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I.Introduction

The Grants Pass model was developed to address the need for a travel demand forecasting tool that could be used for a variety of purposes, including transportation system planning in a manner consistent with the Oregon Transportation Planning Rule, the preparation of subarea transportation studies, the analysis of the transportation system impacts of large-scale development proposals, and the evaluation of the effects large-scale transportation projects.

The general structure of the model follows a basic four-step process consisting of pre-generation, trip generation, trip distribution, and traffic assignment. Within the pre-generation step, all of the necessary inputs for trip generation are produced using a set of household submodels that stratify households by number of workers, household size, and number of workers by household size. The trip generation model produces person trip productions by trip purpose for each hour of the day. Within the trip distribution step, a destination choice model is used to distribute internal-internal trips, while internal-external, external-internal, and external-external trips are handled with separate procedures. Prior to trip distribution, a special model is used to estimate the percentages of external-external traffic at each external station as well as a daily through trip matrix. Trip assignment is performed using a single-class, equilibrium capacity restraint technique.

The model is implemented entirely through a series of script files written in the R statistical programming language, with the exception of traffic assignment, which is carried out in EMME/2.

The development of the model consisted primarily of calibrating and validating the Oregon Small Urban Model (OSUM) for the Grants Pass area. OSUM was estimated by the Oregon Department of Transportation with assistance from Portland Metro staff. The household activity survey data used for the model estimation was collected from a sample of 3,200 households in eight rural counties throughout Oregon.

The first three sections of the documentation provide an overview of the model and model development process (Section I.), an explanation of how the overall model structure was defined (Section II.), and a description of the model zone system and network (Section III.). Section IV. provides references to the survey data used for the OSUM estimation. Section V. describes the general types of input data that are used in the model. Section VI. contains “nuts and bolts” information about the structure of the individual model components. Finally in Section VII., the model validation process and validation results are presented.

II. Model Structure

Identification of Model Requirements

Because the development process for the Grants Pass model consisted primarily of calibrating and validating OSUM for local conditions rather than developing the model "from scratch", the identification of model requirements was done largely as a part of the OSUM development project. These requirements reflect the general modeling needs of small urban areas throughout the state.

As described in the *ODOT Travel Demand Model Development and Application Guidelines*,[1] all models must conform to the TPR. While the TPR does not regulate transportation modeling, it does set the requirements for the preparation of local TSPs that "establish a system of transportation facilities and services adequate to meet identified local transportation needs".[2] Some of these requirements have direct implications for the type of models that are needed for developing TSPs, namely that:

- Within urban growth boundaries, the determination of transportation needs must be based upon population and employment forecasts and distributions for at least 20 years that are consistent with the acknowledged comprehensive plan, as well as measures to encourage reduced reliance on the automobile; and
- TSPs must be based upon the evaluation of system alternatives that may include improvements to existing facilities or services, new facilities and services, including different modes of transportation that could reasonably meet identified needs, transportation system management measures, and demand management measures.

Also, in areas such as Grants Pass that have been designated as in non-attainment of the National Ambient Air Quality Standards, additional requirements are specified within the *ODOT Travel Demand Model Development and Application Guidelines.* The following model features are defined as necessary in non-attainment areas:

- Trip generation model that estimates person trips, with segmentation by trip purpose;
- Auto ownership model that provides information to other model components;

[1] Oregon Department of Transportation, Travel Demand Model Development and Application Guidelines, (1995).
[2] Oregon Land Conservation and Development Department, OAR 660-012-0005, (1999).

- Trip distribution model stratified by same trip purposes as trip generation model and that uses spatial separation measure;
- Network-sensitive mode choice model that separates motorized from non-motorized person trips and estimates vehicle trips;
- Estimation of commercial and external vehicle trips; and
- Traffic assignment using equilibrium capacity restraint technique.

In addition to the development of TSPs, several other required uses for models in small urban areas are the preparation of subarea transportation studies, in which a model is focused for a subarea of the city or county to examine detailed land use or transportation system alternatives, analysis of the transportation system impacts of large-scale development proposals, evaluation of the effects large-scale transportation projects, such as bypasses, and, in certain areas, the establishment and administration of system development charge (SDC) systems.

Alternative Model Forms

The basic form of the model was established as a part of the OSUM development project, so that the consideration of alternative model forms was not relevant for the Grants Pass model. Two significant decisions needed to be made, however, regarding the specifics of implementing OSUM for the Grants Pass area.

The first issue was determining the most appropriate method for estimating external-external (through) trip percentages for the external stations, as well as a daily through trip matrix, because origin-destination survey data for these trips was not available. These are important inputs for small urban area models, since a large percentage of total trips can be comprised of trips with one or both ends outside of the modeling area.

Two methods were considered. The first method was the Modlin model, as documented in *NCHRP Report 365, Travel Estimation Techniques for Urban Planning*.[3] This method estimates through trip ends at external stations based on functional classification, ADT, truck volume, and the population of the modeling area, as well as the distribution of these trips based on the percentage of through trips at each destination station, route continuity between the external station pairs, and the ADT at each destination station. The second method, referred to as the Huff probability model, is based on the implementation of the standard gravity model at the subregional level. Because of its ease of use, the Modlin model was tested first. It was found that with manual adjustments, this method produced reasonable results, which were used within the model. This procedure is described in detail in Section VI. on pages _ - _.

[3] Transportation Research Board, NCHRP Report 365, Travel Estimation Techniques for Urban Planning, (1998).

The second issue to be addressed was related to trip generation in the rural areas outside of the Grants Pass urban growth boundary (UGB). In OSUM, no distinction is made between rural and urban trip generation characteristics. It was found, however, that the model was overestimating tripmaking in the these areas. This was an important issue, since over one-half of total population in the Grants Pass modeling area lies outside of the UGB. Therefore, it was decided that rural trip generation characteristics needed to be explicitly represented within the model. This is described in Section VI. on page _.

Model Structure

(This section to be completed when revised version of OSUM model flow chart received from ODOT).

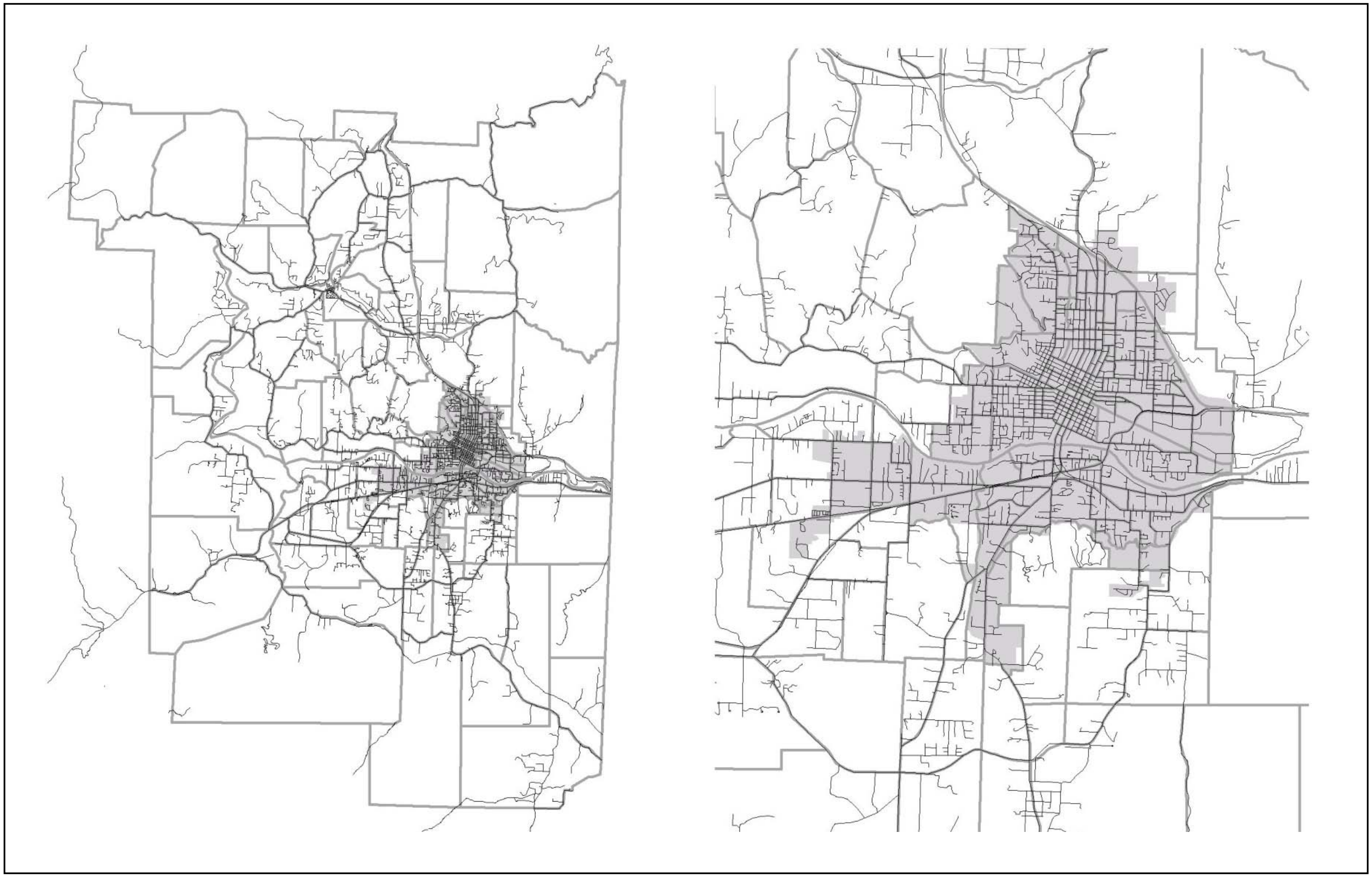
III. Zone System and Highway Network

As shown in Figure 1, the boundaries of the modeling area extend as far north as Sexton Pass along I-5, as far south as Powell Creek Rd., to the Jackson County line to the east, and to the Siskyou National Forest to the west. The internal TAZs are aggregations of census blocks. There are seven external stations located at the periphery of the modeling area on I-5 to the north of Sexton Pass, I-5 to the south at the Jackson County line, Foothill Blvd. at the Jackson Co. line, Rogue River Hwy. (ORE 99) at Savage Creek Rd., Jacksonville Highway (ORE 238) at Applegate Rd. (Jackson Co.), Williams Hwy. at Water Gap Rd., and Redwood Hwy. (US 199) at Waters Creek Rd. The TAZ numbering scheme is 1 – 7 for external stations and 100 – 364 for internal zones.

