Appendix G: Travel Demand Model Documentation

Skagit Council of Governments

TRAVEL DEMAND MODEL DOCUMENTATION

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1 INTRODUCTION

The Skagit Council of Governments (SCOG) Travel Demand Model was developed to provide a solid technical basis for evaluating transportation system needs in coordination with long-term planning in Skagit County, Island County, and local cities. The SCOG Model was built using Visum software and is consistent with local and regional growth plans within the two-county region. The SCOG Model is a composite of two separate model networks, one for Skagit County forecasting (Skagit County Model), and the other for Island County forecasting (Island County Model). The general scope of the model is the area of both Skagit and Island counties. Figures 1 and 2 illustrate the SCOG Model extents.

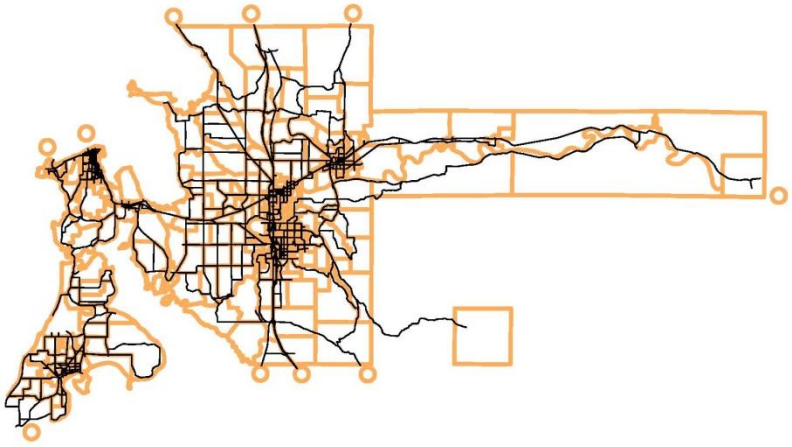

FIGURE 1: SCOG TRAVEL DEMAND MODEL - SKAGIT COUNTY

1.1 MODEL OVERVIEW

The SCOG Model has a base year of 2012 and forecast horizon years of 2036 for the Island County model and 2040 for the Skagit County Model. The model trip assignment represents the PM peak hour period (one-hour volumes) between 4 and 6 p.m. on a typical weekday. The model has a total of 474 Transportation Analysis Zones (TAZs) including 14 external TAZs. However, each county Visum model has under 400 TAZs total (Skagit County Model has 387 and Island County Model has 206). The 2012 Skagit County Model has 1630 lane miles and the Island County Model has 950 lane miles coded that represent freeways, expressways, arterials, collectors, and a few local streets. The two county models overlap geographic areas, meaning they both share the same TAZs within the North Whidbey Island area and Fidalgo Island. Trip generation is performed in a spreadsheet and then exported to the Visum model software. The Skagit County Model and Island County Model use the same trip generation spreadsheet, which allows for consistency between the two models.

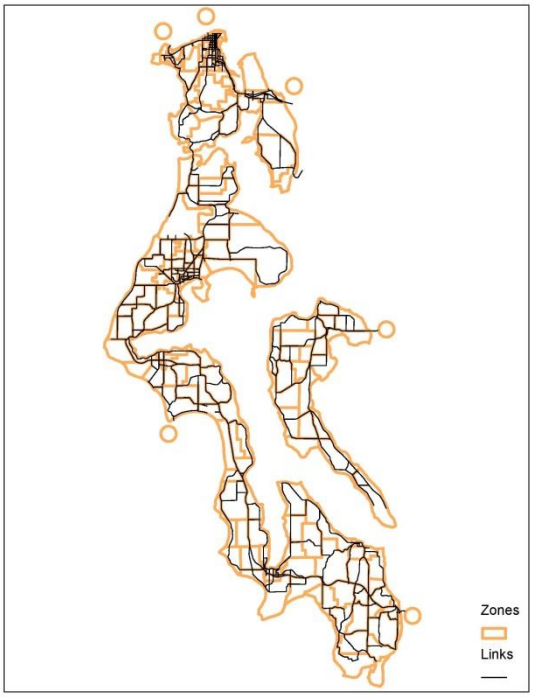

FIGURE 2: SCOG TRAVEL DEMAND MODEL - ISLAND COUNTY

1.2 MODEL DOCUMENTATION OUTLINE

This report provides details about the structure of the model and the assumptions used in constructing the model

- **Chapter 2 - Using the Model**. This section explains the basics of the model and how to do routine analysis with the model. This includes quality control checklists to help confirm that the

model will perform as designed. Specific model details are presented in later chapters and appendices.

