,978	18.4	220,660	4.1	0.7
RMP_PM	11,183	17,098	9.9	170,009	15.8	3.3
RMP_EV	1	5,041	29.0	146,393	0.0	0.0
RMP_Tot	17,928	40,822	16.2	661,719	703	
ART_AM	8,644	106,786	33.3	3,559,889	4.6	1.3
ART_MD	9,143	192,385	33.8	6,504,577	2.4	0.6
ART_PM	30,586	182,814	29.6	5,410,777	17.7	7.3
ART_EV	114	120,375	36.0	4,331,587	0.0	0.0
ART_Tot	48,487	602,359	32.9	19,806,830	9987	
LCL_AM	0	25,690	19.9	510,302	0.0	0.0
LCL_MD	0	54,787	19.6	1,072,349	0.0	0.0
LCL_PM	0	41,850	19.7	824,759	0.0	0.0
LCL_EV	0	34,672	19.9	689,411	0.0	0.0
LCL_Tot	0	157,000	19.7	3,096,822	5040	
Tot_AM	14,818	194,337	39.0	7,578,622		
Tot_MD	13,669	333,727	38.0	12,675,884		
Tot_PM	49,856	314,638	33.9	10,663,363		
Tot_EV	111	214,007	40.7	8,717,409		
TOTAL	78,454	1,056,709	37.5	39,635,279		
Tot_Fwy	12,056	256,528	62.6	16,069,908		
Tot_Rmp	17,928	40,822	16.2	661,719		
Tot_Art	48,487	602,359	32.9	19,806,830		
Tot_Lcl	0	157,000	19.7	3,096,822		
TOTAL	78,470	1,056,709	37.5	39,635,279		

Area: RE, ID: calib, Yr: 2001 MCpost

Roadway Grouping	VMT	LNMILE	STMILE
Freeway31: Older, lower capacity	10,155,299	711	711
Freeway32: Newer, higher capacity	4,077,095	262	262
Freeway33: CD roads	589,704	79	77
Freeway35: Rural/High Spd	1,247,810	157	157
Freeway36,37: Ramps:	661,719	155	153
Principal Arterials: (FT2)	5,179,102	706	650
Minor Arterials: (FT3)	7,505,740	1,458	629
Collectors, Classified: (FT4)	4,020,697	1,723	162
Collectors, Unclassified: (FT5)	218,662	194	0
Locals, Unclassified: (FT6)	0	0	0
Multi-lane Arterials: (FT11-12)	2,264,301	338	335
Rural Highways: (FT21-23)	618,328	246	234
Centroid Connectors: (FT1)	3,096,822	811	0
Freeway Totals: (FT31+32+33+35)	16,069,908	1,209	1,207
Ramp Totals: (FT36+37)	661,719	155	153
Art Totals (FT2-6+11-12+21-23)	19,806,830	4,665	2,010
Local Totals (FT1: centroids)	3,096,822	N/A	N/A
Grand Totals	39,635,279	6,029	3,370
Freeway Percentages	41	20	100
Ramp Percentages	2	3	99
Arterial Percentages	50	77	43
Local (centroid) Percentages	0	N/A	N/A
Total Percentages	92	100	56

Note: STMILE = # & % of LNMILE that is state owned.

Percentages

E:\Model04\legacy_V32_2001\9AnalysisHwy\1HwyStats\County_FTReports\FT_10_RE.model.txt

* These reports are easily generated for any geography (Region, County, City, District, Study Area)
* Spreadsheet-ready to facilitate alternative comparison.

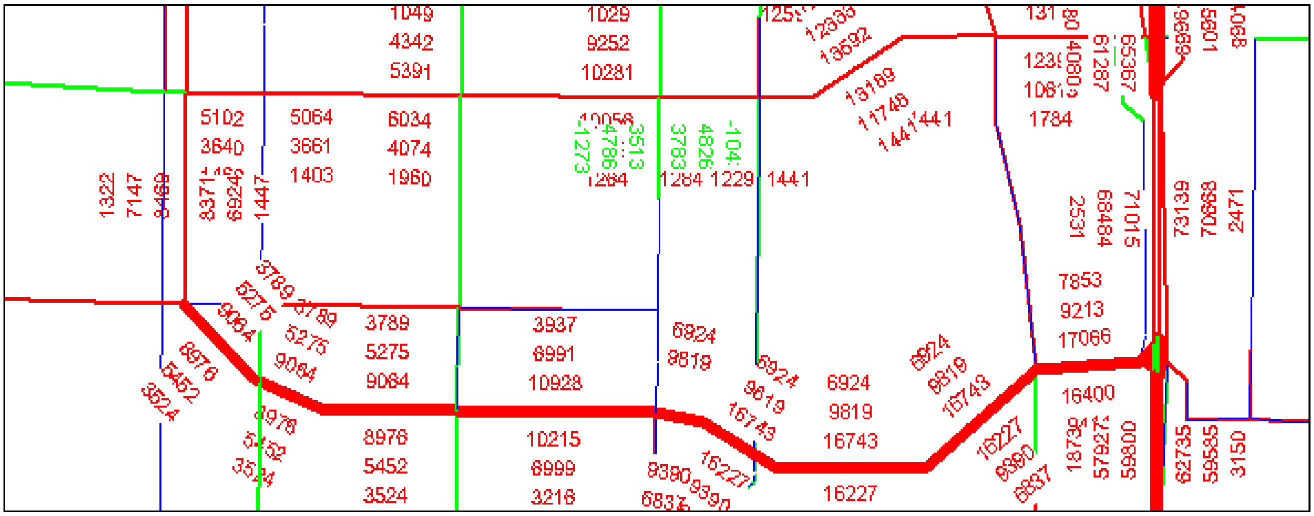
- **Mobile6.s**: Outputs all VMT, speed information to a format required for direct input to Mobile 6.

- **CalibrationStats.s**: We store observed speeds and counts on as many links as we can. A script can then generate the stats below.

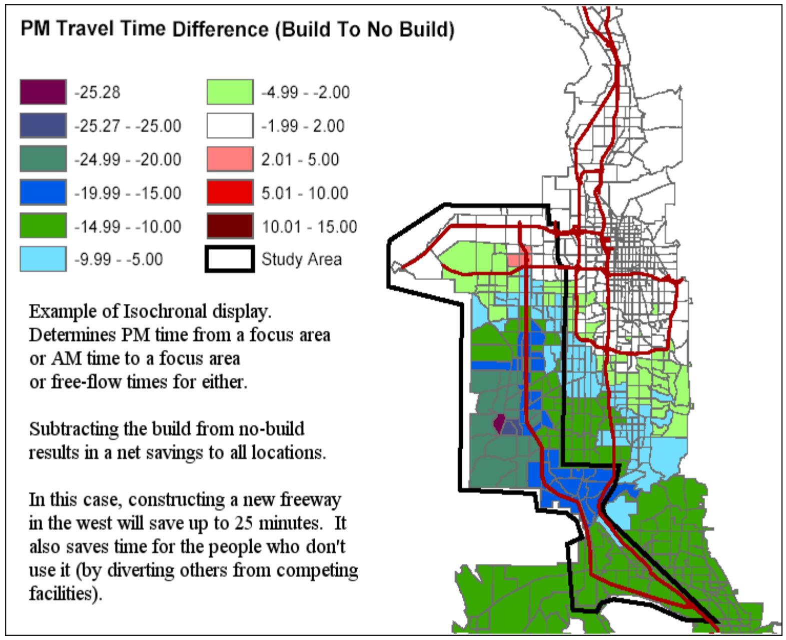
```
                    C A L I B R A T I O N

         Avg. Speeds Weighted By Number Of Segments

 Type          Area Type  Obs. Speed  Est. Speed  Segments

Freeways         Rural       71.12      71.53        24
                 Suburban    63.06      61.96       187
                 Urban       58.67      60.78        80

Pr. Arterials    Rural       38.29      42.74        42
                 Suburban    34.97      33.61       153
                 Urban       28.58      26.29        69
                 CBD         27.06      20.70        33


M. Arterials     Rural       40.47      39.97       139
                 Suburban    32.81      32.39       313
                 Urban       29.15      27.86       158
                 CBD         28.17      21.77        86

Collectors       Rural       29.72      39.26        29
                 Suburban    30.32      29.90       118
                 Urban       27.45      24.95       110
                 CBD         21.61      18.64        38

Master Network codes for Area Types
Rural & Transition  = 1,2
Suburban            = 3
Urban               = 4
CBD                 = 5

Master Network codes of area types for Freeways
Rural & Transition  When FT = 35
Suburban When FT = 31,32,34, and Area Type = 1-3
Urban = When FT =  31,32,34, and Area Type = 4
```

```
R E G I O N A L   C A L I B R A T I O N   S U M M A R Y

All Facility Types
  Total UDOT Counts                       =  36,589,885
  Total Estimated Volume                  =  33,859,182
  Total Difference (Est-Obs               =  -2,730,703
  Total Number of Segments                =       1,661
  %RMSE                                   =       35.93
  %Error (E-O/O)                          =       -7.46
Freeways Only
  Total UDOT Counts                       =   9,054,499
  Total Estimated Volume                  =  10,035,148
  Total Difference (Est-Obs)              =     980,649
  Total Number of Freeway Segments        =         193
  %RMSE                                   =       20.69
  %Error (E-O/O)                          =       10.83
Collectors & Rural Highways
  Total UDOT Counts                       =   5,351,348
  Total Estimated Volume                  =   3,616,747
  Total Difference (Est-Obs)              =  -1,734,601
  Total Number of Freeway Segments        =         537
  %RMSE                                   =       69.50
  %Error (E-O/O)                          =      -32.41
Minor Arterials & Multi-Lane Highway
  Total UDOT Counts                       =  12,995,268
  Total Estimated Volume                  =  11,113,035
  Total Difference (Est-Obs)              =  -1,882,233
  Total Number of M. Arterial Segments    =         632
  %RMSE                                   =       39.72
  %Error (E-O/O)                          =      -14.48
Pr. Arterials
  Total UDOT Counts                       =   9,301,957
  Total Estimated Volume                  =   9,214,885
  Total Difference (Est-Obs)              =     -87,072
  Total Number of P.Arterial Segments     =         308
  %RMSE                                   =       26.38
  %Error (E-O/O)                          =       -0.94
```

- **Compare2Assignments.s**: Takes 1 scenario and subtracts it from another. Subtraction values include Lanes, Volumes, V/C ratios, speeds, etc. A default.vpr is pre-set to display the differences. Example below shows red where volumes increased, green where they decreased, and posts the values and difference.