III. Zone System and Highway Network

Figure 1

Grants Pass Model TAZ System



Highway Network

All roads with a functional classification of minor collector or higher were included in the coded highway network, as well as local roads that connect higher level facilities or subareas or that connect TAZs to the remainder of the network. The more important node and link attributes are listed in Tables 1 and 2 below.

Table 1

Node Attributes

Attribute	Value	Description
I.D.	1-364	Zone centroid
	≥1000	Regular node
Type	C	Zone centroid
	R	Regular node
User Field 1	0/1	No traffic signal/ traffic signal

Table 2

Link Attributes

Attribute	Value	Description
Type	1	Freeway
	2	Principal arterial
	3	Minor arterial
	4	Collector/Minor collector
	5	Local
	9	Centroid connector
	30	Freeway ramp
VDF	1	Signalized facility
	2	All other
	3	Centroid connector
User Field 1	20-65	Free-flow speed

Attribute	Value	Description
User Field 2	450-1900	Capacity/lane

Link speeds were coded using posted speed limits. Capacities were coded based upon facility type and area type using the look-up table shown below.

Table 3

Link Capacity Look-Up Table

Facility Type	CBD	CBD Fringe	Res.	Rural
Freeway	1900	1900	1900	1900
Principal Arterial	700	800	850	950
Minor Arterial	575	625	700	760
Collector/Minor Collector	450	500	525	650
Local	400	450	500	625
Centroid Connector	9999	9999	9999	9999
Freeway Ramp	850/1000	850/1000	850/1000	850/1000

IV. Survey Data

OSUM was estimated using household activity data from a two-day survey of 3,200 households in eight counties (Clatsop, Coos, Deschutes, Josephine, Klamath, Lincoln, Malheur, and Umatilla) that provided a good geographical cross-section of Oregon's rural areas. For specific information on the survey methods, survey data preparation, and survey results, the reader is referred to the *Oregon Travel Behavior Survey, Summary of Findings*[4], prepared by the Oregon Department of Transportation, which may be found at:

http://www.odot.state.or.us/tddtpau/papers/surveys/Final8Counties.pdf.

[4] Oregon Department of Transportation, Oregon Travel Behavior Survey, Summary of Findings, (2000).

V. Input Data

Socioeconomic and Land Use Data

Data	Input To:	Data Source
1. Base year households by size category (TAZ)	1. Household size submodel 2. Household submodel	Census data
2. Base year population (census block)	Household size submodel	Census data
3. Base year households by size category (census block)	Household size submodel	Census data
4. Future population (TAZ)	Household size submodel	City, county staff
5. Future households (TAZ)	1. Household size submodel 2. Household submodel	City, county staff
6. Base year households by income category	Household submodel	Census data
7. Regional households by size-income category	Household submodel	PUMS data
8. Base year households (TAZ)	Special generator model	Census data
9. Retail employment	Destination choice model	1. Base year – ES202 data 2. Future – City, county staff
10. Service employment	Destination choice model	1. Base year – ES202 data 2. Future – City, county staff
11. Other employment	Destination choice model	Calculated*
12. Households	Destination choice model	1. Base year – Census data 2. Future – City, county staff
13. School enrollment	Destination choice model	1. Base year – School district 2. Future – City, county staff
14. Regional households	Modlin model	Census data

* Calculated as: Other Employment = Total Employment – Retail Employment – Service Employment

Travel Time Data

V. Input Data

Auto travel time skims are used as input to the destination choice model. Separate sets of skims are produced for the peak and off-peak time periods. Peak hours are defined as between 7:00 a.m. and 8:00 p.m. and off-peak hours as between 8:00 p.m. and 7:00 a.m.

Free-flow travel times are used for the off-peak period. The skims are prepared by performing a zero-iteration assignment using zero-valued scalar matrix. Following the assignment, intrazonal travel times are computed for each TAZ as one-half of the travel time to the nearest neighboring zone and then added to the free-flow travel time matrix. A terminal time of 0.75 minutes is then added for both the production zone and the attraction zone.

Congested travel times are used for the peak period. The peak period skims are prepared by performing an a.m. peak hour assignment (8:00 - 9:00 a.m.) and adding the intrazonal and terminal times as is done for the off-peak skims. An a.m. rather than p.m. peak hour assignment is performed because this produces congested times in the proper (P–A) direction, which are needed for the destination choice model. (A p.m. peak hour assignment would produce uncongested, or less congested, times in the P-A direction). The final peak period skims are developed after the second iteration of destination choice and trip assignment, since free flow travel times must by necessity be used as input to the destination choice model on the first iteration.

Other Input Data

Data	Input To:	Data Source
1. Time-of-day factors by trip purpose	1. Trip generation model 2. Special generator model	OSUM
2. Daily special generator trips ends	1. Special generator model 2. E-I, I-E models	1. Trip generation rates – *ITE Trip Generation Manual*[5] 2. Trip generation data – local staff
3. % of I-I special generator trips	1. Special generator model 2. E-I, I-E models	Local staff
4. Avg. vehicle occupancy	1. Special generator model 2. Destination choice model	OSUM
5. Directional factors	Destination choice model	OSUM
6. External station ADT	E-I, I-E, E-E, Modlin models	1. Base year – traffic counts 2. Future – extrapolated base year ADT
7. Time-of-day factors for	E-I, I-E, E-E models	Traffic counts

[5] Institute of Transportation Engineers, Trip Generation 6th Edition, (1997).

V. Input Data

Data	Input To:	Data Source
external stations		
8. Percentage of trucks at external stations	Modlin model	Traffic counts
9. Percentage of vans and pickups at external station	Modlin model	Traffic counts

VI. Model Components

The general structure of the model follows a basic four-step process consisting of pre-generation, trip generation, trip distribution, and traffic assignment. Within the pre-generation step, all of the necessary inputs for trip generation are produced using a set of household submodels that stratify households by number of workers, household size, and number of workers by household size. The trip generation model produces daily person trip productions by trip purpose for each hour of the day. A special generator model is also included which estimates daily trip ends for five special generators and then allocates the trips to internal TAZs. Within the trip distribution step, a destination choice model is used to distribute internal-internal trips, while internal-external, external-internal, and external-external trips are handled with separate procedures. Prior to trip distribution, a special model is used to estimate the percentages of external-external traffic at each external station as well as a daily through trip matrix. Trip assignment is performed using a single-class, equilibrium capacity restraint technique.

Within the following sections, each model component is described in a standard format. A brief description of the model's function, relationship to other components, and basic structure is followed by the definition of variables (including variable names), allowable values (if applicable), and data sources. The calibrated model functions are then listed, as well as the estimated model coefficients from the OSUM development project. Because of the lack of base year travel survey data specific to the Grants Pass area, comparisons of observed travel data to estimated model data are not available.

Pre-Generation

In the pre-generation step, estimates are prepared for each TAZ of the number of households by:

- Size category (1, 2, 3, and 4+);
- Number of workers category (0, 1, 2, and 3+); and
- Size and number of workers categories.

These estimates are required inputs to the trip generation models discussed in the next section.

For the base year, the households by size distributions were obtained directly from 2000 Census data. Information on future households by size category was calculated by adding estimates of household growth to the base year distributions. Probabilities for the number of workers per household were estimated based on joint household size and income distributions for both the base and future years. Joint distributions of the number of households by size and number of workers were derived using the joint household size and income distributions and the worker probabilities.

Household Size Submodel

The household size submodel produces estimates of the future number of households by size category for each TAZ. This information is used as input to the trip generation models described in the next section.

The household submodel is implemented within the _________ module shown in the model flowchart according to the following steps:

1. 2000 Census data for the entire model area is used to fit a relationship between average household size and the proportion of households in each household size category. The curves are iteratively fit using cubic splines according to the constraints that:

    - for each average household size, the sum of the proportions equals one;
    - the proportion of one-person households equals one for the average household size of 1.0; and
    - the proportions for the areawide average household size equal the areawide proportions.

2. Future average household size for the model area is calculated from projections of future population and future households.

3. The areawide distribution of future households by size is calculated using the model from Step 1., the average household size from Step 2., and the future household total.

4. The proportion of total new households within each size category is obtained by subtracting the existing households from the future households within each category and then calculating the proportions.

5. Changes in the number of households by size category are calculated for each TAZ by multiplying the total change in households by TAZ by the areawide proportions from in Step 4.

The changes in households by size category are added to the base year household size distributions within the household submodel described on page _ to obtain future distributions by TAZ.

DEFINITION OF VARIABLES

Name	Description	Values	Data Source
HHS_BASE	Base year households by size category (TAZ)	N/A	Census data
POPBASE	Base year population (census block)	N/A	Census data
HHS_BASE	Base year households by size category (census block)	N/A	Census data
POPFUTUR	Future population (TAZ)	N/A	City, county staff
HHFUTUR	Future households (TAZ)	N/A	City, county staff

CALIBRATED MODEL FUNCTIONS

The model does not contain calibrated functions.

ESTIMATED VARIABLE COEFFICIENTS

See above.

Household Worker Submodel

The household worker submodel estimates worker probabilities as a function of household size and income. The probabilities are used in the household submodel together with the joint distribution of households by size and income to calculate the number of households by size and number of workers for each TAZ. This distribution is input to the trip generation model.

The first step in the worker submodel is the calculation of worker utilities for each combination of household size (1, 2, 3, and 4+) and income category *(find out from Sam what the income categories are)*. The utility equations were estimated as a part of the OSUM development project.[6] Following this, worker probabilities are calculated based on the utilities. The probabilities are stored as an array, with the number of workers as the rows, income category as the columns, and household size as the tables.