- **Chapter 3 - Travel Demand Inputs**. This section explains the various model inputs relative to estimating travel demands including land use, trip generation, trip distribution, mode choice, and other parameters.

- **Chapter 4 - Travel Supply Inputs**. This section explains the various model inputs relative to the supply or capacity of the network including planned improvements, roadway capacities, and other parameters.

- **Chapter 5 - Validation and Reasonableness Checks**. This section explains how the model compares to existing data sets at forecasting travel conditions.

2 USING THE MODEL

The main purpose of the model is to run various model scenarios to understand impacts and/or output traffic volume characteristics. Outlined below is how the model can be used or adapted for scenario testing or other analysis. This section describes how the model operates, how to use it when evaluating scenarios, and the method to post-process model volumes.

The anticipated model users of the SCOG model fall into the two general categories below. Chapter 2 is intended primarily for the basic model user.

- **Basic Model User.** These model users are able to perform basic model analysis including select-link/select-zone analysis, small edits to the model network, land use updates to several TAZs, exporting volumes for post-processing, and model plots.

- **Advanced Model User.** These model users can perform all the basic model user tasks as well as changing the TAZ structure, developing a new analysis horizon year, and calibration/validation of the model.

2.1 SELECT-LINK OR SELECT-ZONE ANALYSIS

Using Visum's internal "flow bundle" application, trips using a specific link or zone can be isolated for review. The path volumes are saved for the PM peak period, so flow bundle analysis of the PM peak period does not require the model to be rerun. This can be a very useful tool for determining how forecasted congestion affects trip patterns.

> ***Quality Control Tip:*** Be sure to be careful on how multiple links or zones are selected. The order they are clicked as well as the "and" versus "or" parameters can have significant impacts on the resulting output. In addition, be sure that both origins and destinations are chosen when doing select-zone analyses.

2.2 CHANGING THE MODEL NETWORK

The model was developed with that anticipation that the model network would be changed to test various scenarios. Some of the network editing is streamlined so that when the model procedures are run, many network attributes are automatically updated.

MODEL LINKS

The model relies on “link types” to assist in link editing. Link types are based on the number of lanes and free-flow (posted) speeds. After editing a link, be sure that the link type attribute is correctly coded. The number of lanes, capacity, and speed is updated for every link when the model is run. NOTE: The transport system link attribute is not automatically set, so manual adjustments are necessary to disable a link. Assumed link attributes were based on National Cooperative Highway Research Program (NCHRP) Report 365: Travel Estimation Techniques for Urban Planning. See Appendix A for link types.

MODEL NODES

The model relies on “node types” to help define intersection delays. When the model runs, the turn capacities, turn delays, and intersection capacities are automatically updated and applied based on node type. After editing the network, be sure that the node type attribute is correctly coded. NOTE: The “ControlType” node parameter is not used in the SCOG model. See Appendix A for node types.

MODEL TURNS

Model turn attributes need to be checked, because they can impact how the intersection delays are calculated. Besides two-way stop control (TWSC) intersections (Node Type 5), all node types assign turn capacities and delays based on major-street/minor-street designations as well as turn types (1-left, 2-thru, 3-right, 4-u-turn). Be sure that the nodes “major flows” are correctly oriented, and that the turn type attribute is correctly coded.

For two-way stop control intersections (Node Type 5), the intersection delay is based on intersection capacity and delays and is only applied to the stopped approach. To make this work properly, the approach with the stop sign should have the link attribute “TModel delay link for turns” set to one (1). The rest of the approaches should be set to zero (0).

RUNNING THE MODEL

After making network edits, make sure to activate the procedure steps in “Group Set Network Attributes” when running the model. To run the full model, activate all the procedures. If only the trip assignment needs to be run, only activate the procedures in the “Group Final Assignment” along with “Group Set Network Attributes.”

Quality Control Checklist:

The following is a checklist to review after making any network edits. Using graphic parameters to illustrate the active parameters makes the review go quickly.