- **Isochronal_ByPeriod.s**: A "focus zone" is selected, and various travel times to or from all other zones are written to a .dbf. A pre-defined ArcView project then joins the .dbf to the TAZ shape file for display. Times are: Free flow to/from focus, AM time to/from focus, and PM time to/from focus. Distance from focus is also recorded. Total trips to and from the focus are also recorded.



- **TLFpurp.s**: Produces trip-length frequency data spreadsheet ready for plotting the curves. Also summarizes trips to produce totals and average lengths/times/speeds by purpose.

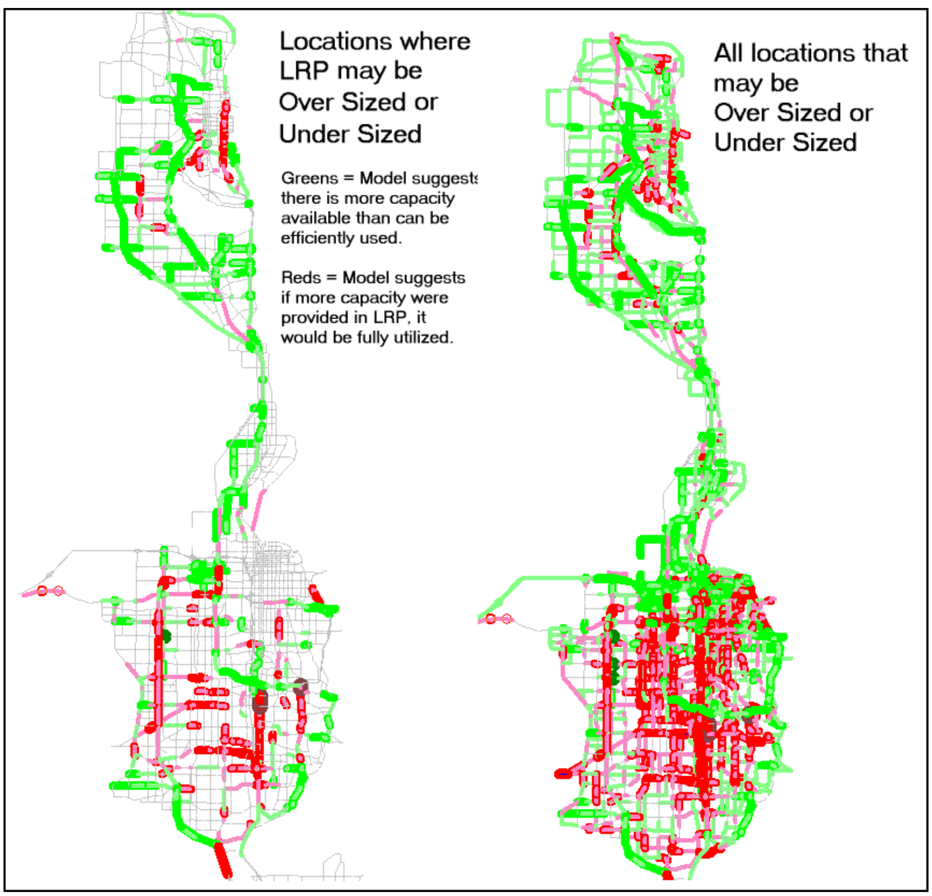
- **TLFtransit.s**: Same as TLFpurp, but produces totals and averages for walking/driving to transit.

By Purpose: Total trips, Ave Dist,
Ave Time, Ave Speed

```
Total trips and average trip lengths by purpose
for area 1RE:
* SE year:       2030
* Network year:  2030
* Run ID:        2030CONF
* location:   E:\model03\V311_LRPconf\V311_2030\

Total HBW trips                      1,601,610
Total HBC trips (Incl. Air, Lag)       117,232
Total HBO trips                      6,475,737
Total NHB trips                      3,640,798
Total IX trips                          95,582
Total XI trips                         286,983
Total COMM trips                     1,218,286
Total XX trips                          13,792
Total of all trips                  13,450,021

Average HBW trip dist (miles)            11.63
Average HBC trip dist (miles)             8.49
Average HBO trip dist (miles)             5.85
Average NHB trip dist (miles)             7.39
Average IX trip dist (miles)             22.73
Average XI trip dist (miles)             22.38
Average COMM trip dist (miles)            4.96
Average XX trip dist (miles)             49.14

Average HBW trip time (minutes)          21.34
Average HBC trip time (minutes)          19.20
Average HBO trip time (minutes)          11.85
Average NHB trip time (minutes)          14.28
Average IX trip time (minutes)           24.67
Average XI trip time (minutes)           34.58
Average COMM trip time (minutes)         10.90
Average XX trip time (minutes)           46.94

Average HBW trip speed (mph)             32.71
Average HBC trip speed (mph)             26.55
Average HBO trip speed (mph)             29.64
Average NHB trip speed (mph)             31.08
Average IX trip speed (mph)              55.30
Average XI trip speed (mph)              38.83
Average COMM trip speed (mph)            27.29
Average XX trip speed (mph)              62.81

Total person-trip miles             99,759,646
  About 4,157 round trips to the moon.

Total person-trip hours              3,188,806
  About 4.9 lifetimes of man-hours spent
  in travel per day (at 75 years/life)
```

- **ScreenlineAdjuster.s**: This script adjusts the modeled volumes of a screenline by the observed volumes. It follows the NCHRP method for adjusting screenline volumes. Basically, the observed percentages on a screenline are used to adjust the modeled percentages, allowing for new capacity. For links with no observed data, the model is assumed correct. The adjustment "red flags" links where the modeled volume goes below observed (a possible scenario, if new capacity elsewhere diverts enough trips). Results are used in the process of creating an "official forecast".

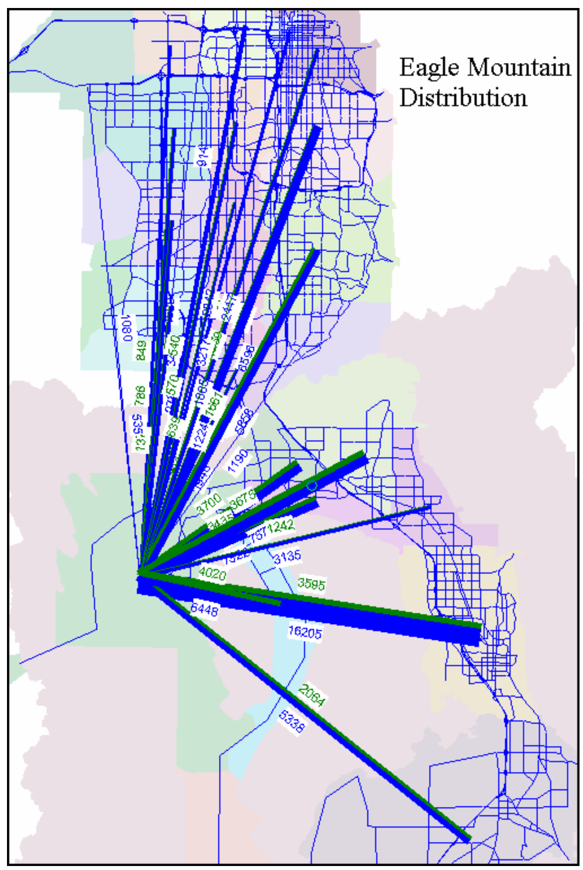
- **Lane Optimization**: Not really a post-processor, this is a switch within distribution and assignment that adjusts the number of lanes in an attempt to target a designated V/C ratio. The result is essentially identical to a V/C ratio plot, but the units are expressed in a form that for some people is easier to understand ("How many lanes do we need?"). An advantage of the method is that it "builds its way out of congestion" (i.e. does not hinder people's trip length via the congestion detected in the feedback loop, but builds/removes lanes until the congestion is "not greater than" the specified V/C). Lanes are decimal values. In the plot below, red shows places where lanes were increased beyond existing/planned. Green is where they were decreased by some fraction below existing/planned. The message is "focus every dollar you can find in the red".



17.3.2 Highway, district based processes

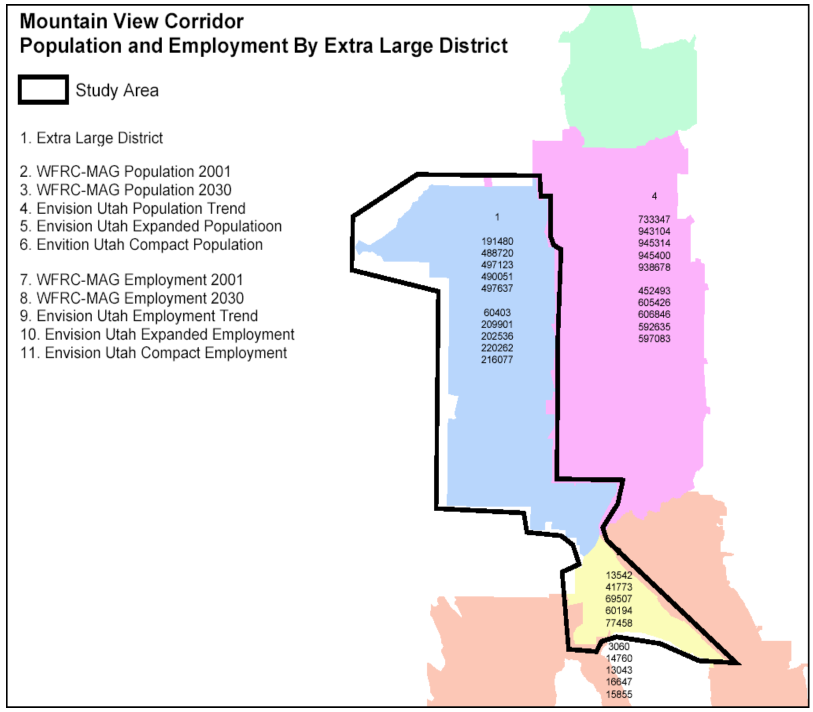
- **HwyStats_Districts.s**: Similar stats as the link-based process above, but summarizes values by district in a .dbf file. Results can then be joined to the district shape file for display. To accomplish, each link is first identified as within a TAZ (GIS intersect). From then on, any TAZ-District lookup file can inform HWYNET which links to include as part of the district. A separate comparison script will subtract the results of one network from those of another, creating a new .dbf of differences and percent differences – a useful display when attempting to show how a build proposal differs from a no-build. Separate tables are produced for freeways, arterials, and all combined. They are further stratified by 4 periods and the daily total. Stats produced by district include pop/emp, lane miles, VMT, VHT assuming free flow, VHT congested, average speed, average mpg (a TTI formula). Links are also flagged as east-west or north-south based on the change in XY. From there, additional stats include EW/NS lane miles, EW/NS lane miles above V/C = 1, EW/NS VMT, EW/NS VMT above V/C = 1.