DEFINITION OF VARIABLES

Name	Description	Values	Data Source
HHSIZE	Household size category	1-4	N/A
INCOME_	Dummy variables for household income category	0, 1	N/A

CALIBRATED MODEL FUNCTIONS

$$Utility_{0\ wkr} = 0$$

$$Utility_{1\ wkr} = -1.462 + 0.6092*HHSIZE + 0.5369*INCOME3 + 0.6864*INCOME4$$

$$Utility_{2\ wkr} = -4.488 + 1.323*HHSIZE + 0.6838*INCOME2 + 1.464*INCOME3 + 2.458*INCOME4$$

$$Utility_{3+\ wkr} = -10.09 + 2.4898*HHSIZE + 1.254*INCOME3 + 2.448*INCOME4$$

6

Pre-Generation - Household Worker Submodel

ESTIMATED VARIABLE COEFFICIENTS

Variable Name	**1 Worker**		**2 Worker**		**3+ Worker**	
	Coeff.	**T - Statistic**	**Coeff.**	**T - Statistic**	**Coeff.**	**T - Statistic**
Constant	-1.462	**?**	-4.488	**?**	-10.09	**?**
HHSIZE	0.6092	**?**	1.323	**?**	2.4898	**?**
INCOME1	0.0	N/A	0.0	N/A	0.0	N/A
INCOME2	0.0	N/A	0.6838	**?**	0.0	N/A
INCOME3	0.5369	**?**	1.464	**?**	1.254	**?**
INCOME4	0.6864	**?**	2.458	**?**	2.448	**?**

(Sam will check on T-statistic values from OSUM development project).

The 0-worker choice utility is held constant at zero.

Household Submodel

The household submodel uses the output from the household size and worker submodels to produce distributions of the number of households by size and worker category (0, 1, 2, and 3+) and the number of households by worker category for each TAZ. For the base year, the household submodel functions as follows:

1. Distributions of the number of households by size category obtained from the 2000 Census data are input for each TAZ.

2. Distributions of the number of households by income category obtained from the 2000 Census data are input for each TAZ.

3. A joint household size and income distribution is calculated for each TAZ from the marginal household size and income distributions using an iterative proportional fitting procedure and a seed matrix. The seed matrix is the joint household size – income distribution for the region obtained from the 2000 Census Public Use Microdata Samples (PUMS) data.

4. A joint household size and worker distribution is calculated for each TAZ using the joint size - income distribution by TAZ and the worker probabilities calculated by the household worker submodel.

5. The distribution of the number of households by worker category is calculated for each TAZ by collapsing the joint size – worker distribution across the size categories.

The household submodel functions in the same manner for the future year, with the exception of steps 1. and 2. In step 1., the distribution of households by size category is calculated for each TAZ by adding the number of additional future households within each category from the household size submodel to the base year distribution. In step 2., the base year distribution of households by income category is multiplied by the total number of future households within each TAZ to obtain the number of future households by income category.

DEFINITION OF VARIABLES

Name	Description	Values	Data Source
HHS_BASE	Base year households by size category	N/A	Census data
HHI_BASE	Base year households by income category	N/A	Census data
NEWHHS	Additional future HHs by	N/A	Household size submodel

Name	Description	Values	Data Source
	size category		
HHFUTUR	Future households	N/A	City, county staff
SEED	Regional households by size-income category	N/A	PUMS data
WKR.PROB	Household worker probabilities	0 – 1.0	Worker submodel

CALIBRATED MODEL FUNCTIONS

The model does not contain calibrated functions.

ESTIMATED VARIABLE COEFFICIENTS

See above.

Trip Generation

The trip generation model is used to estimate the number of trip productions generated by internal TAZs by hour-of-the-day for the following trip purposes:

- Home-based work (HBW)
- Home-based school (HBSCH)
- Home-based shopping (HBSHP)
- Home-based recreation/other (HBRO)
- Non-home-based (NHB)

Trip productions are calculated based on a set of trip generation rates estimated as a part of the OSUM development project. Inputs to the model are the number of households by size and worker categories and the number of households by worker category that are produced by the household submodel.

The model also separately estimates internal trip productions associated with special generators by hour-of-the-day. Inputs to the model are total daily trip ends for the special generators and the percentage of special generator trips produced within the internal modeling area.

If necessary, estimated productions are adjusted to a level corresponding to an assumed minimum average daily household trip generation rate.

The estimated trip productions from the model are input to the destination choice model discussed later.

Standard Model

The standard trip generation model estimates internally-generated trip productions for non-special generator trips according to the following steps:

1. Internal-internal (I-I) trip productions are calculated as:

   - Home-based work productions = HBW trip rate$_i$ * households$_i$

     where i = workers per household category

   - Home-based school productions = HBSCH trip rate$_i$ * households$_i$

     where i = household size category

   - Home-based shopping productions = HBSHP trip rate$_{ij}$ * households$_{ij}$

     where i = workers per household category; and
     j = household size category

   - Home-based recreation/other productions = HBRO trip rate$_{ij}$ * households$_{ij}$

     where i = workers per household category; and
     j = household size category

   - Non-home-based productions = NHB trip rate$_{ij}$ * households$_{ij}$

     where i = workers per household category; and
     j = household size category

2. Internal-external (I-E) vehicle trip productions are calculated based on the average daily traffic at each external station and the corresponding proportion of traffic that is comprised of I-E trips. These are converted into person trips by multiplying by an average external vehicle occupancy rate.

3. A target trip generation total for the modeling area is calculated by multiplying the assumed average daily household trip generation rate (9.2) by the number of households in the modeling area. The sum of the estimated I-I, I-E, and special generator trip productions (see following section) is subtracted from the trip generation target. If a deficiency is found, step 4. is performed to adjust the estimated trip productions upward to match the target trip generation value.

4. If needed, the adjustment process is carried out for the HBSHP, HBRO and NHB trip purposes only. It is based on a methodology outlined in Transportation Research Record No. 1412[7] which addresses the problem of underreporting of trips in household surveys for these trip purposes. The report found that the rate

[7] Transportation Research Board, Transportation Research Record 1412, (1994).

of underreporting varies by household size. Thus, the estimate of unreported trip productions from step 3. is first apportioned to areawide households based on household size using the following size weighting factors: 1-person = 1; 2-persons = 1.4; 3-persons = 2; and 4+ persons = 3. These are allocated by trip purpose within each household size category based on the proportion of total I-I productions for each purpose. The unreported trip productions by household size category and trip purpose are then allocated to individual TAZ according to the proportion of areawide I-I trip productions by size and purpose for each TAZ. Total trip productions by trip purpose for each TAZ are calculated by adding the unreported productions to the initial I-I trip production estimates from step 1. and summing across size categories.

5. The NHB trip productions by TAZ are summed to an areawide total and then allocated to non-residential TAZs using utility equations from OSUM that estimate the attractiveness of NHB tripmaking.

6. The total daily trip productions are allocated to each hour of the day using diurnal factors by trip purpose.

7. If present, a user-specified rural trip generation adjustment factor is applied to non-special generator trip productions for rural TAZs.

The output of the model is a set of I-I trip production vectors by hour-of-the-day for each trip purpose.

DEFINITION OF VARIABLES

Name	Description	Values	Data Source
HH.WKR.DIST	Households by worker category	N/A	Household submodel
HH.SIZE.DIST	Households by size category	N/A	Household size submodel
SIZE.BY.WKR	Households by size and worker categories	N/A	Household submodel
DIURNAL	Time-of-day factors by trip purpose	N/A	OSUM
EE.PCT	% of E-E trips at external stations	N/A	Modlin model
RURALZONE	Rural TAZ indicator	0, 1	Model user
RURAL.GEN.FACTOR	Rural trip generation adjustment factor	0.0 – 1.0	Model user

TRIP PRODUCTION RATES

Calibrated Rates

HBW

Workers per Household	
0	0.049
1	1.384
2	2.649
3+	4.700

HBSCH

Household Size	
1	0.017
2	0.098
3	1.169
4+	2.916

HBSHP

Household Size	Workers per Household			
	0	**1**	**2**	**3+**
1	0.504	0.320	0.000	0.000
2	1.150	0.779	0.485	0.000
3	1.461	0.709	0.764	1.146
4+	2.730	1.458	1.095	0.619

HBRO

Household Size	Workers per Household			
	0	**1**	**2**	**3+**
1	1.418	0.838	0.000	0.000
2	2.447	2.196	1.587	0.000
3	2.757	3.130	2.960	2.764

Household Size	Workers per Household			
	0	1	2	3+
4+	2.072	2.755	3.291	3.076

NHB

Household Size	Workers per Household			
	0	1	2	3+
1	1.195	1.577	0.000	0.000
2	2.182	2.534	2.809	0.000
3	2.358	2.875	4.006	4.025
4+	1.792	3.222	4.821	4.953

Estimated Rates

The estimated trip production rates are the same as the calibrated rates. The only exception to this is the estimated trip rates for the NHB trip purpose, which are shown below.

NHB

Household Size	Workers per Household			
	0	1	2	3+
1	0.796	1.052	0.000	0.000
2	1.454	1.689	1.873	0.000
3	1.572	1.916	2.671	2.684
4+	1.195	2.148	3.214	3.302

Special Generator Model

The trip generation portion of the special generator model estimates internal trip productions for special generators within the modeling area. The special generators are three retail centers (Fred Meyer, Walmart, and Grants Pass Shopping Center), Rogue Community College, and Three Rivers Hospital. This is done by estimating the number of internal daily person trip attractions for each special generator, then allocating these attractions, in the form of trip productions, to the internal TAZs. For each special generator, daily vehicle trip attractions are calculated by multiplying the daily vehicle trip ends by the percentage of internal trips. Daily person trip attractions are obtained by multiplying the vehicle trip attractions by the average vehicle occupancy factor for the primary trip purpose associated with the special generator (e.g., the home-based shopping trip purpose for a retail mall). The daily vehicle trip ends, percentage of internal trips, and primary trip purpose are established as user inputs to the model.

The daily person trip attractions are allocated as trip productions to each internal TAZ based on the probability of the attractions having a linkage to the TAZ. The probabilities are calculated as the number of households within a TAZ divided by the total households for all internal TAZs. The daily trip productions are allocated to each hour of the day using the diurnal factors for the primary trip purpose associated with the special generator.

The output of the model is a set of I-I trip production vectors by hour-of-the-day for each special generator.