1. When editing the shape of a link, is the box to “take over length-polygon” checked?
2. Are the link types coded correct?
3. Are the node types coded correct?
4. Is the “TModel delay link for turns” set for stop-controlled approach links?
5. Are the major flows correctly oriented at nodes with traffic control?
6. Are turn type number correct at nodes with traffic control?
7. Are there any “prohibited turns” and “u-turns” in places not expected?

8. When running the model after network edits, were the procedure steps run in “Group Set Network Attributes” activated?

2.3 CHANGING LAND USE

Land use inputs, trip generation, and trip balancing occur in the Trip Generation Spreadsheet.

RESIDENTIAL LAND USE

Residential land use inputs are summarized by number of households per TAZ. In addition, the total number of households must be subdivided into cross-classification categories of persons per household and workers per household. This distribution into cross-classification categories is not an automatic spreadsheet process.

To make residential land use changes to existing conditions, make edits to the existing trip generation spreadsheet on the “Ex Land Use (HH)” tab.

To make residential land use changes to future conditions, make edits to the future trip generation spreadsheet on the “Fut Land Use (HH)” tab. NOTE: this tab represents growth only in households. This is the same process for both the 2036 Island County Model and the 2040 Skagit County model.

EMPLOYMENT LAND USE

Employment land use inputs are summarized by number of employees per TAZ, by the categories discussed in Chapter 3. Changing land use has become more difficult with recent employment data suppression policies. Existing employment data is not available to consultants. SCOG processes existing employment data in a separate worksheet, and then transfers the resulting trips into the “SCOG Emp Input” tab.

To make employment land use changes to existing conditions, work with SCOG to make changes and re-export to the “SCOG Emp Input” tab. Alternately, use the factors to scale existing trips to match the number of trips expected in a zone (see Columns O and P on the “Trips_Both Models” tab).

For the 2036 Island County Model employment changes, you will be making edits on the “Fut Land Use (EMP)” tab, which represents growth only in employees. Only make this type of edits to the Island County TAZs (number 600 or higher).

For the 2040 Skagit County Model employment changes, you will be making edits on the “SCOG Emp Input” tab. Work with SCOG to get the total 2040 attraction trips by trip purpose. Only make this type of edits to the Skagit Model TAZs (below number 600).

EXPORT TRIPS TO VISUM

Once the land use changes are made as discussed above, the model trips (Productions and Attractions) will be automatically calculated and are ready to export to Visum. First, open the Visum model file and open a Zone listing, and open the list layout “LanduseInput”. Next open the trip generation spreadsheet and select the tab to be exported (either “Island Co Export” or “Skagit Co Export”). Copy the contents of that spreadsheet tab, and paste into the Zone listing. Save the Visum file.

RUNNING THE MODEL

After making the land use edits, make sure to activate all the procedure steps. All model steps should be run when making land use edits.

Quality Control Checklist:

The following is a checklist to review after making any land use edits.

1. Were the households expanded into the cross-classification categories?

2. For future horizon scenarios, remember that the residential land use being edited represent growth only, not total land use quantities. Future land use changes depend on the county on how they are updated.

3. After exporting, spot check that the production or attraction values in Visum match the spreadsheet values?

4. When running the model after land use edits, were all the procedure steps run?

2.4 Changing the TAZ Structure

Given the complexity of the two county models and the trip generation spreadsheet, it is not recommended to change the TAZ structure (the number of TAZs). The model uses multipoint assignment (MPA), so an alternate method to control where trips enter/exit the model is to provide more TAZ centroid connectors and assign shares (weights) to each connector.

2.5 Changing Model Horizon Year

Changing the model horizon year involves both land use changes and changes to external TAZ assumptions. It is not recommended to change the model horizon year without careful adjustments to the trip generation spreadsheet, external traffic volume forecasts, and forecasts of the external-to-external trip table. Because both models share overlapping areas, horizon year changes require land use updates to both county areas, not just one county.

2.6 Post-Processing Model Volumes

Post-processing refers to adjusting raw future model volumes to account for model calibration or validation differences inherent in all travel demand models.

The “difference method” is the recommended method to estimate post-processed future turning movement volumes at study intersections. The difference method works by subtracting the existing model volume from the future model volume, and adding that difference to existing counts. The difference method does not produce reasonable results 100 percent of the time, so the results need to be checked for reasonableness, similar to all model post-processing methodologies.

A basic model user can easily copy a Visum listing of turns (or links) and paste into a premade spreadsheet to automate the bulk of the post-processing work.