- **District2District.s**: Reduces any matrix from zonal I-J's to district I-J's. Also separates short distance (0-5 mile) trips from long distance trips. Desire line plots are then easily made to highlight trips that might seek a faster, long-haul facility from those that are more localized. See example at right.



- **District2District_HwyChoice.s**: Identifies volume on any given link as being between a given I-J district pair. Works for about 4-6 district pairs max. Creates separate matrices for each I-J interaction, then assigns each matrix, and finally re-labels the resulting volumes as "Vol_Dist1-Dist3". An effective way of displaying who's who on the roadways (which markets are most served by a proposal).

- **DemographicsAnalysis.s**: Summarizes pop/emp by district for up to 5 unique demographic files. An easy way to tell how an alternative land use proposal differs from a base (or a future from a present). Feed it any TAZ-District lookup table.



17.3.3 Transit / Mode Choice processes

- **SharesAndLinkedTrips.s**: Summarizes the results of the Mode Choice model. Trips are all "linked trips" as opposed to boardings. An absolute share of the total trips, and a nest level relative share are also computed (see below).

Shares and linked trips report: Logit Mode Choice results by purpose. Absolute share as well as the relative share (nest level share).

```
/* N ===== TripCategory|   HBWtrip HBWabs HBWrel    HBCtrip HBCabs HBCrel    HBOtrip HBOabs HBOrel    NHBtrip NHBabs NHBrel|   TOTtrip TOTabs TOTrel */
  1 Total Trips       | 1,308,554 100.00 100.00     70,136 100.00 100.00 4,966,176 100.00 100.00 2,918,112 100.00 100.00| 9,262,979 100.00 100.00
  2   Non-Motorized   |    34,164   2.61   2.61      3,816   5.44   5.44   586,803  11.82  11.82   141,949   4.86   4.86|   766,732   8.28   8.28
  3   Motorized       | 1,274,390  97.39  97.39     66,320  94.56  94.56 4,379,373  88.18  88.18 2,776,163  95.14  95.14| 8,496,247  91.72  91.72
  4                   |                                                                                                 |
  5   * Auto          | 1,212,331  92.65  95.13     41,695  59.45  62.87 4,343,205  87.46  99.17 2,744,219  94.04  98.85| 8,341,450  90.05  98.18
  6                   |                                                                                                 |
  7       Auto,1 pers |   972,640  74.33  80.23     35,160  50.13  84.33 1,591,981  32.06  36.65 1,322,810  45.33  48.20| 3,922,591  42.35  47.03
  8       Auto,2 pers |   179,686  13.73  14.82      5,522   7.87  13.24 1,376,793  27.72  31.70   794,553  27.23  28.95| 2,356,555  25.44  28.25
  9       Auto,3+pers |    60,004   4.59   4.95      1,013   1.44   2.43 1,374,433  27.68  31.65   626,859  21.48  22.84| 2,062,309  22.26  24.72
 10                   |                                                                                                 |
 11   * Transit       |    62,063   4.74   4.87     24,625  35.11  37.13    36,172   0.73   0.83    31,947   1.09   1.15|   154,806   1.67   1.82
 12                   |                                                                                                 |
 13       Local Bus   |    27,731   2.12  44.68      9,545  13.61  38.76    21,153   0.43  58.48    14,745   0.51  46.15|    73,174   0.79  47.27
 14         LCL Walk  |    25,083   1.92  90.45      8,521  12.15  89.27    20,849   0.42  98.56    13,851   0.47  93.93|    68,304   0.74  93.34
 15         LCL Drive |     2,648   0.20   9.55      1,024   1.46  10.73       304   0.01   1.44       894   0.03   6.07|     4,870   0.05   6.66
 16                   |                                                                                                 |
 17       Express Bus |     4,117   0.31   6.63        210   0.30   0.85       288   0.01   0.80       263   0.01   0.82|     4,878   0.05   3.15
 18         EXP Walk  |     1,387   0.11  33.69         39   0.06  18.61       124   0.00  43.01       155   0.01  58.90|     1,705   0.02  34.95
 19         EXP Drive |     2,730   0.21  66.31        171   0.24  81.39       164   0.00  56.99       108   0.00  41.10|     3,173   0.03  65.05
 20                   |                                                                                                 |
 21       Light Rail  |    21,167   1.62  34.11      9,646  13.75  39.17    11,192   0.23  30.94    13,725   0.47  42.96|    55,730   0.60  36.00
 22         LRT Walk  |    10,284   0.79  48.59      4,083   5.82  42.33     7,021   0.14  62.73    12,397   0.42  90.32|    33,786   0.36  60.62
 23         LRT Drive |    10,883   0.83  51.41      5,562   7.93  57.67     4,171   0.08  37.27     1,328   0.05   9.68|    21,944   0.24  39.38
 24                   |                                                                                                 |
 25       Comm. Rail  |     9,038   0.69  14.56      5,224   7.45  21.21     3,520   0.07   9.73     3,204   0.11  10.03|    20,986   0.23  13.56
 26         CRT Walk  |     2,285   0.17  25.28        523   0.75  10.02     1,004   0.02  28.53     2,116   0.07  66.03|     5,928   0.06  28.25
 27         CRT Drive |     6,753   0.52  74.72      4,701   6.70  89.98     2,515   0.05  71.47     1,088   0.04  33.97|    15,058   0.16  71.75
 28
 29 Run ID (RID card): 2030CONF
 30 Socio-Economic year modeled:         2030
 31 Network infrastructure year modeled: 2030
 32 E:\model03\V311_LRPconf\V311_LRP_2030\9AnalysisTran\9Shares\SharesAndLinkedTrips_WFRC.2030CONF.txt
```

- **RouteSummary.exe**: Stats on modeled routes. See description below.

ID	R	LINE	H1	H2	WY	BRDTOT	RTLEN	RUNT	RECT	MPH	BPK	BOK	T/H/B	TPK	TOK	TTOT	MPK5	MOK8	MTOT	BRD/T	BRD/M	LNK
129	BR	BRT1300E	15	15	2	8901.6	20.8	46	4	27.3	6.1	6.1	1.3	40	64	104	833	1332	2165	85.6	4.1	172
130	BR	BRTEastTC	15	15	2	2766.4	17.9	35	3	30.8	4.6	4.6	1.7	40	64	104	714	1143	1857	26.6	1.5	158
131	BR	BRTFortUn	15	15	2	438.1	3.1	8	1	24	1	1	7.8	40	64	104	123	197	320	4.2	1.4	26
132	BR	BRTRedwood	15	15	2	7623.9	24.5	52	4	28.6	6.9	6.9	1.2	40	64	104	982	1571	2553	73.3	3	176
135	BR	BRTMVIEWN	15	15	2	5606.3	39.5	68	6	34.7	9.1	9.1	0.9	40	64	104	1582	2531	4112	53.9	1.4	264
		Total				**33,618**	**106**	**209**	**18**	**145**	**28**	**28**	**13**	**200**	**320**	**520**	**4,234**	**6,774**	**11,007**	**244**	**11**	**796**
123	RL	RAIR2U	15	15	2	7494.5	11	45	4	14.5	6.1	6.1	1.3	40	64	104	439	703	1142	72.1	6.6	50
124	RL	RMIDJORD	15	15	2	20235.5	26.1	64	5	24.4	8.6	8.6	0.9	40	64	104	1043	1668	2711	194.6	7.5	72
125	RL	RNSLRT	15	15	2	19491.4	26.6	58	5	27.6	7.7	7.7	1	40	64	104	1065	1704	2770	187.4	7	66
126	RL	RWVC2U	15	15	2	17585.8	19.9	60	5	19.9	8	8	1	40	64	104	795	1272	2068	169.1	8.5	94
127	RL	RSugarHouse	15	15	2	1986.1	2.2	5	0	28.8	0.6	0.6	12.9	40	64	104	89	143	232	19.1	8.6	8
128	RL	RCRT_OGPR	20	60	2	23886.6	80.1	95	8	50.8	9.5	3.2	0.6	30	16	46	2404	1282	3686	519.3	6.5	74
	BR Totals					**90,680**	**166**	**327**	**27**	**166**	**41**	**34**	**18**	**230**	**336**	**566**	**5,835**	**6,772**	**12,609**	**1,162**	**45**	**364**

Route Summary report: A C++ exe that crunches through TRNBUILD dbf assignments to list stats like headway, boardings, route length, run time, average mph, buses required to operate the line at any point in the peak, total revenue miles, boards/mile, boards/trip.

Revenue-milesare used to calibrate network s to known values, and projected growth.