DEFINITION OF VARIABLES

Name	Description	Values	Data Source
HHBASE	Base year households (TAZ)	N/A	Census data
TRIPS	Daily special generator trip ends	N/A	1. Trip generation rates – *ITE Trip Generation Manual*[8] 2. Trip generation data – local staff
INT.PCT	% of I-I special generator trips	N/A	Local staff
OCC	Avg. vehicle occupancy	≥1.0	OSUM
DIURNAL	Time-of-day factors by trip purpose	N/A	OSUM

[8] Institute of Transportation Engineers, Trip Generation 6th Edition, (1997).

TRIP PRODUCTION RATES

Calibrated Rates

Special generator trip ends are calculated outside of the model using trips rates from the *ITE Trip Generation Manual*.[9]

Estimated Rates

See above.

[9] Institute of Transportation Engineers, Trip Generation 6th Edition, (1997).

Trip Distribution

Within the trip distribution step, separate trip matrices are developed for the internal-internal (I-I), internal-external (I-E), external-internal (E-I), and external-external (E-E) trip types. I-I matrices are developed by trip purpose and hour-of-the-day using the trip productions from the trip generation model and a destination choice model based on the multinomial logit formulation in OSUM. Daily I-E and E-I matrices are estimated using special procedures in which trip ends at the external stations are linked to internal TAZs based on the relative number trip ends within each internal TAZ. A daily E-E trip matrix is estimated using the Modlin model, as described on pages _ - _. Diurnal factors are applied to the external trip matrices to produce I-E, E-I, and E-E trips by hour-of-the-day. At the end of the step, the internal and external trip matrices are combined to form hourly total trip matrices that are used in the trip assignment step.

Destination Choice Model

The destination choice model is used to distribute non-special generator I-I trips by trip purpose and hour-of-the-day. For each production zone, the number of trips distributed to a destination zone is calculated as a function of the trip productions and the destination choice probability for that zone. The destination choice probability reflects the relative attractiveness of a specific destination zone compared to all other zones. The attractiveness of a zone is represented as a utility, which is estimated as a function of size variables for the zone (retail, service, and other employment, households, and school enrollment) and the travel time from the production zone.

For destination zones containing special generators, the portions of the size variables attributable to the special generators are subtracted, since special generator trips are distributed separately. Peak or off-peak travel times are used depending on the time of day. Peak hours are defined as between 7:00 a.m. and 8:00 p.m. and off-peak hours as between 8:00 p.m. and 7:00 a.m. The coefficients for the size and travel time variables for each trip purpose are input as a data matrix by the user.

Following the trip distribution, the special generator trips from the previous step are added to the non-special generator trips. The appropriate trip purpose for adding the special generator trips is determined by the primary trip purpose for the special generator, as defined by the user.

The total I-I person trip matrices are converted to origin-destination format by applying directional factors by trip purpose and time-of-day. Average vehicle occupancy rates by trip purpose are then used to convert the person trips to vehicle trips. The resulting hourly O-D vehicle trip matrices are stored as an array. The hourly person trip matrices are summed to create daily person trip matrices by trip purpose.

DEFINITION OF VARIABLES

Name	Description	Values*	Data Source
RETL____	Retail employment	N/A	1. Base year – ES202 data 2. Future – City, county staff
SERV____	Service employment	N/A	1. Base year – ES202 data 2. Future – City, county staff
OTHR.EMP	Other employment	N/A	N/A**
HH____	Households	N/A	1. Base year – Census data 2. Future – City, county staff
SCHE____	School enrollment	N/A	1. Base year – School district 2. Future – City, county staff

Name	Description	Values*	Data Source
__.TIME	Peak and off-peak travel times	N/A	EMME/2 assignment model
DIRECTIONAL	Directional factors	N/A	OSUM
OCC	Avg. vehicle occupancy	$\geq$1.0	OSUM

* Discrete variables
** Calculated as: Other Employment = Total Employment – Retail Employment – Service Employment

CALIBRATED UTILITY FUNCTIONS

U_{HBW} = -0.25*__.TIME + 0.02057*__.TIME ^{2} + -0.0005853*__.TIME ^{3} + log (RETL____ + 1.2115*SERV____ + 1.2969*OTHR.EMP)

U_{HBSCH} = log (SCHE____)

U_{HBSHP} = -0.5630*__.TIME + 0.02665*__.TIME ^{2} + -0.0004983*__.TIME ^{3} + log (RETL____ + 0.0095*SERV____ + 0.0106*OTHR.EMP + 0.0286*HH____)

U_{HBRO} = -0.3664*__.TIME + 0.01607*__.TIME ^{2} + -0.0003687*__.TIME ^{3} + log (RETL____ + 1.4534*SERV____ + 0.5103*OTHR.EMP + 0.6123*HH____)

U_{NHB} = -0.5463*__.TIME + 0.03555*__.TIME ^{2} + -0.001*__.TIME ^{3} + log (RETL____ + 0.3088*SERV____ + 0.1678*OTHR.EMP + 0.1967*HH____)

ESTIMATED VARIABLE COEFFICIENTS

Variable Name		HBW	HBSCH	HBSHP	HBRO	NHB
__.TIME	Coeff.	-.25	0.0	-.5630	-.3664	-.5463
	T – Stat.	?	?	?	?	?
__.TIME ^{2}	Coeff.	.02057	0.0	.02665	.01607	.03555
	T – Stat.	?	?	?	?	?
__.TIME ^{3}	Coeff.	-.0005853	0.0	-.0004983	-.0003687	-.001
	T – Stat.	?	?	?	?	?
RETL____	Coeff.	1.0	0.0	1.0	1.0	1.0
	T – Stat.	?	?	?	?	?
SERV____	Coeff.	1.2115	0.0	.0095	1.4534	.3088
	T – Stat.	?	?	?	?	?
OTHR.EMP	Coeff.	1.2969	0.0	.0106	.5103	.1678
	T – Stat.	?	?	?	?	?
HH____	Coeff.	0.0	0.0	.0286	.6123	.1967
	T – Stat.	?	?	?	?	?
SCHE____	Coeff.	0.0	1.0	0.0	0.0	0.0

Destination Choice Model

Variable Name		HBW	HBSCH	HBSHP	HBRO	NHB
	T – Stat.	?	?	?	?	?

(Sam will check on T-statistic values from OSUM development project).

External-Internal and Internal-External Trip Distribution Models

The E-I and I-E trip distribution models distribute trips between internal zones and external stations. E-I trips are trips produced outside of the modeling area with destinations inside of the modeling area. The production ends of E-I trips are represented at external stations. I-E trips are the converse of E-I trips.

Within the E-I model, external trips destined for special generators are estimated separately from trips with non-special generator destinations. The first step is the identification of the number of external productions associated with each special generator. This is done by multiplying the special generator trip ends by the percentage of E-I special generator trips. These percentages are provided as a user input. (The derivation of the E-I, I-E, and E-E percentages of total traffic at the external stations is described on pages _ - _.). The production ends of these trips are then allocated based on the ratio of the E-I trips at each external station to the sum of the E-I trips at all external stations.

The remaining E-I trips are calculated by subtracting the E-I special generator trips from the total E-I trips for each external station. Total E-I trips are obtained by multiplying the external station ADT by the percentage of E-I trips, which is provided as a user input. The number of non-special generator E-I trips destined for a particular internal zone is determined based on the attraction probability of the zone. This probability is calculated as the ratio of total daily attractions (all trip purposes) for the zone to the sum of total daily attractions for all internal zones. A distribution of these trips is produced by multiplying the probabilities by the total non-special generator E-I trips for each external station. This distribution is added to the special generator trips to form a total daily E-I vehicle trip matrix in P-A format.

The I-E model functions in a similar manner to the E-I model. I-E attractions at each external station are calculated as the product of the ADT and the I-E percentage for the external station (provided as a user input). The production ends of the I-E trips are determined based on the production probabilities for the internal zones. These probabilities are calculated as the ratio of the total daily productions (all trip purposes) for each zone to the sum of total daily productions for all internal zones. The distribution of I-E trips is obtained by multiplying the probabilities by the total I-E trips for each external station.

In the final step of the process, the daily E-I and I-E trips are distributed temporally by applying user-supplied diurnal factors that vary by external station.

External-Internal, Internal-External Trip Distribution Models

DEFINITION OF VARIABLES

Name	Description	Values*	Data Source
TRIPS	Daily special generator trip ends	N/A	1. Trip generation rates – *ITE Trip Generation Manual*[10] 2. Trip generation data – local staff
INT.PCT	% of I-I special generator trips	N/A	Local staff
EE.PCT	% of E-E trips at external stations	N/A	Modlin model
ADT	External station ADT	N/A	1. Base year – Traffic counts 2. Future – extrapolated base year ADT**
EI.ATTRAC	Total daily attractions (internal zones, all purposes)	N/A	Destination choice model
DIURNAL	Time-of-day factors for external stations	N/A	Traffic counts

* Discrete variables
** Annualized ADT growth rates based on ODOT 2022 traffic volume forecasts available at:
http://www.odot.state.or.us/tddtpau/papers/analysis/2022_Future_Volumes.PDF

CALIBRATED MODEL FUNCTIONS

The model does not contain calibrated functions.

ESTIMATED VARIABLE COEFFICIENTS

See above.

[10] Institute of Transportation Engineers, Trip Generation 6th Edition, (1997).

External-External Trip Distribution Model

The E-E trip distribution model distributes trips between external stations. E-E trips are trips with both the origin and destination outside of the modeling area. E-E trip ends are represented at the external stations.

A daily E-E trip matrix is estimated using the Modlin model, as described on pages _ - _. Hourly matrices are then created by applying external time-of-day factors. Because different results are obtained depending on whether the factors are used on an origin (row-wise) or destination (column-wise) basis, intermediate matrices are first developed by applying the factors both ways. The final E -E trip matrices by hour-of-the-day are obtained by summing the intermediate matrices and dividing by two, reflecting the average of the two methods. These matrices are added to the corresponding I-I, E-I, and I-E matrices to produce total hourly vehicle trip matrices.