3 Travel Demand Inputs

Travel demand inputs relate to any element that places trips on study area roadways. Land use plans, trip generation rates, and trip distribution parameters are discussed. Trips linked to areas outside the model study area (external trips) are discussed, as well as traffic counts.

3.1 LAND USE

Socio-economic information is the basis for estimating the quantity of travel activity in the study area. This land use information was summarized by the categories shown in Table 1. These land use categories are the basic building blocks of travel demand.

Type	Code	Units	Description
Residential	HH(a)_(b)	Households	Households are segmented for cross-classification purposes. The first number "(a)" represents the number of people in the household from 1 to 4 or more. The second number "(b)" represents the number of workers in the household from 0 to 3 or more.
Employment	RETAIL	Employees	Retail trade, food services
	FIRES	Employees	Finance, insurance, real estate, services
	GOV	Employees	Government
	EDU	Employees	Education
	WTCU	Employees	Wholesale trade, transportation, utilities
	MANU	Employees	Manufacturing
	RESOURCE	Employees	Agriculture, forestry, fishing, mining
	HEALTH	Employees	Heath care, social assistance

TABLE 1: LAND USE CATEGORIES

To generalize travel activity by small areas, transportation analysis zones (TAZs) were developed. The SCOG model has a total of 474 TAZs. These TAZs were established by reviewing current GIS data sets, US Census boundaries, and past SCOG modeling efforts. Figures 1 and 2 show the general size and extents of the model TAZs.

HOUSEHOLDS

Forecast employment allocations were derived from the Washington State Office of Financial Management population estimates for Island and Skagit counties. Initial allocations at the Urban Growth Area (UGA) level were adopted by the Growth Management Act Steering Committees. Island County used 2036 estimates for its model update. Skagit County applied a straight line growth formula to the 2036 estimates to establish 2040 forecast population by UGA. Berk Consulting helped develop a population allocation model to allocate UGA-level population forecasts to the TAZ level.

First, the forecast population numbers were converted to households based on existing household size information. The forecast households were then proportionally distributed by UGA to the TAZ level based on the following characteristics:

- Zoning
- Access to water rights
- Capacity for additional households
- Recent redevelopment
- Access to sewerage
- Proximity to UGAs

EMPLOYMENT

Forecast employment allocations were derived from the Washington State Office of Financial Management employment estimates for Island and Skagit counties. Initial allocations at the UGA level were adopted by the Growth Management Act Steering Committees. Island County used 2036 estimates for its model update. Skagit County used a straight line growth formula on the 2036 estimates

to establish 2040 forecast employment by UGA. Berk Consulting helped develop an employment allocation model to allocate UGA-level employment forecasts to the TAZ level.

In the Skagit employment allocation model the following factors were used to "weight" TAZs for employment allocations:

- Available employment capacity by sector
- Existing employment by sector

These factors were applied to TAZs to develop a modeled allocation of jobs based on estimated job totals by UGA.

3.2 TRIP GENERATION

Trips are generated by land uses and are assigned a trip type. In the SCOG model, there are five basic trip types (or the general purpose of the trip):

- Home-Based-Work (HBW): Vehicle trips that have their origin or destination at the place of residence and the other end at the resident's place of employment.

- Home-Based-Other (HBO): Vehicle trips that have their origin or destination at the place of residence and the other end at somewhere other than the resident's place of employment.

- Non-Home Based (NHB): Vehicle trips with no residential trip end.

- King or Snohomish County (KSCO): Any vehicle trip with one trip end in King or Snohomish County.

- Recreation Destinations (REC): Any vehicle trip with one trip end at a major recreation destination, such as: Anacortes Ferry, Keystone Ferry, or SR 20 in eastern Skagit County.

Trip generation rates used in the SCOG Model reflect weekday PM peak hour trips. Households produce a certain amount of trips, and employment areas attract a certain amount of trips. The total households within each TAZ were separated into groups according to household size and number of workers per household, with trip rates ranging from 0.24 to 2.21 depending on household characteristics. These household trip rates are based on the *2008 North Sound Travel Survey* (NuStats, April 2009). Trip rates for employees ranged from 0.35 to 1.8 depending on the employee classification, and are based on the previous SCOG Model. Detailed trip generation rates by trip type are included in Table 2.