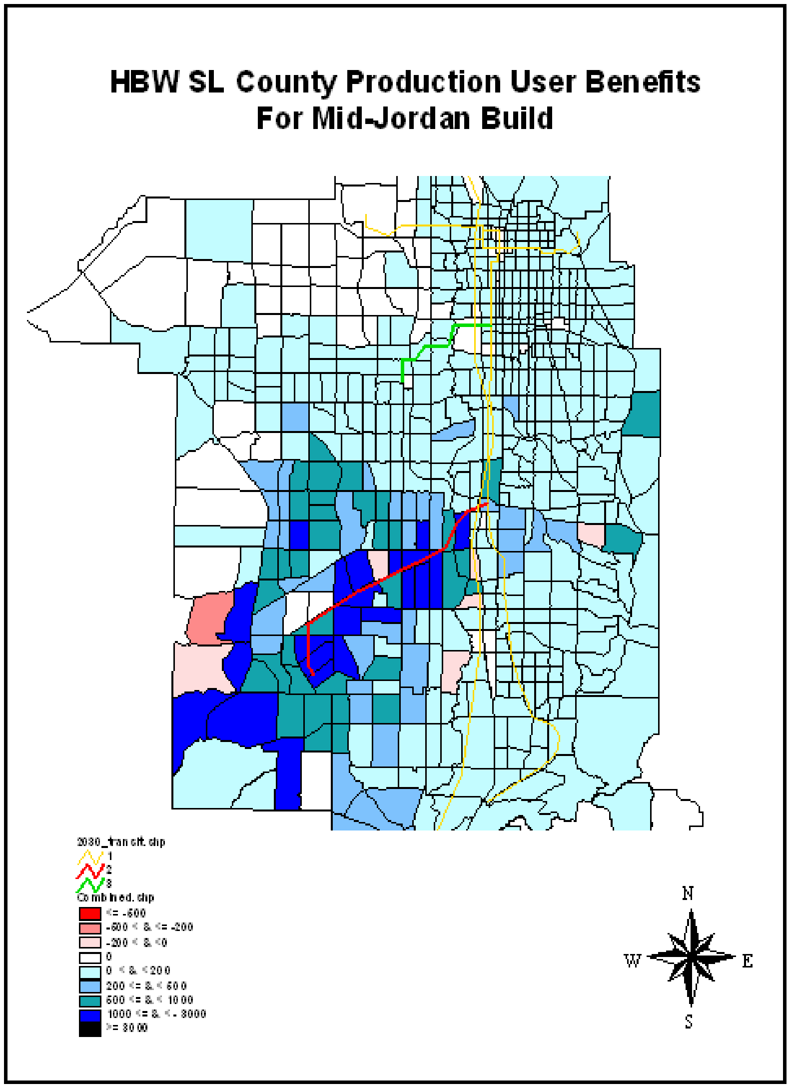
Total Peak Bus Miles	7,796
Total Bus Miles	18,338
Peak Rail Miles	5,835
Total Rail Miles	12,609

- **StationActivity.sps**: Detailed stats on any particular route (SPSS script). See below.

Station-level activity report: An SPSS (like SAS) script that crunches through dbf transit files to total boardings by station (P's & A's). A "track segment" is then identified to determine the share that the "track" contributes to the whole.

A	B	NAME	SEQ	A_NAME	B_NAME	Daily Trips Produced at A (P's)	Daily "inbound" boards at A (P's/2=O's)	Daily "outbound" returns to A (P's/2=D'	Daily Trips Attracted to B	Daily "inbound" arrivals at B (A's/2=D's)	Daily "outbound" returns starting from B (A's/2=O'	Screen line volume	DIST	TIME	MODE	STOP_A	STOP_B
12590	12589	RCRT_OGPR	1	S Provo East Bay	NS Bend	335	167	167	0	0	0	167	49	0.65	8	1	0
12589	12588	RCRT_OGPR	2	NS Bend	S Orem/UVSC	0	0	0	121	61	61	107	431	5.75	8	0	1
12588	12587	RCRT_OGPR	3	S Orem/UVSC	NS Vinyard Bend	771	385	385	0	0	0	492	409	5.11	8	1	0
12587	12586	RCRT_OGPR	4	NS Vinyard Bend	S American Fork/Pleasant Grove	0	0	0	1	0	0	492	160	2	8	0	1
12586	12599	RCRT_OGPR	5	S American Fork/Pleasant Grove	NS Bend	397	199	199	0	0	0	690	312	3.98	8	1	0
12599	12585	RCRT_OGPR	6	NS Bend	NS Bend around Lehi	0	0	0	0	0	0	690	171	2.18	8	0	0
12585	12584	RCRT_OGPR	7	NS Bend around Lehi	S Lehi	0	0	0	183	92	92	599	41	0.52	8	0	1
12584	12549	RCRT_OGPR	8	S Lehi	NS Bluffdale Bend	1549	775	775	0	0	0	1373	56	1.05	8	1	0
12549	12548	RCRT_OGPR	9	NS Bluffdale Bend	NS Draper Bend (Bangerter Hwy)	0	0	0	0	0	0	1373	348	4.75	8	0	0
12548	12626	RCRT_OGPR	10	NS Draper Bend (Bangerter Hwy)	S S SJordan (106th)	0	0	0	207	103	103	1270	334	4.55	8	0	1
12626	12580	RCRT_OGPR	11	S S SJordan (106th)	NS Bend near 9000 S	1084	542	542	0	0	0	1812	181	2.13	8	1	0
12580	12577	RCRT_OGPR	12	NS Bend near 9000 S	NS Bend near Center St	0	0	0	0	0	0	1812	190	2.24	8	0	0
12577	12627	RCRT_OGPR	13	NS Bend near Center St	S Murray Intermodal (5400 S)	0	0	0	956	478	478	1334	295	3.47	8	0	1
12627	12576	RCRT_OGPR	14	S Murray Intermodal (5400 S)	NS Bend near 3900 S	666	333	333	0	0	0	1667	198	2.97	8	1	0
12576	12575	RCRT_OGPR	15	NS Bend near 3900 S	NS Bend near 3300 S	0	0	0	0	0	0	1667	149	2.24	8	0	0
12575	12629	RCRT_OGPR	16	NS Bend near 3300 S	S SLC Intermodal (600 W, 200 S)	0	0	0	2515	1257	1257	410	418	6.27	8	0	1
12629	12574	RCRT_OGPR	17	S SLC Intermodal (600 W, 200 S)	NS Bend at 600 N	317	158	158	0	0	0	568	129	1.89	8	1	0
12574	12666	RCRT_OGPR	18	NS Bend at 600 N	NS Bend near Beck St	0	0	0	0	0	0	568	206	3.01	8	0	0
12666	12630	RCRT_OGPR	19	NS Bend near Beck St	NS Bend near I-215	0	0	0	0	0	0	568	208	3.04	8	0	0
12630	12631	RCRT_OGPR	20	NS Bend near I-215	S W.Bount (500 S)	0	0	0	253	127	127	441	318	4.65	8	0	1
12631	12579	RCRT_OGPR	21	S W.Bount (500 S)	NS Bend near Parrish Ln	72	36	36	0	0	0	477	253	2.98	8	1	0
12579	12632	RCRT_OGPR	22	NS Bend near Parrish Ln	NS Turn South	0	0	0	0	0	0	477	314	3.69	8	0	0
12632	12633	RCRT_OGPR	23	NS Turn South	S Farmington (Lagoon)	0	0	0	158	79	79	398	106	1.25	8	0	1
12633	12547	RCRT_OGPR	24	S Farmington (Lagoon)	NS Bend near Burton Ln	101	50	50	0	0	0	448	279	3.22	8	1	0
12547	12636	RCRT_OGPR	25	NS Bend near Burton Ln	S Layton (Gentile St)	0	0	0	248	124	124	324	407	4.7	8	0	1
12636	12637	RCRT_OGPR	26	S Layton (Gentile St)	S Clearfield (S HAFB)	196	98	98	101	50	50	372	410	5.86	8	1	1
12637	12653	RCRT_OGPR	27	S Clearfield (S HAFB)	NS Clearfield Bend	126	63	63	0	0	0	435	148	2.07	8	1	0
12653	12638	RCRT_OGPR	28	NS Clearfield Bend	S Roy (N of HAFB)	0	0	0	18	9	9	426	272	3.8	8	0	1
12638	12640	RCRT_OGPR	29	S Roy (N of HAFB)	NS Turn South	67	34	34	0	0	0	460	107	1.69	8	1	0
12640	12652	RCRT_OGPR	30	NS Turn South	NS Bend	0	0	0	0	0	0	460	122	1.93	8	0	0
12652	12651	RCRT_OGPR	31	NS Bend	NS Bend	0	0	0	0	0	0	460	189	2.98	8	0	0
12651	12641	RCRT_OGPR	32	NS Bend	NS Turn West	0	0	0	0	0	0	460	136	2.15	8	0	0
12641	12642	RCRT_OGPR	33	NS Turn West	S Ogden Intermodal	0	0	0	919	460	460	0	66	1.04	8	0	1
					Provo to SL track activity	4802	2401	2401	3983	1991	1991	4393					
					SL to Ogden track activity	878	439	439	1697	849	849	1288					
					Total	5680	2840	2840	5680	2840	2840	5680					
					Total Track activity - Provo side	7555	3777	3777	7652	3826	3826	7603					
					Total Track activity - Ogden side	3863	1932	1932	3767	1883	1883	3815					
					Total	11418	5709	5709	11418	5709	5709	**11418**	Total route boardings				

- Tools for FTA's Summit program: The model has "switches" to produce output preformatted for the Summit program. Summit must be run separately for each purpose, and the various parameter files have been prearranged to make it easier to work with. Post-Summit runs have 15 Gigabytes of data in our model. The pre-formatting helps reduce the task of running and mapping Summit results to about 2 hours of staff time. A user benefit plot of "winners and losers" (blue/red) is shown.



18 NETWORK CODING

18.1 HOW TO CODE MANAGED LANES AND TOLLWAYS

This section describes how to code the highway networks to utilize the managed lanes functionality of the WFRC/MAG models. Consider obtaining the most recent WFRC-MAG master network if possible.

The coding convention is different for mixed facilities (where managed lanes (HOV/HOT) parallel general purpose lanes) than it is for tollways.

18.1.1 Coding Dedicated Tollway 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.

The LOS on the tollway is used in trip distribution, reflecting the theory that freeway access, tolled or not, should influence trip distribution to some extent.

18.1.2 Coding Mixed Facilities (HOV lanes/HOT lanes)

Mixed facilities are coded with the managed lane links inside the general purpose links. While the model will not break if you do not follow this convention, using this convention makes it easier to retrofit a freeway that has already been coded with a managed lane.

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. You must be careful to 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.

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

To install new managed lanes or utilize existing managed lanes on the master net.

- Set Cube to view 1-way links.
- Copy an existing managed lane likely to have similar attributes (same county, etc.)
- Paste the link into the median of a freeway (can go on outside, doesn't really matter, but then you run into interchanges and arterials).
- Use nodes above 13,000 (not critical, but we've been doing that, and it is useful for display purposes)
- Once pasted, set the lane and FT attributes as necessary. You may want to have created scenario lane and FT fields in advance, and pre-loaded them with the closest match to what you're doing. Default is 1 managed lane, but you can have 2 or more per direction.
- Once a single link's attributes are perfected, copy that one and paste additional links as necessary.
- An HOV link is defined as FT=34. This coding will allow only vehicles with 2 or more persons to use the lane.
- An HOT lane is FT=39. This will allow anyone to use the lane so long as they pay the fair specified in the control center. (There, you can allow HOV trips to be free, or to pay half what a single pays, or make everyone pay the same).

Install short links to access the managed lanes.