DEFINITION OF VARIABLES

Name	Description	Values*	Data Source
EXT.SEED	Daily seed matrix of external-external vehicle trips	N/A	Modlin model
EE.PCT	% of E-E trips at external stations	N/A	Modlin model
ADT	External station ADT	N/A	1. Base year – traffic counts 2. Future – extrapolated base year ADT**
DIURNAL	Time-of-day factors for external stations	N/A	Traffic counts

* Discrete variables
** Annualized ADT growth rates based on ODOT 2022 traffic volume forecasts available at: http://www.odot.state.or.us/tddtpau/papers/analysis/2022_Future_Volumes.PDF

CALIBRATED MODEL FUNCTIONS

The model does not contain calibrated functions.

ESTIMATED VARIABLE COEFFICIENTS

See above.

Time-of-Day Factors

Time-of-day (diurnal) factors are used to estimate travel by hour of the day. Separate sets of factors are used for the I-I trips and external trips. The I-I factors are broken down by trip purpose. They are applied to the daily trip productions output by the trip generation model. These factors were estimated from data collected in the 1996 Oregon Travel Behavior Survey. The external factors are applied to the daily E-I, I-E, and E-E trips developed in the trip distribution step. They were estimated based on traffic counts and vary by external station.

Internal-Internal Time-of-Day Factors

Hour	Trip Purpose				
	HBW	HBSCH	HBSHP	HBRO	NHB
1	0.0011	0.0000	0.0009	0.0005	0.0000
2	0.0058	0.0000	0.0000	0.0024	0.0010
3	0.0046	0.0000	0.0000	0.0000	0.0000
4	0.0025	0.0188	0.0030	0.0000	0.0050
5	0.0182	0.0000	0.0000	0.0071	0.0020
6	0.0294	0.0149	0.0000	0.0165	0.0037
7	0.0619	0.0369	0.0016	0.0193	0.0034
8	0.1074	0.1135	0.0005	0.0341	0.0147
9	0.0515	0.2011	0.0231	0.0510	0.0346
10	0.0578	0.0000	0.0835	0.0491	0.0482
11	0.0345	0.0000	0.1068	0.0637	0.0907
12	0.0417	0.0360	0.0849	0.0595	0.1038
13	0.0541	0.0024	0.0689	0.0707	0.0955
14	0.0718	0.0320	0.1149	0.0455	0.0768
15	0.0493	0.0769	0.0785	0.0596	0.0822
16	0.0694	0.2933	0.0958	0.0705	0.1077
17	0.0941	0.0486	0.0957	0.0831	0.0994
18	0.0851	0.0442	0.0866	0.0752	0.0898
19	0.0516	0.0346	0.0516	0.0819	0.0432
20	0.0341	0.0102	0.0392	0.0584	0.0331
21	0.0228	0.0143	0.0349	0.0746	0.0245
22	0.0147	0.0134	0.0242	0.0444	0.0138
23	0.0131	0.0091	0.0058	0.0266	0.0125
24	0.0242	0.0000	0.0004	0.0070	0.0153
Total	1.0000	1.0000	1.0000	1.0000	1.0000

External Time-of-Day Factors

Hour	External Station						
	I-5 (N.)	I-5 (S.)	Foothill Blvd.	ORE 99	ORE 238	Williams Hwy.	US 199
1	0.0120	0.0080	0.0113	0.0113	0.0113	0.0113	0.0113
2	0.0101	0.0073	0.0113	0.0113	0.0113	0.0113	0.0113
3	0.0095	0.0044	0.0113	0.0113	0.0113	0.0113	0.0113
4	0.0096	0.0059	0.0113	0.0113	0.0113	0.0113	0.0113
5	0.0129	0.0088	0.0113	0.0113	0.0113	0.0113	0.0113
6	0.0199	0.0179	0.0113	0.0113	0.0113	0.0113	0.0113
7	0.0288	0.0387	0.0266	0.0333	0.0450	0.0399	0.0413
8	0.0428	0.0611	0.0490	0.0814	0.0685	0.0691	0.0570
9	0.0518	0.0578	0.0498	0.0524	0.0861	0.0638	0.0595
10	0.0608	0.0583	0.0548	0.0590	0.0494	0.0731	0.0630
11	0.0648	0.0574	0.0714	0.0607	0.0610	0.0505	0.0635
12	0.0643	0.0562	0.0714	0.0603	0.0630	0.0717	0.0622
13	0.0645	0.0548	0.0888	0.0656	0.0498	0.0717	0.0692
14	0.0666	0.0627	0.0606	0.0779	0.0546	0.0465	0.0708
15	0.0694	0.0701	0.0739	0.0651	0.0590	0.0691	0.0715
16	0.0689	0.0814	0.0988	0.0739	0.0960	0.0784	0.0732
17	0.0738	0.0817	0.0942	0.1010	0.0799	0.0916	0.0853
18	0.0676	0.0778	0.0896	0.0827	0.0789	0.0717	0.0768
19	0.0541	0.0594	0.0448	0.0463	0.0574	0.0571	0.0480
20	0.0449	0.0441	0.0149	0.0230	0.0263	0.0213	0.0281
21	0.0362	0.0305	0.0141	0.0156	0.0191	0.0093	0.0226
22	0.0286	0.0282	0.0075	0.0118	0.0159	0.0252	0.0181
23	0.0220	0.0142	0.0113	0.0113	0.0113	0.0113	0.0113
24	0.0164	0.0134	0.0113	0.0113	0.0113	0.0113	0.0113
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Directional Factors

Within the trip distribution step, directional factors are used to convert the hourly internal-internal trips from P-A format to O-D format. These factors were estimated from data collected in the 1996 Oregon Travel Behavior Survey. Directional factors, as such, are not used for the external (E-I, I-E, and E-E) trips. For the E-I and I-E trips, the daily P-A matrices are converted to O-D matrices by summing them with their transpose and dividing by two. The external time-of-day factors are then applied to produce hourly O-D matrices. Similarly for the E-E trips, the daily seed matrix provided by the user is in O-D format. Following rebalancing, this matrix is converted to hourly E-E trip matrices by applying the external time-of-day factors.

Hour	Trip Purpose									
	HBW		HBSCH		HBSHP		HBRO		NHB	
	P-A	A-P	P-A	A-P	P-A	A-P	P-A	A-P	P-A	A-P
1	0.000	1.000	0.523	0.477	0.000	1.000	0.000	1.000	0.500	0.500
2	0.000	1.000	0.523	0.477	0.514	0.486	0.000	1.000	0.500	0.500
3	0.645	0.355	0.523	0.477	0.514	0.486	0.511	0.489	0.500	0.500
4	0.238	0.762	1.000	0.000	0.000	1.000	0.511	0.489	0.500	0.500
5	0.794	0.206	0.523	0.477	0.514	0.486	1.000	0.000	0.500	0.500
6	1.000	0.000	1.000	0.000	0.514	0.486	0.993	0.007	0.500	0.500
7	0.951	0.049	0.682	0.318	1.000	0.000	0.981	0.019	0.500	0.500
8	0.960	0.040	0.935	0.065	1.000	0.000	0.844	0.156	0.500	0.500
9	0.986	0.014	0.762	0.238	0.876	0.124	0.829	0.171	0.500	0.500
10	0.735	0.265	0.523	0.477	0.801	0.199	0.720	0.280	0.500	0.500
11	0.611	0.389	0.523	0.477	0.655	0.345	0.651	0.349	0.500	0.500
12	0.568	0.432	0.069	0.931	0.529	0.471	0.523	0.477	0.500	0.500
13	0.505	0.495	1.000	0.000	0.543	0.457	0.563	0.437	0.500	0.500
14	0.691	0.309	0.292	0.708	0.663	0.337	0.642	0.358	0.500	0.500
15	0.435	0.565	0.715	0.285	0.309	0.691	0.442	0.558	0.500	0.500
16	0.206	0.794	0.258	0.742	0.405	0.595	0.374	0.626	0.500	0.500
17	0.214	0.786	0.078	0.922	0.416	0.584	0.379	0.621	0.500	0.500
18	0.037	0.963	0.000	1.000	0.229	0.771	0.454	0.546	0.500	0.500
19	0.051	0.949	0.394	0.606	0.427	0.573	0.635	0.365	0.500	0.500
20	0.101	0.899	1.000	0.000	0.529	0.471	0.357	0.643	0.500	0.500
21	0.128	0.872	0.355	0.645	0.265	0.735	0.138	0.862	0.500	0.500
22	0.000	1.000	0.000	1.000	0.264	0.736	0.106	0.894	0.500	0.500
23	0.488	0.512	0.000	1.000	0.215	0.785	0.094	0.906	0.500	0.500
24	0.135	0.865	0.523	0.477	0.000	1.000	0.106	0.894	0.500	0.500

Directional Factors

Special Purpose Models

Special purpose models are models that are developed and implemented outside of the main model structure. They are needed to address specific components of travel demand or the local transportation system that cannot be reflected within the main model. An example of this would be a model to estimate truck trips.

Within the Grants Pass model, a special purpose model called the Modlin model is used to estimate through trip ends at external stations as well as the distribution of these trips between the external stations. The model was developed because of the lack of origin-destination survey data and the importance of accurately representing the large number of trips within the Grants Pass modeling area that have one or both ends outside of the modeling area.

Modlin Model

The percentages of E-I, I-E, and E-E traffic at the external stations and the E-E seed matrix used in the external models are estimated using the Modlin model. The percentage of through traffic at an external station is estimated based on the functional classification of the highway, the average daily traffic at the external station, the percent of trucks excluding vans and pick-ups, the percentage of vans and pick-ups, and the population of the study area. The equation used for this is:

$$Y_i = 76.76 + 11.22*I - 25.74*PA - 42.18*MA + 00012*ADT_i + 0.59*PTKS_i - 0.48*PPSi - 0.000417*POP$$

where:

Y_i	=	percentage of through trip ends of the ADT at external station *i*
I	=	interstate (0 or 1)
PA	=	principal arterial (0 or 1)
MA	=	minor arterial (0 or 1)
ADT_i	=	average daily traffic at external station *i*
$PTKS_i$	=	percentage of trucks excluding vans and pick-ups at external station *i*
PPS*i*	=	percentage of vans and pickups at external station *I*
POP=		population inside the cordon area

Once the percentage of through trips is estimated, the number of through trips is calculated at each external station.