Code[1]	Units	Total	Productions[2]			Attractions[3]		
			HBW	HBO	NHB	HBW	HBO	NHB
HH1_0	Households	0.24	0.0000	0.1933	0.0483	0	0	0
HH1_1	Households	0.32	0.1340	0.1116	0.0734	0	0	0
HH2_0	Households	0.37	0.0000	0.2977	0.0744	0	0	0
HH2_1	Households	0.49	0.1238	0.2825	0.1056	0	0	0
HH2_2	Households	0.75	0.3158	0.2631	0.1729	0	0	0
HH3_0	Households	0.51	0.0000	0.4057	0.1014	0	0	0
HH3_1	Households	0.67	0.1125	0.4150	0.1419	0	0	0
HH3_2	Households	1.02	0.3442	0.4507	0.2294	0	0	0
HH3_3	Households	1.44	0.6048	0.5040	0.3312	0	0	0
HH4_0	Households	0.78	0.0000	0.6233	0.1558	0	0	0
HH4_1	Households	1.03	0.1296	0.6839	0.2149	0	0	0
HH4_2	Households	1.57	0.3966	0.8341	0.3431	0	0	0
HH4_3	Households	2.21	0.8363	0.8740	0.5022	0	0	0
RETAIL	Employees	1.80	0	0	0	0.2880	0.7560	0.7560
FIRES	Employees	0.70	0	0	0	0.2100	0.2870	0.2030
GOV	Employees	0.70	0	0	0	0.2940	0.2520	0.1540
EDU	Employees	1.56	0	0	0	0.7800	0.7488	0.0312
WTCU	Employees	0.59	0	0	0	0.4543	0.0177	0.1180
MANU	Employees	0.37	0	0	0	0.1554	0.0222	0.1924
RESOURCE	Employees	0.35	0	0	0	0.2800	0.0000	0.0700
HEALTH	Employees	1.06	0	0	0	0.3180	0.4346	0.3074

TABLE 2: TRIP GENERATION RATES

Source: Transpo Group, 2015

1. Code represents the land use category. See Table 1 for land use definitions.
2. Productions represent residential land uses. The trips rates were based on information in *2008 North Sound Travel Survey* (NuStats, April 2009). Trip from HBW, HBO, and HNB were reassigned to types KSCO and REC based location within the county.
3. Attractions represent employment land uses. The trips rates were based on the previous SCOG model. Trips from HBW, HBO, and HNB were reassigned to types KSCO and REC based location within the county.

Trip generation assigns trips first to the HBW, HBO, and NHB trip types by TAZ. Then a portion of these trips are reassigned to the KSCO and REC trip types. The reason that KSCO and REC trip types were added in the model was to better link sub-regions within the model to key external TAZs. The percent of trips of a sub-region area that traveled to King County, Snohomish County, and recreational areas were based on several studies including the *2008 North Sound Travel Survey* (NuStats, April 2009), the *2006 Washington State Ferry Origin-Destination Survey* (WSDOT, June 2007), and *Census Transportation Planning Products* (2006-2010 five-year estimates).

Trip generation calculations occur in a spreadsheet outside the Visum software platform. The spreadsheet version is more transparent for outside reviews, and is more robust when local and regional agencies update their plans and model inputs. The spreadsheet also allows for the trip generation to be consistent between the Skagit County Model and the Island County Model, even in overlapping areas. When the trip generation spreadsheet is updated, there is a very simple procedure to import the new information in Visum.

3.3 TRIP DISTRIBUTION

Trips are distributed between TAZs using the “gravity” model, which is incorporated into the Visum software. This gravity model is built on the theory that, all else being equal, the attraction between two masses will be proportional to the size of the masses and inversely proportional to the distance

between the masses. In the travel demand model, the number of trips in a TAZ is used to reflect the size of the mass, and route travel time is used to reflect the distance factor in the gravity model.

The gravity model has parameters to adjust these relationships for each trip purpose. Simply put, these parameters influence average trip lengths of each trip type. In the SCOG Model, the "Combined" utility function controls the impact of the distance factor in the gravity model. In equation form, the function is $f(U) = a*(U^b)*(e^{cU})$ where U is travel time between zones. Congested travel times are used for distributing trips. The parameters differ by trip type as shown in Table 3 and are based on guidance in *NCHRP 716 Travel Demand Forecasting: Parameters and Techniques* (TRB, 2012).