- Copy an existing FT=38 access link. Whether the lanes are turned off for a given scenario is not critical, though it is critical that the links have lanes and a functional type for the scenarios where you model managed lanes. You could in fact have the FT 38 lanes always on to avoid chancing that they might be off. If the managed lane is off, these access links will access nothing and so will not be used.
- Think about where to paste it using the same logic as if you were actually driving relative to the proposed scenario. (i.e., you can't reach a center managed lane directly from the ramp, so if possible put the access link a bit down stream of the ramp. You may not have a convenient mainline node to connect to, but I would avoid splitting a mainline link, since you may unfortunately break the transit networks. It's not a big deal to connect directly to/from ramps). Make sure you don't reverse these one-way links or they can't be used.

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. You must first estimate reasonable mainline roadway speeds and distributions before you can do mode choice (the point where people will decide whether to use a managed lane). To account for the extra capacity provided by managed lanes, the distribution model artificially inflates the general purpose capacity if a managed lane is in use parallel to the general purpose lanes. For example, you code the general purpose network as LN = 4 on the mainline (of capacity 2300), and LN = 1 on the managed (managed capacity of 2300), for a total of 5 freeway lanes of potential "throughput". Since distribution will see only one the mainline link, the idea is to adjust that mainline capacity from 4 to 5 lanes of effective capacity. Here's how that is done:

- You must code the network with an attribute on the mainline that identifies that link as having a parallel managed lane using the "HOV_LYEAR" field and setting it equal to something like "12010", which means "#lanes, year it is drivable". The HOV_LYEAR field has 5 numeric characters, the first being the number of parallel managed lanes per direction, and the second being the year in which that managed lane begins operation. If the model finds non-zero values in this field, it thinks there is a managed lane there, so be careful. If your intention is not to model a managed lane, set the HOV_LYEAR field to zero.

- If you want to test the field for more than one year, you can make more than one HOV_LYEAR field (but you must include the field in the control center so it is transferred to the scenario net).
- BE CAREFUL: If for some reason you go back and get rid of the managed lane, or want to model it as a GP lane (by setting the mainline back to 5), don't forget do delete this flag from this field too, or distribution will see 6 lanes.

What doesn't work well

It doesn't seem to work well to just recode the managed lane to the same FT as the mainline, as a means of easily testing a "no managed lane" scenario. The accesses create a lot of potentially different paths, and the model gets carried away assigning one lane to V/C = 1.2, while the neighboring lanes of the same type are V/C = 0.8. A few links down the values reverse. To model no managed, just set a lane field where the managed = 0, and the mainline = previous + 1, then set HOV_LYEAR_NB (no build) = 0.

Additional thoughts

The implementation was tricky, and as it stands the algorithm basically requires anyone who will ever use a managed lane during the trip to access the lane at the first possible point, and egress at the last possible point. This is somewhat different than the "painted stripe" lane we have now, where many people tend to stay in general flow until it bogs, then they slide over. Thus it is difficult to replicate observed values at all points along the HOV system. (We tend to over estimate the use at most points from the CBD to the Midvale area, but come much closer from there to where the lane ended in 2003). Perhaps the algorithm more closely reflects barrier separation (probably necessary for a tolled facility anyway). It also would arguably be more representative of reality in future conditions when most of the mainline is bogged down (and thus people really would enter ASAP and exit AL(late)AP.

18.2 TRANSIT NETWORK CODING

To be useful, transit alternatives should generally be comparable in their basic structure. This requires a "base" scenario, and variations built from the base. Effects can then be associated with the known variations. If networks are vastly different, reasons for variation in ridership are not easily known.

18.2.1 General Overview

- Select an existing transit network that best matches the network you want to develop. Copy it to: ..\3ModeChoice\lin_*. Link the model to the network by specifying its location in the control center.
- **Modify the transit network on the scenario network:** Build the transit network in Viper using the appropriate highway *scenario* network, and not the master network. This ensures that the routing you develop for "2010" will not use roads that will only be available in "2020". (To create a highway scenario network (i.e. a highway network for a given year), you must run the "02NetProcessor.s" script in the network processing folder.)
- Modify the **"3readlines.txt"** file in the lin_* directory, if necessary.
    - o **File Paths:** Confirm that all paths and filenames are correct. From WordPad, use CNTL+H to search and replace path/file names.
    - o **Transit only links:** Confirm that 3bus.link and 3rail.link will be called.
    - o **Transit support links:** Confirm that all appropriate *.sup files will be called. (Note: There is no affect if you call more of these than necessary).
    - o **Route definitions:** Confirm that all appropriate *.lin files will be called.
- Set up the ***Trnfiles.txt** file, which is used by one of the post processors.

18.2.2 Run the "TransitRouteTester.s" Script

The transit route tester (**"**TransitRouteTester.s**")** is a script that checks your transit network against the appropriate scenario network and tests whether they fit together. If for some reason they don't, you will get errors where the transit network doesn't fit onto the highway network. DO THIS ONLY AFTER YOU HAVE SET UP YOUR MODEL RUN (i.e. after you have specified filenames, paths, transit directories, master and scenario networks), AND ONLY AFTER YOU HAVE RUN THE NetProcessor.s SCRIPT. This exercise will show you where the transit network you chose to modify doesn't fit on the highway scenario network you chose to use for the analysis.

If this **"**TransitRouteTester.s**"** finishes with return code=2, the highway and transit networks are not in sync, and you must fix the inconsistencies:

Open .prn file and search for "F(" (fatal errors). This shows which links the transit network is choking on. Open the hwy network, search for node with problem, and identify whether hwy net or transit net needs to be changed. Change transit net directly in the *.lin file, or using transit manager in Viper. You can also add transit links to "3lin_* \3bus.link" to handle roads that buses use, but that are not part of hwy net.

18.2.3 Modify or create the routes defining the scenario

LINE: A route is defined as a **LINE** record: All LINE records must have the following cards, and they must be in this order:

LINE NAME="O605", MODE=4, ONEWAY=F, FREQ[1]=30, FREQ[2]=30, (other optional cards), N=1243, etc. The N= card is last, followed by the node string that defines the route.

- **NAME**: The NAME card must be no more than 11 characters, no spaces. The following naming conventions should be followed:
  - 1st characters represent primary region of operation, and other features of the route. Examples: O=Ogden, S=Salt Lake, OS=Iter-Og-SL, ON=Og New route, M=MAG, MS=Inter-MAG-SL, MSN=New MS route, MX = MAG inter-area express, MSX=MAG-SL express, R=Rail
  - After region identifier, use UTA's route number. For minor modifications in routing, continue with UTA's number.
  - If testing a new route, do not use a number, as it will be misunderstood as an existing UTA route. Describe the route instead (e.g. "ONWestWeber").
- **MODE**: 4 = local bus, 5 = BRT, 6 = express bus, 7 = LRT, 8 = CRT
- **ONEWAY**: is true if route is *only* inbound in the AM and *only* outbound in the PM. Check mode and make sure it's right. If ONEWAY=FALSE, TP+ will automatically generate the reverse direction of the route. If the bus goes on one side of the freeway, and comes back on the other, it is not necessary to code it this way. TP+ allows buses to drive up the off-ramps into on-coming traffic.
- **FREQ**: The frequency of service has been determined as the average "peak" and "off-peak" headways reported in each route's published brochure. Modifications for future years are made to simulate improved or reduced service, and to better match rail headways.
- **SPEED/TF:** On links that use HOV lanes on I-15, Insert "SPEED=65" after the appropriate node. After the last HOV node, reset to the regular speed using "TF=1".

18.2.4 Design each transit scenario to the appropriate magnitude

Because transit ridership is clearly sensitive to the amount of service, it is important that each transit scenario not drastically under or over estimate the region's funding ability – unless that is the purpose of the scenario.

- UTA reports their existing weekday service at approximately 58,000 bus-miles. The model accounts for about 49,000 of these miles. Remaining miles are attributed to service outside the region, night-routes, worker-service routes, and some single-trip routes.
- Long range plan assumptions are that it is financially feasible to construct and operate the proposed rail lines, as well as to double the bus-miles by the year 2030.
- Hence, when designing systems, a good target for 2030 bus miles is 100,000 miles.
- The assumption for 2010 is that the region can construct and operate the full commuter rail line, LRT from the airport to the medical center, and 65,000 modeled bus-miles.

- The assumption for 2020 (or sooner) is that the region can construct and operate the Jordan, Draper, and WVC spurs; and 80,000 modeled bus-miles.
- Scenarios in which there is fewer rail would free some funds for more buses.

18.2.5 Develop a rail operating plan

There are numerous ways to route trains. For example, West Jordan can be directly interlined to the U of U, or you can force a transfer at the 4th S/Main station. It is useful to consult with the various concerned parties to come up with a plan or plans that can be most easily analyzed.

18.2.6 Additional Considerations when Adding a Rail Line

Define the Route: All rail routes should be defined on nodes above 12500. Any 12500+ node that is also a rail stop should be connected to the highway network via a centroid connector. This will ensure that the model can generate walk-to-transit access to rail stations. If using the Viper editor, use Shift-click/Alt-click to create direct links between "12501-12502". Otherwise, it will erroneously route your train along city streets.

Confirm the mode: Regular bus=4, BRT=5, Xbus=6, LRT=7, CRT=8.

Confirm stops: Check the LINE record in Viper and ensure that non-stop nodes have a minus sign ("-") in front. When the route is selected, stops will have a big dot, non-stops have a little dot.

Adjust background bus network: If adding a new rail line to the mix, the new line will probably make it possible to eliminate some routes, truncate others at a rail stop, and change headways to coordinate with the rail. Adjusting the background buses to estimate the future bus-rail integration plan requires considerable professional judgment, and it is advisable to coordinate with UTA.

Generally the process of adjusting a background bus network proceeds is as follows:

- Identify bus service that competed with rail, and consider removing or truncate it into a rail station.
- Set all buses that serve a rail station at headways that are multiples of the rail headway (if rail is 10,20; bus should be 10,20 or 20,40 or 30,60; but not 15, 30). You may or may not want to redeploy the bus O&M savings by any of the following:
- If you truncate ½ the line, you can run the line twice as often.
- You can extend the bus further into the suburbs.
- You may want to add a bus or two that serves the new rail. In addition, it may be appropriate to increase or decrease the overall bus service that an area had previously. The key is that the system-wide changes above the base should be traceable and directly related to the proposed project.