The distribution of the estimated through trips at an external station to each of the destination stations is estimated using a set of equations, one for each functional classification. The functional classification of the destination station determines which equation is to be used.

Interstate:

$$Y_{ij} = -2.70 + 0.21*PTTDES_j + 67.86*RTECON_{ij}$$

Primary Arterial:

$$Y_{ij} = -7.40 + 0.55*PTTDES_j + 24.68*RTECON_{ij} + 45.62*ADT_j \Big/ \sum_{j=1}^{n} ADT_j$$

Minor Arterial:

$$Y_{ij} = -0.63 + 86.68*ADT_j \Big/ \sum_{j=1}^{n} ADT_j + 30.04*RTECON_{ij}$$

where:

Y_{ij}	=	percentage distribution of through trip ends from origin station *i* to destination station *j*
$PTTDES_j$	=	percentage through trip ends at destination station *j*
$RTCON_{ij}$	=	route continuity between stations *i* and *j* (1 = yes, 0 = no)
ADT_j	=	average daily traffic at the destination station *j*

The through trip percentages are applied to the through trips for each external station to produce a through trip matrix. The initial matrix is not symmetrical around the intrazonal diagonal as it should be, since it represents through tripmaking for the daily time period. To correct this, the individual matrix elements are averaged. In the resulting matrix, however, the row and column totals do not sum to the estimated through trips for each external station. Therefore, the row and column totals are set equal to one-half the total estimated through trips. The matrix is then rebalanced using an iterative proportional fitting procedure.

For the Grants Pass model, the matrix produced using the Modlin model was adjusted to reflect higher volumes of through trips between the two I-5 external stations. The adjustment was based on the analysis of freeway interchange traffic counts.

The Modlin model is applied for the base year only. The base year model outputs (percentage of through trips at external stations and through trip matrix) are used as both base year and future year inputs to the other model modules.

DEFINITION OF VARIABLES

Name	Description	Values*	Data Source
I	Dummy variable for interstate functional classification	0, 1	Model user

Name	Description	Values*	Data Source
PA	Dummy variable for principal arterial functional classification	0, l	Model user
MA	Dummy variable for minor arterial functional classification	0, 1	Model user
ADT	ADT at ext. station	N/A	Traffic counts
PTKS	Percentage of trucks at origin ext. station	N/A	Traffic counts
PPS	Percentage of vans and pickups at origin ext. station	N/A	Traffic counts
POP	Population inside cordon area	N/A	Census data
PTTDES	Percentage of through trips at destination ext. station	N/A	Modlin model (part 1)
RTCON	Route continuity between origin and destination ext. stations	0, 1	Model user

* Discrete variables

CALIBRATED MODEL FUNCTIONS

See function definitions above.

ESTIMATED VARIABLE COEFFICIENTS

Model estimation was not performed.

Assignment

Trip assignment is the final step in the model chain in which zone-to-zone auto vehicle trips from the trip distribution step are assigned to the auto network. The output of trip assignment is directional link volumes or, optionally, intersection turning movement volumes for the time period associated with the input vehicle trip matrix.

An equilibrium, capacity constrained equilibrium assignment method is utilized within the EMME/2 software. The underlying principle of this technique is described as follows in the *EMME/2 Users Manual*:

> "The algorithm implemented to solve the equilibrium (capacity constrained) auto traffic assignment problem is the linear approximation algorithm. The behavioral assumption of the equilibrium traffic assignment problem is that each user chooses the route that he perceives the best; if there is a shorter route than the one that he is using, he will choose it. This results in flows that satisfy the user optimal principle, that no user can improve his travel time by changing routes. The consequence is that the equilibrium traffic assignment corresponds to a set of flows such that all paths used between an origin-destination pair are of equal time".[11]

The specific type of equilibrium assignment that is used is a fixed demand, single-class assignment.

The volume-delay functions used within the assignment specify the relationship between the travel time on each link in the network and other attributes of the link, such as volume. The BPR form of volume-delay function is used, as given below:

$$t = t_0(1 + \alpha X^{\beta})$$

where:

t is the estimated link travel time;

t_0 is the free-flow travel time;

α and β are empirical coefficients; and

X is the volume-to-capacity ratio.

Link length, free flow speed, and capacity are the link attributes used within the volume-delay functions for estimating travel time. The functions used to perform hourly traffic assignments are shown below:

fd1 = (length*60 / ul1)*(1 + .05*(volau / (ul2*lanes))^10)

fd2 = (length*60 / ul1)*(1 + .2*(volau / (ul2*lanes))^10)

[11] Les Conseillers INRO Consultants, Inc., EMME/2 Users Manual, (1999).

fd3 = length*60 / ul1

where:

length is the link length;

ul1 is the free-flow speed;

volau is the link volume;

ul2 is the capacity/lane; and

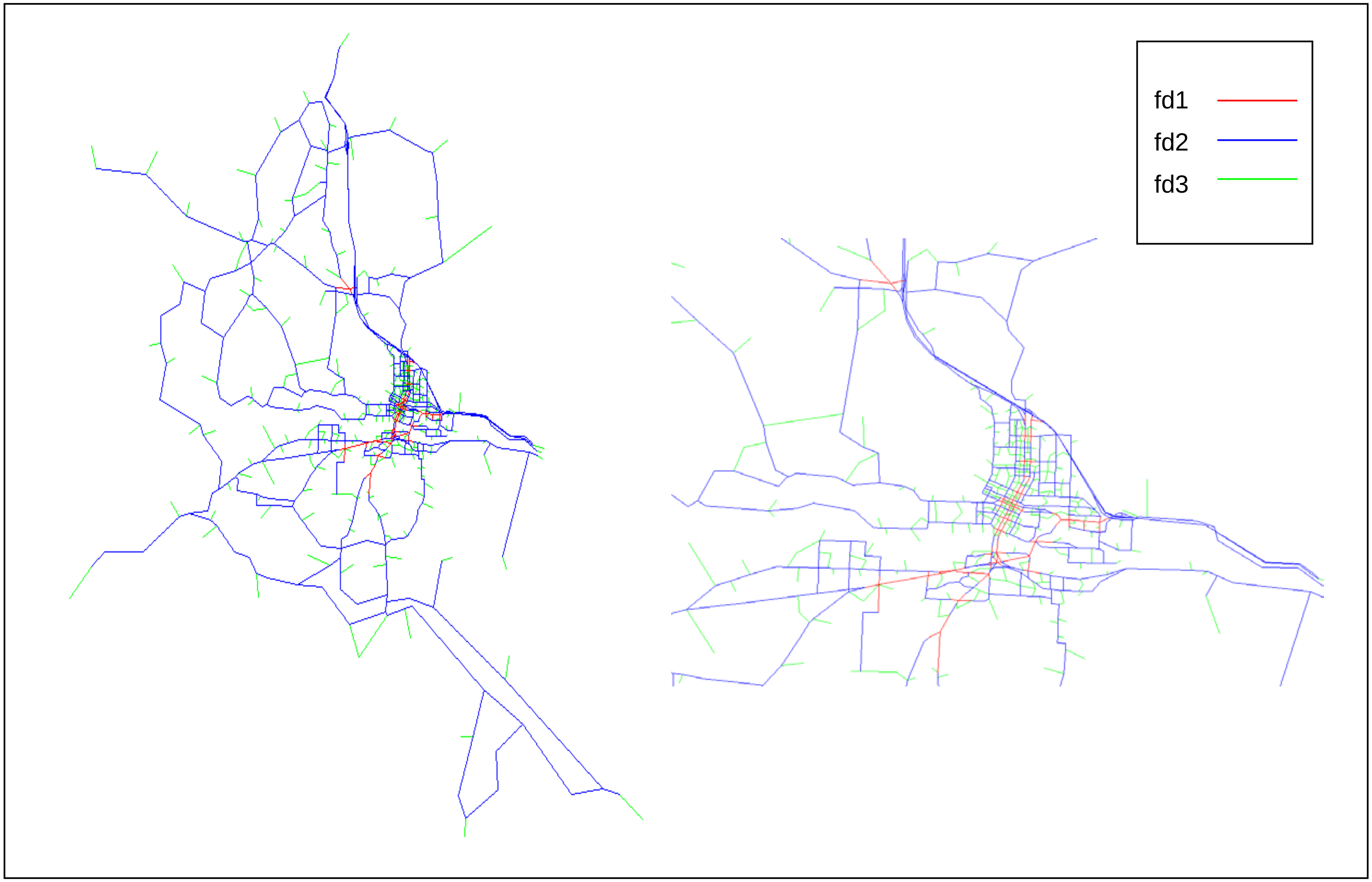
lanes is the number of lanes.

The first volume-delay function is used for roadways with signalized intersections, while the second function is used for all other roadways (see Figure 2). The third function, which does not contain a delay term, is used for centroid connectors only.

A second set of functions are used to perform daily traffic assignments. These are identical to the hourly functions, except that the hourly capacities are multiplied by 24.

Figure 2

Hourly Volume-Delay Functions



VII. Model Validation

Model validation is the assessment of a model's overall performance by comparison of the estimated volumes from the assignment model to observed volumes (i.e., traffic counts). Three primary types of comparisons were used for the Grants Pass model validation. These are:

- link scatterplots;
- percent root mean square error; and
- number of links by error range.

The model was validated separately for the daily and p.m. peak hour (4:00 – 5:00 p.m.) time periods. The results of the validation are presented in the sections below.

Daily Validation

Link scatterplots show the results of regressing assigned link traffic volumes on the corresponding link traffic counts. The scatterplot, together with the regression statistics, provide a measure of how well the model replicates overall traffic flows on the network. As shown in Figure 3, the model performs very well for the daily time period, with the slope of the regression line near 1 and an R^2 (coefficient of determination) value of over 0.95. As would be expected, the data points for the lower-volume links generally are more widely dispersed around the regression line than those for the higher-volume links, indicating the larger degree of model error for the lower-volume links.