	Skagit County Model			Island County Model		
	a	**b**	**c**	**a**	**b**	**c**
Home-Based Work (HBW)	100	-0.02	-0.125	100	-0.45	-0.125
Home-Based Other (HBO)	100	-0.90	-0.10	100	-1.30	-0.10
Non-Home Based (NHB)	100	-0.30	-0.10	100	-0.90	-0.10
King or Snohomish County (KSCO)	100	-0.02	-0.125	100	-0.45	-0.125
Recreation (REC)	100	-0.02	-0.125	100	-0.45	-0.125

TABLE 3: GRAVITY MODEL DISTRIBUTION PARAMETERS
Source: Transpo Group, 2015

Trip distribution in the SCOG model assigns productions (households) to attraction (destinations) for PM peak hour trips. The model then converts those matrices into origin and destination matrices.

3.4 EXTERNALS

External TAZs account for trips which start and/or end outside the model study area. The SCOG model has 14 external TAZs. Trip generation for these TAZs is based on the following data sources:

- Current daily traffic volumes
- Historical traffic volumes
- Land use growth forecasts

Existing and forecasted external trips were converted to either productions or attractions by trip type in the trip generation process. Trips from both internal and external TAZs were then distributed according to the gravity model process. External-to-external trips were estimated separately.

3.5 MODE CHOICE

Trip generation procedures produce vehicle trips directly from land use inputs. The conversion of daily person trips to vehicle trips by household type was based on mode split information in the *2008 North Sound Travel Survey* (NuStats, April 2009).

3.6 TIME-OF-DAY

Trip generation procedures produce weekday PM peak hour trips directly from land use inputs. The conversion of daily person trips to weekday PM peak hour trips by household type was based on time-of-day information in the *2008 North Sound Travel Survey* (NuStats, April 2009).

3.7 Traffic Counts

Existing traffic counts are significant in the development of the model because they directly account for existing travel demands. These existing volume inputs are used in key metrics that determine the validation and reasonableness of the existing year model. Regional roadway counts (daily and hourly) were obtained from local agencies and WSDOT and represent year 2012 or later.

4 Travel Supply Inputs

Travel supply inputs relate to any elements that process trips on study area roadways. Overall network structure is explained as well as link and node types. Volume-delay relationships for various link and nodes types are also discussed.

4.1 Existing Street Network

The street network models the available travel supply. In the travel demand model, the street network is composed of links (roadways segments) and nodes (intersections). At the nodes, capacities at turns (turning movements) are used to represent basic traffic control constraints. Travel demand enters and exits the street network at nodes called TAZ centroids. These centroids are connected to the network with links called connectors.

In the SCOG model, the scope of the street network includes most major roads in Skagit and Island counties. Street alignments and attributes of the existing street network (such as posted speeds, lanes, and traffic controls) were obtained from GIS data sources and field observation in spot areas. Visum software allows direct integration with available GIS information. A map of the network is shown in Figures 1 and 2.

4.2 Future Baseline Street Network

Adapted from the existing street network, the future baseline street networks include various planned, programmed, or otherwise committed network improvements. As part of the Island County Model development and planning process, several future 2036 baseline network improvements were assumed:

- Race Road to Houston Road Connector Phase 1 and 2.
- Add traffic signals to the following intersections: SR 20/Troxell Rd; SR 20/Banta Rd; and SR 525/Harbor Ave.
- SR 20, Morris Road to Jacobs Road Safety Improvements. See WSDOT project website for more information on new alignments and intersections.

The 2040 Skagit County Model future baseline planned improvements assumptions were as follows:

- Jameson Arterial Extension
- College Way at I-5 Widening
- Josh Wilson Road Phase I
- Francis Road @ SR 9 Roundabout
- Sharpes Corner Intersection Improvements
- Miller-Gibralter Intersection Improvements

4.3 LINK TYPES

Link types are used to define the basic roadway attributes assumed by the model. Specific link capacities are assigned to each link type based on access control type, posted speeds, restricted vehicle modes, and number of lanes. For consistency and quality control purposes, the SCOG model automatically updates link speeds and capacities based on a link type lookup table (when the model runs). This reduces the risk for link attribute errors in the model. The link type look up table is provided in Appendix A.

4.4 NODE TYPES AND TURN CAPACITIES

Similar to link types, node types are used to define basic intersection control types. These types account for most basic types of intersections. These node types set the assumed turn capacities and basic turn delays from the major and minor approaches. Specific turn capacities are assigned to each node type, based on whether the intersection is uncontrolled, stop-controlled, or controlled with a traffic signal or roundabout.