18.2.7 Add Support Links

Ensure that each rail station has appropriate walk links. Develop or modify an existing support link file (see *.sup in the 3lin_* directory). As changes/additions are made, ensure they are included in the default setup. *.sup files are organized by track segment rather than route. Support records are viewed and modified in the Viper transit editor, similar to LINE records. In model space, anyone who wishes to walk for any portion of their journey may do so on any available walk link. Support modes are as follows:

11 = Auto-generated walk access/egress links. The rule is if the zone centroid is within ½ mile of a bus stop, or within ¾ mile of a rail stop (via the highway network), then walk access will be generated for the zone.

12 = User-defined access/egress links. 12 is intended to catch whatever 11 misses. When adding a rail stop, many zone centroids may actually be closer to the stop than the highway network paths suggest. In these cases, a 12 is inserted with an appropriate distance (must be under ¾ mile, or model will not use it).

20 = Auto-generated transfer links between transit lines.

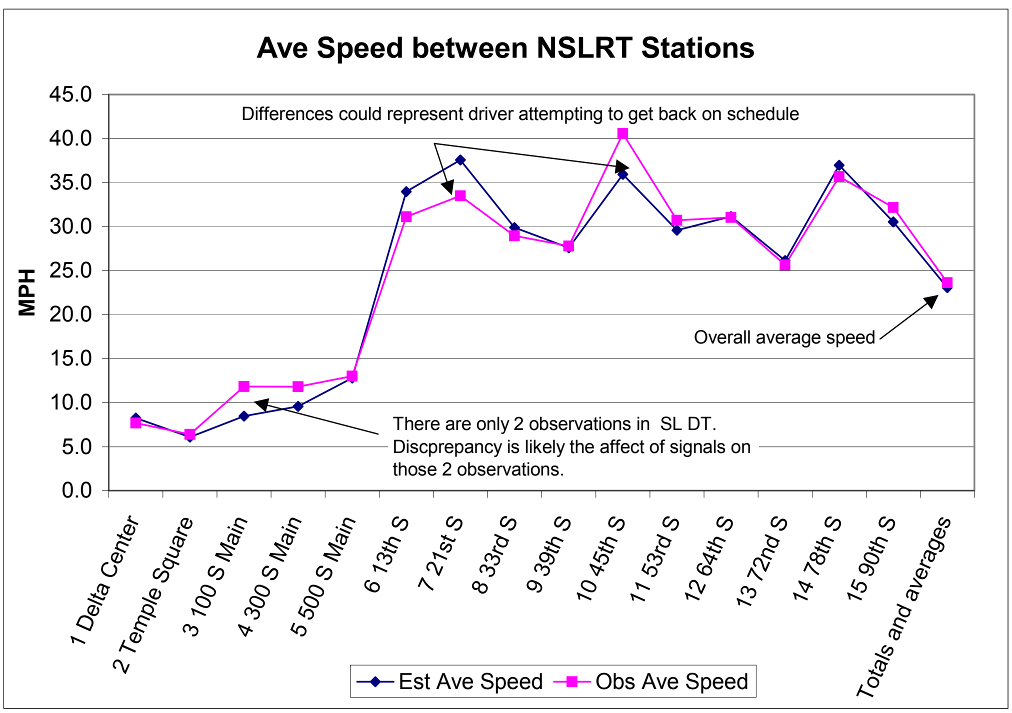
21 = User-defined transfer links.

18.2.8 Rail Speed Calculator

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 details that is necessary, 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.

The links of the rail lines are specified as separate inputs, where distance and speed are fixed. A rail speed model was developed to estimate average link speeds. Key variables in the model include accel/decel 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 30 highlights the estimated speed vs. the observed speed for the north-south TRAX line.

Figure 30: Validation of the Rail Speed Calculator



19 RUNNING SUMMIT

This document steps through the process of producing an FTA New Starts Summit analysis. If you have any questions contact WFRC modelers. This section was written for modelers familiar with the WFRC/MAG model and SUMMIT, and as such:

- This assumes you know how to set up a model run
- This assumes you know how to set up a baseline and build transit network, and what the conceptual differences between them are
- This assumes you know something about Summit and what it does

Here is an outline of the procedure for running SUMMIT:

- Run the build and baseline scenarios & produce TDM output for Summit. In the ControlCenter, set the following control: `SummitGenerateInput = 1`
    - The travel model should produce a series of text files in the 3cTmpSummit directory
        - The files are organized by trip purpose and time period:
            - HBW: home-based work
            - HBO: home-based other
            - NHB: non-home-based
            - HBC: home-based college
            - PK: peak periods (AM and PM)
            - OK: off-peak periods
            - There is no OK period for HBC (PK is daily)
    - Within each purpose/period sub-folder there are separate files for each travel market segment modeled by the mode choice model
        - HBW: (low/high income & 0/1/2+ vehicle segments)
        - HBO: (low/high income & 0/1/2+ vehicle segments)
        - NHB: no segmentation
        - HBC: no segmentation
- There are "header" text files which are small files and "summit" text files that tend to be very large files
    - For HBW/HBO/NHB each summit text file will be around 80 MB
    - The HBC summit text file will be ½ MB

- The summit text files that the travel model produces need to be converted to binary files for reading into Summit software
    - Copy the "SLCONV.exe" program into each sub-directory within 3cTmpSummit directory (except for the benefits and roll-up directories)
    - Double-click slcconv.exe and follow the directions
        - Enter the 3-character trip purpose (HBW/HBO/NHB/HBC)
        - Enter the 2-character period (PK/OK)
    - This program produces 5 files, you only need one (SLCONV.FTA):
        - SLCONV.ERR (an error file which should not have anything in it)
        - **SLCONV.FTA (the binary version of all the text files)**
        - SLCONV.REC (a file useful for debugging the code)
        - SLCONV.RPT (a report file similar to what SUMMIT produces; for debugging again)
        - SLCONV.TLF (a trip length frequency file similar to what SUMMIT produces; for debugging again
- SLCONV.FTA needs to be renamed by purpose/period and whether it is build or baseline output
    - Rename and copy each of these files to a sub-directory of 3cTmpSummit called something like "1benefits_GroupLevel"
    - 1benefits_GroupLevel is organized again by trip purpose and time period
- Within this benefits directory Summit needs to be run for each purpose/period
    - NOTE: you do not need to use the 1benefits_GroupLevel directory within both the build and baseline model directories; you only need to use one of the directories and files from both runs need to be placed in that directory
    - The binary files for build and baselines alternatives must be copied to the same directory, by purpose and time period
    - To easily rename and move all of the large binary files, use the batch files provided at the root of 3cTmpSummit
    - Rename the binary files:
        - Include the purpose and period in the new name of the file
        - Include whether the file is from the build and baseline in the new name of the file
        - Use a *.UBN file extension (not sure if this is necessary, but it works)
    - The DOS batch files allow you to easily rename many files
    - BE CAREFUL about the DOS batch file – make sure the names and directories are correct ("move" is cut-and-paste so the binary files will get moved to where you specify, possibly overwriting what was there)

    - You can safely delete the large text files once the binary files have been renamed and moved
- Summit must be run for each trip purpose and time period
    - The summit program is summit.exe and must be copied to each period/purpose subdirectory of 1benefits_GroupLevel
    - Summit needs 4 files to run:
        - TAZ-district equivalency: ***filename***.eqv (an example of the format has been provided) - summit output gets summarized at the district level
        - Two binary input files, one for baseline and one for build
        - Control file: *filename*.CTL (an example has been provided) – the control file tells Summit what to do
        - Set up the control file
- Consult FTA for a complete understanding of the SUMMIT Control file
    - Here are a few key commands:
        - freport='HBW_CRT_Ok.rpt' specify name of output report file (summary of user benefits)
        - fequiv='DistLrg.eqv' specify name of district file
        - ftable1='HBW_CRT_BASE_Ok.UBN' specify name of base user benefits input
        - ftable2='HBW_BUILD_Ok.UBN' specify name of build user benefits input
        - ftlfd='HBW_CRT_Ok.tlf' specify name of output trip length frequency file
        - frcsums='HBW_CRT_Ok.rcs' specify name of output row/column sums file
        - frcvals='HBW_CRT_Ok.rcv' specify name of output row/column values
        - fstrats='HBW_CRT_Ok.str' specify name of output file
        - fddub='HBW_CRT_Ok.d2d' specify name of district-to-district file
        - frcub='HBW_CRT_Ok.rcu' specify name of output file
        - ndists=13 specify # of districts in eqv file
        - nzones=1438 specify # of zones in model output
        - softtabi='tranplan' don't worry about this
        - !softmap='atlasgis' this is commented out
        - maxdp=60,0,0,0,60,0,0,0,60 max benefits per market
        - prteqv=t whether or not to print equivalencies in report file

- Roll-up the benefits into one summary file
    - Once the group level benefits have been produced the district-ot-district tables can be "rolled-up" into 1 useful summary report
    - Summit is used for this, but the control file is different
    - In the 1roll-up_GroupLevel directory there is an example control file (*.ctl), and an example district-Taz eqv file (must be the same as used in group level analysis)
    - The other inputs Summit needs to roll-up the district-to-district files are the d2d files themselves (one for each purpose and period)

20 MODEL HISTORY

20.1 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 fairly 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.

20.2 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. The methods and parameters in versions 1 and 2 were very similar.

20.3 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.

20.4 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)

20.5 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

20.6 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 survey data collected in 2006.

21 MODEL VALIDATION STUDIES

In 2002, the Utah Department of Transportation (UDOT), the Wasatch Front Regional Council (WFRC), and the Sierra Club signed a Memorandum of Agreement (MOA) to conduct a series of model-related studies. Two of the studies that resulted are referenced in this section. The first study compares modeled auto speeds against observed speed data. The second study analyzes the model's response to increasing roadway lane miles and specifically compares the model's ability to induce demand for roadways compared to research findings.

21.1 SPEED VALIDATION STUDY

In 2003 the WFRC completed a study that compared the estimated auto speeds from the regional travel model to actual speed data collected from 2000 to 2002[1]. This comparison was done by facility type and area type. With this comparison, WFRC was able to validate the speed estimates forecasted by the model, demonstrating that the model does a reasonable job estimating travel speeds that are input into the MOBILE emissions modeling.

An average observed and modeled speed was calculated for each segment by facility type and area type, and these averages were compared. The report contains all of the details of how this was accomplished, but below are some of the results taken directly from the report (note that table numbers have not been changed from the original report). The next three pages contain a comparison of AM Peak (6-9 AM), PM Peak (3-6 PM) and Midday (9 AM – 3 PM) observed and modeled speeds.

[1] The study report, titled "Wasatch Front Regional Council Speed Study", was finalized December 18, 2003 and is available from WFRC upon request.