In rough terms, the percent root mean square error (% RMSE) represents the average relative difference between the assigned traffic volumes and traffic counts. For the model validation, the % RMSE was calculated by volume category as shown in Table 4 on the following page. In the Grants Pass area, the highest volume category generally corresponds to freeway/principal arterials, the second category corresponds to principal arterials, the middle two categories correspond to principal/minor arterials and minor arterials/collectors, and the lowest volume category corresponds to collectors/minor collectors. The % RMSE value of 28.01% for all links is consistent with the findings from the link scatterplot and is within the aggregate validation target of 30% suggested by the FHWA.[12]

[12] Travel Model Improvement Program, Model Validation and Reasonableness Checking Manual, (1997).

Figure 3

**Link Scatterplot
Daily Validation**

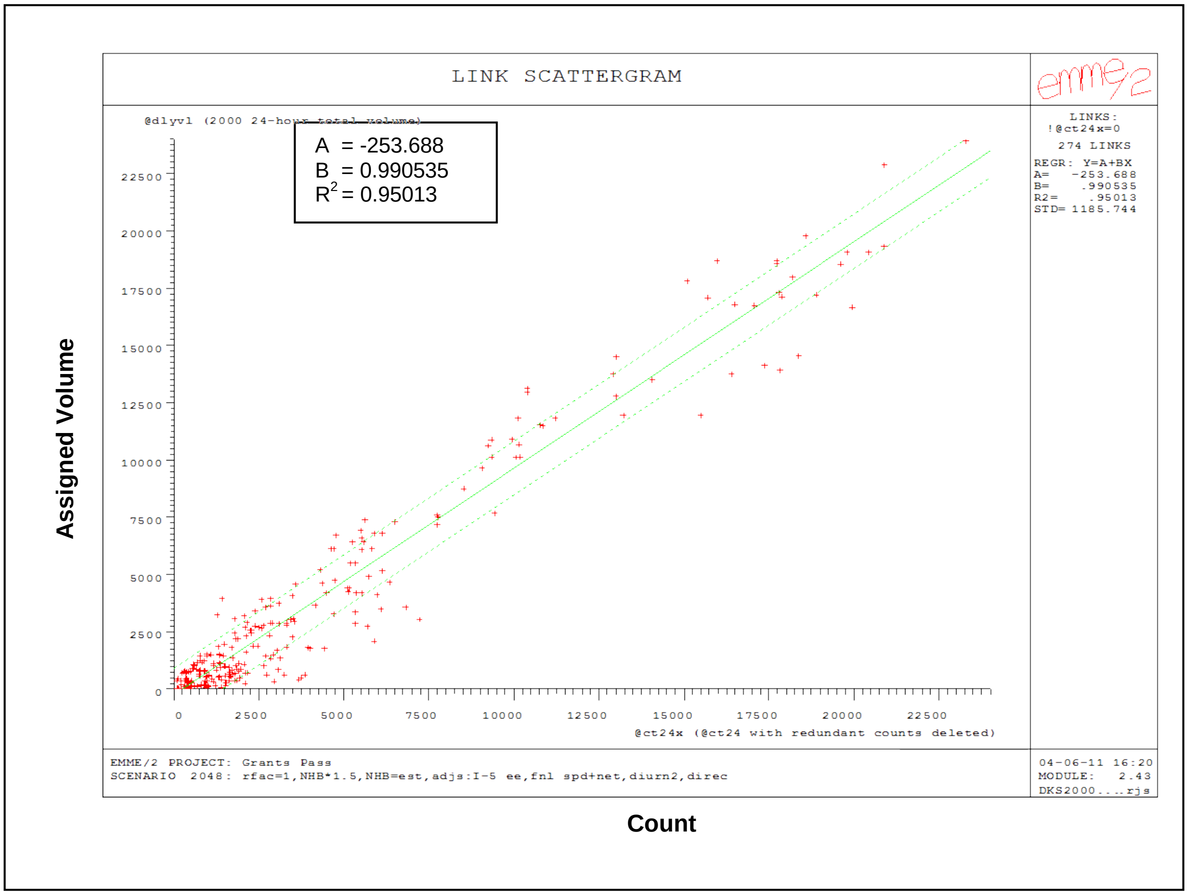


Table 4

**% RMSE
Daily Validation**

Link Volume Category	Functional Classification	% RMSE
$\geq$ 16,000 vpd	Freeway/Principal Arterial	10.31%
8,000 – 15,999 vpd	Principal Arterial	13.60%
4,000 – 7,999 vpd	Principal/Minor Arterial	29.23%
2,000 – 3,999 vpd	Minor Arterial/Collector	47.36%
1 – 1,999 vpd	Collector/Minor Collector	69.36%

Link Volume Category	Functional Classification	% RMSE
All Links		28.01%

A summary of relative link volume error presented in Table 5 shows that the assigned traffic volume is within +15% of the count on one-third of all links and within +30% on 50% of all links. A relatively low percentage of the links fall within the higher error categories (3.6% in the >+100% category and 25.9% in the –50% to – 100% category), and nearly all of these are lower-volume links (see Appendix A for a listing of link volume error summaries by volume range). There is a fairly even distribution between the percentage of overestimated and underestimated links (42.3% vs. 57.7%), which is also reflected in the overall percentage error of –6.8%.

Table 5

Relative Link Volume Error
Daily Validation

All Links			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	3.6%	+ or -15%	32.8%
+50% to +100%	5.1%	+ or -30%	49.6%
+30% to +50%	6.9%	+ or -50%	65.3%
+15% to +30%	8.0%	+ or -100%	96.4%
0% to +15%	18.6%	> +100%	3.6%
-15% to 0%	14.2%		
-30% to -15%	8.8%		
-50% to -30%	8.8%		
-50% to -100%	25.9%		
Total	100.0%		
% Overestimated Links		42.3%	
% Underestimated Links		57.7%	
Overall % Error*		-6.8%	

* Calculated as: (∑ Assigned Vol. / ∑ Counts – 1)*100

PM Peak Hour Validation

The scatterplot for the p.m. peak hour assignment shown in Figure 4 on the following page is similar to that for daily time period. The slope of the regression line is very close to 1 and the R^2 value meets the FHWA's suggested validation target of 0.88.[13] The correlation of the assigned link volumes to traffic counts is slightly lower for the p.m. peak hour assignment due to the shorter length of the time period. It should be noted that an unusually large percentage (57%) of the sample links that the scatterplot is based on fall within the lowest volume category of less than 200 vph, so that if this percentage was lower the results would be even better.

The % RMSE value of 37.15% for the p.m. peak hour assignment is close to the FHWA's suggested validation target of 30%. Again, if not for the high percentage of low-volume links within the sample, this value would be well within the target.

Table 6

**% RMSE
PM Peak Hour Validation**

Link Volume Category	Functional Classification	% RMSE
≥ 1,600 vph	Freeway/Principal Arterial	1.12%
800 – 1,599 vph	Principal Arterial	12.13%
400 – 799 vph	Principal/Minor Arterial	30.67%
200 – 399 vph	Minor Arterial/Collector	44.83%
1 – 199 vph	Collector/Minor Collector	60.87%
All Links		37.15%

Relative link volume errors for the p.m. peak hour assignment for all links are shown in Table 7. The assigned volumes for over 20 % of all links are within ±15 % of the corresponding traffic count, while nearly one-half are within ± 30%. The proportions of over and underestimated links are roughly 35% / 65%, with an overall percentage error of –12.7%.

[13] Travel Model Improvement Program, Model Validation and Reasonableness Checking Manual, (1997).

Figure 4

Link Scatterplot
P.M. Peak Hour Validation

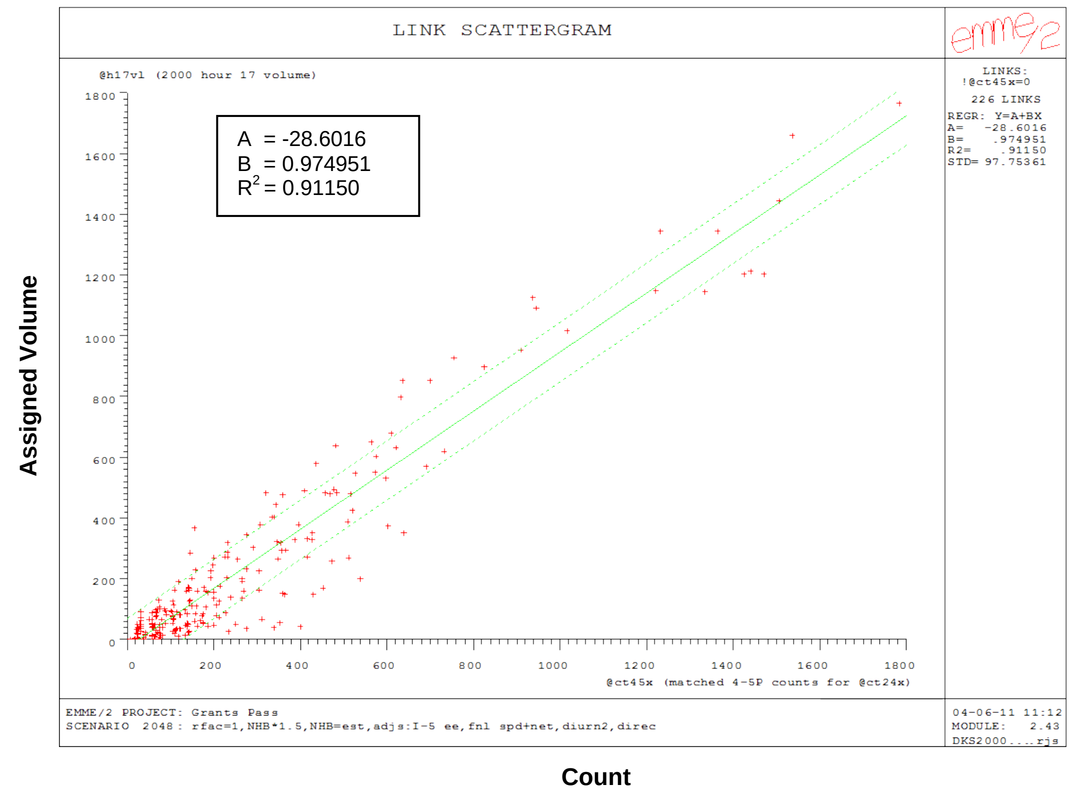


Table 7

Relative Link Volume Error – All Links
P.M. Peak Hour Validation

All Links			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	1.8%	+ or -15%	20.8%
+50% to +100%	3.5%	+ or -30%	45.1%
+30% to +50%	8.8%	+ or -50%	65.9%
+15% to +30%	11.5%	+ or -100%	98.2%

All Links			
0% to +15%	10.2%	> +100%	1.8%
-15% to 0%	10.6%		
-30% to -15%	12.8%		
-50% to -30%	11.9%		
-50% to -100%	28.8%		
Total	100.0%		
% Overestimated Links		35.8%	
% Underestimated Links		64.2%	
Overall % Error*		-12.7%	

* Calculated as: (∑ Assigned Vol. / ∑ Counts – 1)*100

The results shown in Table 8 demonstrate the accuracy of the model for the higher-level facilities. The recommended validation targets for these facilities contained in the *ODOT Travel Demand Model Development and Application Guidelines* are:

- 75% of major arterial link volumes with 10,000 vehicles per day within ±30%; and
- 50% of major arterial link volumes with 10,000 vehicles per day within ±15%.[14]

For the Grants Pass model, 100% of the assigned volumes for these links are within 30% of the counts and 73.3% are within ±15%.

Table 8

Relative Link Volume Error – Links With > 800 VPH
P.M. Peak Hour Validation

>800 vph / Freeway - Principal Arterial			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or –15%	73.3%
+50% to +100%	0.0%	+ or –30%	100.0%
+30% to +50%	0.0%	+ or –50%	100.0%
+15% to +30%	13.3%	+ or –100%	100.0%

[14] Oregon Department of Transportation, Travel Demand Model Development and Application Guidelines, (1995)

>800 vph / Freeway - Principal Arterial			
0% to +15%	33.3%	> +100%	0.0%
-15% to 0%	40.0%		
-30% to –15%	13.3%		
-50% to –30%	0.0%		
-50% to –100%	0.0%		
Total	100.0%		
% Overestimated Links		46.7%	
% Underestimated Links		53.3%	
Overall % Error*		-2.2%	

* Calculated as: (∑ Assigned Vol. / ∑ Counts – 1)*100

Relative error summaries for the p.m. peak hour for all link volume categories are listed in Appendix A.

Appendix A

RELATIVE LINK VOLUME ERROR SUMMARIES

Daily Validation

All Links			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	3.6%	+ or -15%	32.8%
+50% to +100%	5.1%	+ or -30%	49.6%
+30% to +50%	6.9%	+ or -50%	65.3%
+15% to +30%	8.0%	+ or -100%	96.4%
0% to +15%	18.6%	> +100%	3.6%
-15% to 0%	14.2%		
-30% to -15%	8.8%		
-50% to -30%	8.8%		
-50% to -100%	25.9%		
Total	100.0%		
% Overestimated Links		42.3%	
% Underestimated Links		57.7%	
Overall % Error*		-6.8%	

>16,000 vpd / Freeway - Principal Arterial			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or –15%	75.0%
+50% to +100%	0.0%	+ or –30%	100.0%
+30% to +50%	0.0%	+ or –50%	100.0%
+15% to +30%	0.0%	+ or –100%	100.0%
0% to +15%	30.0%	> +100%	0.0%
-15% to 0%	45.0%		
-30% to –15%	25.0%		
-50% to –30%	0.0%		
-50% to –100%	0.0%		
Total	100.0%		
% Overestimated Links		30.0%	
% Underestimated Links		70.0%	
Overall % Error*		-5.0%	

* Calculated as: (∑ Assigned Vol. / ∑ Counts – 1)*100

Daily Validation (cont.)

>8,000 – 15,999 vpd / Principal Arterial			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or –15%	69.2%
+50% to +100%	0.0%	+ or –30%	100.0%
+30% to +50%	0.0%	+ or –50%	100.0%
+15% to +30%	23.1%	+ or –100%	100.0%
0% to +15%	57.7%	> +100%	0.0%
-15% to 0%	11.5%		
-30% to –15%	7.7%		
-50% to –30%	0.0%		
-50% to –100%	0.0%		
Total	100.0%		
% Overestimated Links		80.8%	
% Underestimated Links		19.2%	
Overall % Error*		6.0%	

4,000 - 7,999 vpd / Principal – Minor Arterial			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or –15%	45.5%
+50% to +100%	0.0%	+ or –30%	72.7%
+30% to +50%	6.8%	+ or –50%	88.6%
+15% to +30%	13.6%	+ or –100%	100.0%
0% to +15%	22.7%	> +100%	0.0%
-15% to 0%	22.7%		
-30% to –15%	13.6%		
-50% to –30%	9.1%		
-50% to –100%	11.4%		
Total	100.0%		
% Overestimated Links		43.2%	
% Underestimated Links		56.8%	
Overall % Error*		-9.0%	

* Calculated as: (∑ Assigned Vol. / ∑ Counts – 1)*100

Daily Validation (cont.)

2,000 - 3,999 vpd / Minor Arterial – Collector			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or -15%	28.3%
+50% to +100%	3.8%	+ or -30%	49.1%
+30% to +50%	9.4%	+ or -50%	69.8%
+15% to +30%	11.3%	+ or -100%	100.0%
0% to +15%	18.9%	> +100%	0.0%
-15% to 0%	9.4%		
-30% to -15%	9.4%		
-50% to -30%	11.3%		
-50% to -100%	26.4%		
Total	100.0%		
% Overestimated Links		43.4%	
% Underestimated Links		56.6%	
Overall % Error*		-20.0%	

1 - 1,999 vpd / Collector – Minor Collector			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	7.6%	+ or -15%	16.8%
+50% to +100%	9.2%	+ or -30%	24.4%
+30% to +50%	8.4%	+ or -50%	43.5%
+15% to +30%	3.1%	+ or -100%	92.4%
0% to +15%	7.6%	> +100%	7.6%
-15% to 0%	9.2%		
-30% to -15%	4.6%		
-50% to -30%	10.7%		
-50% to -100%	39.7%		
Total	100.0%		
% Overestimated Links		35.9%	
% Underestimated Links		64.1%	
Overall % Error*		-21.9%	

* Calculated as: ($\sum$ Assigned Vol. / $\sum$ Counts – 1)*100

P.M. Peak Hour Validation

All Links			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	1.8%	+ or -15%	20.8%
+50% to +100%	3.5%	+ or -30%	45.1%
+30% to +50%	8.8%	+ or -50%	65.9%
+15% to +30%	11.5%	+ or -100%	98.2%
0% to +15%	10.2%	> +100%	1.8%
-15% to 0%	10.6%		
-30% to -15%	12.8%		
-50% to -30%	11.9%		
-50% to -100%	28.8%		
Total	100.0%		
% Overestimated Links		35.8%	
% Underestimated Links		64.2%	
Overall % Error*		-12.7%	

>1,600 vph / Freeway - Principal Arterial			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or –15%	100.0%
+50% to +100%	0.0%	+ or –30%	100.0%
+30% to +50%	0.0%	+ or –50%	100.0%
+15% to +30%	0.0%	+ or –100%	100.0%
0% to +15%	0.0%	> +100%	0.0%
-15% to 0%	100.0%		
-30% to –15%	0.0%		
-50% to –30%	0.0%		
-50% to –100%	0.0%		
Total	100.0%		
% Overestimated Links		0.0%	
% Underestimated Links		100.0%	
Overall % Error*		-1.1%	

* Calculated as: (Σ Assigned Vol. / Σ Counts – 1)*100

P.M. Peak Hour Validation (cont.)

800 – 1,599 vph / Principal Arterial			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or –15%	71.4%
+50% to +100%	0.0%	+ or –30%	100.0%
+30% to +50%	0.0%	+ or –50%	100.0%
+15% to +30%	14.3%	+ or –100%	100.0%
0% to +15%	35.7%	> +100%	0.0%
-15% to 0%	35.7%		
-30% to –15%	14.3%		
-50% to –30%	0.0%		
-50% to –100%	0.0%		
Total	100.0%		
% Overestimated Links		50.0%	
% Underestimated Links		50.0%	
Overall % Error*		-2.2%	

400 - 799 vph / Principal - Minor Arterial			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or –15%	31.4%
+50% to +100%	0.0%	+ or –30%	65.7%
+30% to +50%	8.6%	+ or –50%	88.6%
+15% to +30%	14.3%	+ or –100%	100.0%
0% to +15%	22.9%	> +100%	0.0%
-15% to 0%	8.6%		
-30% to –15%	20.0%		
-50% to –30%	14.3%		
-50% to –100%	11.4%		
Total	100.0%		
% Overestimated Links		45.7%	
% Underestimated Links		54.3%	
Overall % Error*		-10.0%	

* Calculated as: (∑ Assigned Vol. / ∑ Counts – 1)*100

P.M. Peak Hour Validation (cont.)

200 - 399 vph / Minor Arterial – Collector			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	0.0%	+ or -15%	14.9%
+50% to +100%	0.0%	+ or -30%	51.1%
+30% to +50%	8.5%	+ or -50%	74.5%
+15% to +30%	17.0%	+ or -100%	100.0%
0% to +15%	4.3%	> +100%	0.0%
-15% to 0%	10.6%		
-30% to -15%	19.1%		
-50% to -30%	14.9%		
-50% to -100%	25.5%		
Total	100.0%		
% Overestimated Links		29.8%	
% Underestimated Links		70.2%	
Overall % Error*		-22.1%	

1 - 199 vph / Collector – Minor Collector			
Error Range	**% of Links**	**Error Range**	**% of Links**
>+100%	3.1%	+ or -15%	14.0%
+50% to +100%	6.2%	+ or -30%	31.0%
+30% to +50%	10.1%	+ or -50%	52.7%
+15% to +30%	8.5%	+ or -100%	96.9%
0% to +15%	6.2%	> +100%	3.1%
-15% to 0%	7.8%		
-30% to -15%	8.5%		
-50% to -30%	11.6%		
-50% to -100%	38.0%		
Total	100.0%		
% Overestimated Links		34.1%	
% Underestimated Links		65.9%	
Overall % Error*		-23.3%	

* Calculated as: $(\sum \text{Assigned Vol.} / \sum \text{Counts} - 1)*100$