Figure 31: 6-9 AM Speed Comparison from 2003 Speed Study

Table 3:
Avg. AM Observed Speed (mph)

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	66.6	63.0	59.0	N/A
Principal Arterial	46.8	34.7	31.0	24.3
Minor Arterial	44.1	30.7	30.9	25.0
Collector	N/A	27.5	26.6	20.7

Table 4a:
Avg. AM Modeled Speed (mph)
For Roads With Observed Speeds Only

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	63.8	61.0	60.0	N/A
Principal Arterial	46.4	36.8	30.9	31.6
Minor Arterial	40.8	34.1	30.7	25.2
Collector	N/A*	30.1	25.9	21.2

Table 5a:
Avg. AM Modeled Speed (mph)
For All Roads

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	63.4	63.0	62.7	N/A
Principal Arterial	43.7	36.6	31.1	30.4
Minor Arterial	40.7	34.6	30.1	25.7
Collector	N/A	30.6	26.1	21.9

Table 4b:
Avg. AM Speed Difference
For Roads with Observed Data

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	-2.8	-2.0	1.0	N/A
Principal Arterial	-0.4	2.0	-0.1	7.3
Minor Arterial	-3.4	3.4	-0.2	0.2
Collector	N/A	2.6	-0.7	0.5

Table 5b:
Avg. AM Speed Difference
For All Roads

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	-3.2	0.0	3.7	N/A
Principal Arterial	-3.1	1.9	0.1	6.1
Minor Arterial	-3.5	4.0	-0.8	0.7
Collector	N/A	3.2	-0.5	1.2

Figure 32: 3-6 PM Speed Comparison from 2003 Speed Study

Table 6:
Avg. PM Observed Speed (mph)

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	65.6	62.0	56.7	N/A
Principal Arterial	45.0	31.4	29.1	22.1
Minor Arterial	43.0	29.6	27.8	24.9
Collector	N/A	27.6	28.2	20.9

Table 7a:
Avg. PM Modeled Speed (mph)
For Roads With Observed Speeds Only

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	60.6	60.4	57.2	N/A
Principal Arterial	43.3	31.5	27.5	28.5
Minor Arterial	40.7	30.1	27.3	23.2
Collector	N/A	29.1	24.9	20.0

Table 8a:
Avg. PM Modeled Speed (mph)
For All Roads

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	61.6	62.5	59.5	N/A
Principal Arterial	41.4	32.3	27.0	27.5
Minor Arterial	39.6	31.8	27.2	23.8
Collector	N/A	29.9	25.3	21.5

Table 7b:
Avg. PM Speed Difference
For Roads with Observed Data

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	-4.9	-1.5	0.5	N/A
Principal Arterial	-1.6	0.0	-1.7	6.4
Minor Arterial	-2.2	0.6	-0.5	-1.7
Collector	N/A	1.4	-3.4	-0.9

Table 8b:
Avg. PM Speed Difference
For All Roads

	Area Type Group			
Facility Type	**Rural**	**Suburban**	**Urban**	**CBD**
Freeway	-4.0	0.5	2.8	N/A
Principal Arterial	-3.6	0.9	-2.1	5.4
Minor Arterial	-3.4	2.2	-0.6	-1.2
Collector	N/A	2.3	-2.9	0.6

Figure 33: 9 AM - 3 PM Speed Comparison from 2003 Speed Study

Table 9:
Avg. Midday Observed Speed (mph)

Facility Type	Area Type Group			
	Rural	**Suburban**	**Urban**	**CBD**
Freeway	67.3	67.2	65.5	N/A
Principal Arterial	46.5	34.3	29.3	20.7
Minor Arterial	40.8	31.8	30.4	24.4
Collector	N/A	29.4	28.0	20.6

Table 10a:
Avg. Midday Modeled Speed (mph)
For Roads With Observed Speeds Only

Facility Type	Area Type Group			
	Rural	**Suburban**	**Urban**	**CBD**
Freeway	65.0	65.0	64.7	N/A
Principal Arterial	48.0	37.6	31.8	30.7
Minor Arterial	41.7	34.9	31.6	25.1
Collector	N/A	30.7	25.8	20.2

Table 11a:
Avg. Midday Modeled Speed (mph)
For All Roads

Facility Type	Area Type Group			
	Rural	**Suburban**	**Urban**	**CBD**
Freeway	65.0	65.0	64.7	N/A
Principal Arterial	44.7	37.7	32.2	31.3
Minor Arterial	41.3	35.3	30.4	26.0
Collector	N/A	30.8	26.2	21.9

Table 10b:
Avg. Midday Speed Difference
For Roads With Observed Speeds Only

Facility Type	Area Type Group			
	Rural	**Suburban**	**Urban**	**CBD**
Freeway	-2.3	-2.2	-0.9	N/A
Principal Arterial	1.5	3.3	2.5	10.0
Minor Arterial	0.9	3.1	1.2	0.7
Collector	N/A	1.3	-2.2	-0.4

Table 11b:
Avg. Midday Speed Difference
For All Roads

Facility Type	Area Type Group			
	Rural	**Suburban**	**Urban**	**CBD**
Freeway	-2.3	-2.2	-0.8	N/A
Principal Arterial	-1.8	3.4	2.8	10.6
Minor Arterial	0.5	3.5	0.0	1.6
Collector	N/A	1.4	-1.8	1.9

21.2 STUDY OF THE MODEL'S SENSITIVITY TO INDUCED DEMAND

In 2002, the Utah Department of Transportation (UDOT), the Wasatch Front Regional Council (WFRC), and the Sierra Club signed a Memorandum of Agreement (MOA) to conduct a model sensitivity analysis of the WFRC model. The purpose of this analysis was to determine the model's ability to represent induced travel and to calculate the elasticity of vehicle-miles traveled (VMT) for "no-build" and "highway build" scenarios.

The Consultant team of Cambridge Systematics, Inc. and Fehr & Peers Associates, Inc. was selected by UDOT to conduct the required sensitivity analysis[1]. As required by the MOA, UDOT's Consultant team was required to "conduct a sensitivity test that indicates the model's representation of induced travel by simulating a no-build scenario and a highway-build scenario and calculating the elasticity of vehicle miles traveled (VMT) with respect to lane-miles of freeway and travel time. UDOT also will conduct sensitivity tests of the WFRC travel demand sub-models' representation of induced travel. This can be done by holding constant the following components of induced travel from the future base case scenario to the highway-build scenario: 1) land use; 2) auto ownership; 3) trip generation; 4) trip distribution; 5) mode choice; and 6) traffic assignment. It was agreed by study stakeholders that the trip generation elements of the model including auto ownership and land use/population forecasts, would be held constant for all sensitivity scenarios tested.

This study focused on assessing the ability of the currently available Version 2.1 of the WFRC/MAG TP+ models to simulate induced travel and conform to expected ranges of model elasticity. Based on analyses conducted during this study, the project team has concluded that this version of the WFRC/MAG model is sensitive to changes in the highway network and appears to result in logical cause and effect relationships based on summaries of a wide range of model-generated statistics. These expected relationships include the following:

- Model elasticities fall within the expected range of acceptability based on comparisons with elasticities cited in a variety of research papers;
- The most dramatic elasticities equate with adding the most significant highway corridor project, the Mountain View Corridor (Alternative 3);
- Elasticities reported under "build" conditions are impacted more by the trip distribution step than the mode choice or highway assignment steps;
- Vehicle-miles traveled generally increased with the addition of specific roadway projects while vehicle-hours traveled generally decreased; and
- Regional congested roadway speeds increased with the addition of each highway project while the percent transit trips decreased as did trip lengths.

It is hoped that the findings of this study will add credence to the findings of recent and ongoing Environmental Impact Studies in showing that the WFRC/MAG travel demand model appears to provide logical results. It is further desired that this effort will add to the body of research on induced travel and

---

[1] The study report is titled "Wasatch Front Regional Council (WFRC) Model Sensitivity Testing and Training Study" and is available from WFRC or UDOT upon request.

provide a better understanding of the anticipated effects new roadway projects have on vehicle-miles traveled and percent transit mode split. Finally, it is anticipated that the results from this study will be useful in conducting additional sensitivity assessments with updated versions of the WFRC/MAG model and will establish an anticipated set of performance standards for future year model simulations.

22 FORMAL PEER REVIEWS

22.1 MAY 18 - 19, 1999 PEER REVIEW

The Federal DOT, in cooperation with WFRC, UDOT, and UTA, facilitated a peer review of the WFRC travel demand models. The review was conducted Tuesday and Wednesday, May 18 -19, 1999 at the Bountiful, Utah City Hall. The purpose of the review was to help WFRC respond to questions raised during the public participation process on the validity and capabilities of the model used for the development of the WFRC Long Range Transportation Plan. An impartial panel of travel demand practitioners was convened to: (1) review the WFRC model and its assumptions with respect to the current state of the practice, and (2) identify approaches that would enhance the model to better respond to policy issues of local concern. Members of the public were also given the opportunity throughout the review to identify these policy issues. Panel members as well as other participants are listed as follows:

Panel Members

- Paul Hershkowitz, HNTB Corporation, East Lansing, MI
- Mark Schlappi, Systems Analysis Program Manager, Maricopa Association of Governments, Phoenix, AZ
- Richard E. Walker, Travel Forecasting Manager, Metro Regional Government, Portland, Oregon

Other Participants

- Elizabeth Sherry Riklin, Community Planner, Federal Transit Administration, Washington DC
- Brian Gardner, Federal Highway Administration, Washington, DC
- Harlan Miller, Federal Highway Administration, Utah Division Office
- Don Cover, Federal Transit Administration, Region VIII
- Susan Martin, Federal Transit Administration, Region VIII
- Jeff Houk, Environmental Protection Agency

In addition, many other public and private groups attended the peer review, including the Utah Attorney General's Office, UDOT, UTA, WFRC, MAG, local government, consulting firms, resource agencies, advocacy groups, and the University of Utah. A detailed list of attendees can be found in the peer review documentation. (WFRC, Travel Demand Model Peer Review, "Summary of Proceedings.")

Comments and Recommendations (May, 1999)

The peer review panel concluded that WFRC is utilizing standard travel demand modeling procedures and recommended that the following initiatives be undertaken to respond to issues of local concern:

- Immediate (January 2000)
    - Convene a Travel Demand Model Steering Committee
    - Merge the Salt Lake City and Ogden travel demand models into one unified model
    - Create daily, AM Peak, PM peak, and midday trip tables

    - Validate the trip distribution model
    - Implement a feedback mechanism to trip distribution using the successive averages approach for convergence
    - Prepare adequate documentation of the travel demand model assumptions and validation
- Short Term (2002 Long Range Plan)
    - Enhance the model components to improve its ability to generate information on issues of local concern
- Long Term (Beyond the 2002 Long Range Plan)
    - Continue to explore and incorporate model enhancements to maintain its ability to generate information on issues of local concern

Table 30: May 1999 Peer Review Recommendations

Model Component	Immediate Improvements (*January 2000)*	Short Term Improvements (*2002 Long Range Plan)*	Long Term Improvements (*2005 Long Range Plan)*	*General Comments*
General Recommendations	• Assemble Validation Data Base • Document Validation • Establish travel demand model steering committee • Combine SLC and Ogden Models	• Conduct an External Station Survey • Conduct a Commercial Survey • Include non-motorized trips through the model steps	• Conduct a Stated Preference Survey to support the refinement of a the mode choice component of the model	• *Execute full model set for each alternative analyzed*
TAZs and Network	• Include modified delay functions for freeway links • Define link capacities as possible capacities not "level of service C" capacities	• Split peripheral zones • Code HOV lanes into network • Explore alternatives to the BPR curves for freeways and arterials		
Socio-Economic and Land Use	• Conduct a Delphi Review of Land Use Allocations	• Conduct Delphi Review of Land Use Allocations • Include households, income and age as basic data base for the worker model • Incorporate an auto ownership model reflecting urban design and accessibility variables	• Incorporate the Urban Sims Model	
Trip Generation	• Compare Peer City Trip Rates • Document explanation of significant differences	• Cross Classification Model: productions are a function of households, income, auto ownership •		• The Peer Review Panel found the household survey to be adequate.

Model Component	Immediate Improvements (*January 2000*)	Short Term Improvements (*2002 Long Range Plan*)	Long Term Improvements (*2005 Long Range Plan*)	*General Comments*
Trip Distribution	• Feedback: successive averages approach to convergence • AM Peak , PM Peak and mid-day trip tables to create input skims for distribution	• Bring in travel time costs as function of distance	• Explore Logit Distribution Model	• The Peer Review Panel determined that the auto speeds included in the distribution model were acceptable.
Mode Choice	• Include 1992 Mode Choice documentation in overall documentation • Improve highway assignment to eliminate "floor" on bus speeds	• revise mode choice model to include socio-economic and urban design variables • develop logit HBO and NHB mode choice models • Include walk and bike modes • Include HOV component in mode choice model • Calibrate on local data	• Incorporate stated preference survey • Establish rail as a separate mode • Investigate incorporation of HOT lanes techniques into model set	• The Peer Review Panel encourages a before and after study of North South LRT; • The Peer Review Panel suggests that WFRC consider utilization of transferable model structure in the short term; • The Peer Review Panel identifies the separate college trip component as a good model refinement; • The Peer Review Panel encourages the inclusion of variables which describe the place, i.e. urban design variables.
Transit Assignments	• Document route boarding: and route assignment comparison		• Document path building assumptions	

Model Component	**Immediate Improvements** (***January 2000)***	**Short Term Improvements** (***2002 Long Range Plan)***	**Long Term Improvements** (***2005 Long Range Plan)***	***General Comments***
Traffic Assignments	• Develop and apply assignment validation criteria such as recommended by FHWA and Caltrans, Michigan DOT and other cities • Create peak period (multi-hour, AM, PM) and mid-day assignments • Document assignment assumptions, calibration and validation	• Develop peak spreading tool to forecast AM and PM peak hour demand • Develop HOV assignments capability • Conduct travel speed study		

22.2 JANUARY 2002 PEER REVIEW

A peer review was held January 7 - 8, 2002 at the WFRC office building in Salt Lake City, Utah. The review was one of the initial steps in an effort to improve the travel demand model set within the context the ongoing changes in the state-of-the-practice in travel demand model development and application. This effort was launched in response to ongoing lawsuits over the Legacy Highway, upcoming NEPA documents and New Starts funding requests for commuter rail lines and light rail extensions, and conformity determinations for the region's transportation plan. Review participants included:

- Jim Ryan, FTA
- Will Jeffries, Director of Transportation Planning, WFRC
- Mick Crandall, Manager of Travel Forecasting, WFRC
- several WFRC technical staff
- Brian Gardner, FHWA Headquarters
- Harlan Miller, FHWA Utah division
- Bill Davidson, Parsons Brinkerhoff

The 2002 peer review also followed up on the 1999 peer review. It concluded that many of the appropriate recommendations have been implemented since the 1999 review within resource constraints and that the recommendations put forward by the 1999 review focused on extending the WFRC models firmly towards "best" practice modeling.

The peer review further concluded that:

1. overall, the Regional Travel Model compares quite favorably to peer, large urban areas across the United States
2. the complete set of models represents appropriate "standard" practice with selected model components/elements which reflect "best" practice
3. the model system is clearly capable of addressing area wide conformity determinations along with corridor specific analyses.

The peer review offered the following suggested improvements to the Regional Travel Model. (These recommendations are internally consistent with and for the most part extend the recommendations offered by the 1999 peer review panel.)

- On-Board Survey Data:
    - Upon release of the Fall 2001 On-Board Survey, there will be an opportunity to carefully evaluate light rail (as well as bus) riders, their travel markets and distribution patterns.
    - Combined with the 1993 Home-Interview Survey, the disaggregate estimation of original mode choice model coefficients may be possible.
- Near Term Suggested Improvements:

- Originally estimate a set of utility variable coefficients for each purpose-specific model using data from the 1993 Home-Interview Survey and the most recent On-Board Transit Survey; or, at a minimum, design and implement nested logit mode choice models for existing purposes and (if necessary) individual coefficient values
- Modify park-and-ride and transit specifications in the mode choice model to achieve better supply and demand equilibrium
- Better represent destination zone parking cost and availability, perhaps with a parking lot choice model
- Incorporate HOV and commuter rail service into mode choice logit structure
- Incorporate the measurement and representation of walk access and egress time for transit users.
- Use 1993 Home-Interview Survey to originally estimate auto ownership model specifically for WFRC metropolitan area
- Redefine the "special generators" into a set of special travel markets and more directly model their behavior
- Incorporate stratification into the Home-Based Work trip distribution model
- Review and possibly combine Ogden, Salt Lake, and Provo/Orem cross-classification trip production rate tables

Two selected aspects of the current *highway assignment process* would benefit from a careful review, and if appropriate, modest adjustments to the set of parameters which underlie the application. The algorithm used to compute highway network impedance relies upon an equation which is a function of time and distance. The variable relationships reflected in this computation were implemented to address a systematic over-assignment of volumes to higher level roadway facilities. To a large extent, this impedance measure works in concert with the volume-delay functions used to compute travel speeds based upon roadway volumes. There have been a number of recent advances in the theory and underlying principles that are used to specify both the impedance function and the volume-delay relationships. Testing and evaluating these improvements would be the subject of this sixth area of possible enhancement.

Following the development, implementation, and calibration of each of the six areas of potential improvements to the models, a *current year model validation* effort would be undertaken to demonstrate the ability of the models to replicate base year conditions. If possible, the model validation year should be updated, depending upon the availability of traffic count and transit ridership data.

Comments and Recommendations (January, 2002)

The existing model set is generally consistent with current practice at MPOs in regions of similar size and complexity that have similar responsibilities.

Some components of the travel-forecasting model set need attention in the near term:

- Trip Distribution

- The distribution of trips by persons from car-less households should be based on an accessibility measure that recognizes the presence or absence of transit service rather than the highway travel time used in the current procedure.
- The distribution of trips to/from campuses by' college students should be derived from enrollment records at each of the colleges within the metropolitan area — and not through a trip distribution model. Forecasts of future student-commuter patterns can be accomplished though factoring of the base-year patterns to account for enrollment growth on each campus.
- Careful analysis is warranted of the performance of trip distribution models in future-year forecasting. Where iterations fail to achieve consistency on the estimated and predicted trip attractions in individual zones, inspection of the results may shed light on the reasonableness of predicted growth patterns. Iteration failure might suggest the infeasibility of a land use forecast that substantially increases distances between residential, employment, and commercial locations.

- Mode Choice
  - The mode choice analysis for home-based non-work and non-home-based trips should be accomplished with choice models rather than the factoring process used in the current procedure.
  - While the structure of the mode choice model for home-based-work trips is generally sound, several variables, coefficients, and constants in that model need updating. In particular, the term that increases the transit share for light rail and commuter rail as a function of travel distance should be dropped. (That term is likely a major contributor to the preliminary WFRC forecast of 35,000 daily commuter rail trips in 2025.) Validation against the fall-200 1 on-board survey should be the principal means of deriving new parameters for the model that recognize current transit ridership patterns on both bus and rail.
- Transit Validation
  - Part of The validation against current transit patterns should include inspection of transit access volumes and the adequacy of representation of transit access within the forecasting procedures. If walk-access volumes are misrepresented, then a return may be warranted to the former coding of the walk-accessibility to/from transit in each zone.
  - Care will be needed to recognize explicitly the effects of capacity limitations on current rail ridership during calibration of new model parameters. Ideally, these effects will be captured in "shadow prices" external to the models rather than constants internal to the models. That result will permit reliable analysis of the effects of planned capacity expansion (more park/ride spaces and some additional light rail vehicles).
  - To the extent that several special travel markets are contributing significant ridership to the rail system, methods should be developed to predict those ridership components.
  - That approach will avoid the over-statement of ridership contributed by the conventional travel markets that are considered by the current models. Special travel markets that deserve

attention may include travel to special events, travel by air-passengers to/from the airport, circulation travel within downtown, and travel by non-residents.

- Validation against current highway and transit volumes and speeds should also be used to clean up various minor difficulties identified during the discussion, including a reassessment of the heavy weight on distance (75% distance and 25% time) in the path-building criterion for highway assignment.
- Socio-demographic forecasting
    - Closer coordination with local jurisdictions might be useful in predicting the magnitude and patterns of socio-demographic changes in each jurisdiction.
    - An approach is needed to recognize the impact of major transportation system changes on growth patterns. A panel of experts, including local planning staffs, would be sufficient. Calls to the MPOs in Washington DC and Milwaukee might provide helpful insights into the approaches used by other MPOs. Continued investigation of the UrbanSim land-use forecasting model may also prove useful in the long run.