For consistency purposes, the SCOG Model automatically updates capacities and base delays of turns based on the node type. This reduces the risk for model coding error, and reduces the effort in maintaining the model. Node type descriptions are included in Appendix A.

4.5 VOLUME-DELAY FUNCTIONS

Volume-delay functions dictate the level of delay along roadways or at intersections as traffic volumes approach network capacity. In other words, they calculate traffic congestion. Volume-delay functions were used to calculate both link (roadway) delays and turn (intersection-related) delays.

In the SCOG Model, link delays were calculated with “Conical” functions and generally follow the characteristics outlined below:

- Freeway Links. Congested speeds remained at freeway speeds until approximately 80 percent of capacity. At 90 percent, speeds drop close to 45 mph. At capacity, speeds represent stop and go conditions (about 30 mph).

- Non-Freeway Links. At 80 percent of capacity, congested speeds drop to about 60 to 70 percent of free-flow speeds. At capacity, congested speeds drop to about 30 to 35 percent of free-flow speeds.

In the SCOG Model, base turn delays were assigned to each turn based on intersection type. Additional turn delays were calculated with the “TModel Nodes” function. This function is sensitive to the volume-to-capacity ratios at the turning movement level. Characteristics of this function parameter set include:

- At 50 percent of turn capacity, additional delays are less than 5 seconds per vehicle.

- At 80 percent of capacity, additional delays are approximately 30 seconds per vehicle.

- At capacity, additional delays are approximately 75 seconds per vehicle.

4.6 Other Inputs

Multipoint assignment (MPA) was used for several TAZs in the SCOG Model. MPA refers to assigning a specific percentage of travel demand to a connector for TAZs that have multiple connectors, rather than allowing the shortest path to the centroid dictate connector traffic. However, the default setting for each TAZ is to not use MPA unless it is needed.

5 Validation and Reasonableness Checks

The process of model validation and reasonableness checks confirms if the model building blocks, if correctly applied, reasonably predict real world travel patterns and is valid for forecasting and other transportation planning purposes. Several statistics were reviewed that were associated with screen line volumes and individual link volumes. Distribution and trip generation characteristics were reviewed using various checks.

5.1 Screen Line Analysis

Screen lines (a boundary line which identifies all links between two areas) were defined to compare model travel patterns to actual travel patterns between two areas. Screen line locations for each county model are shown in Figures 3 and 4.

Table 4 shows the screen line results for the Skagit County Model, and Table 5 shows the results for the Island County Model. Percent difference maximums vary by volume and are based on guidance from *Travel Model Validation and Reasonableness Checking Manual* (FHWA, 2010), but generally anything less than 22 percent is acceptable.

	Southbound			Northbound			Both Directions		
	Model[1]	Count[2]	Diff[3]	Model	Count	Diff	Model	Count	Diff
North-South Movements									
Deception Pass	596	695	-17	688	645	6%	1,284	1,340	-4%
Southwest County	674	660	2%	753	645	14%	1,427	1,305	9%
Skagit River at I-5	3,005	2,450	18%	3455	3,640	-5%	6,460	6,090	6%
Mount Vernon City	4,248	4,580	-8%	4,533	5,265	-16%	8,781	9,845	-12%
	Westbound			**Eastbound**			**Both Directions**		
East-West Movements									
Fidalgo/Mainland	1,607	1,400	16%	1,435	1,690	18%	3,042	3,090	-2%
Northwest County	1,976	1,670	15%	1,891	2,210	-17%	3,867	3,880	0%
Mount Vernon City	714	845	-18%	1,131	1,355	-20%	1,845	2,200	-19%
West Sedro-Woolley	1,677	1,435	14%	2,050	1,990	3%	3,727	3,425	8%
East Sedro-Woolley	404	335	17%	531	540	-2%	935	875	6%

TABLE 4: SCEEN LINE RESULTS - SKAGIT COUNTY MODEL

1. Represents the sum of all model volumes crossing the screen line in that direction
2. Represents the sum of all count volumes crossing the screen line in that direction
3. Represents to percent difference between the count and model volumes. Percent difference maximums vary by volume and are based on guidance from *Travel Model Validation and Reasonableness Checking Manual* (FHWA, 2010), but generally anything less than 22 percent is acceptable.

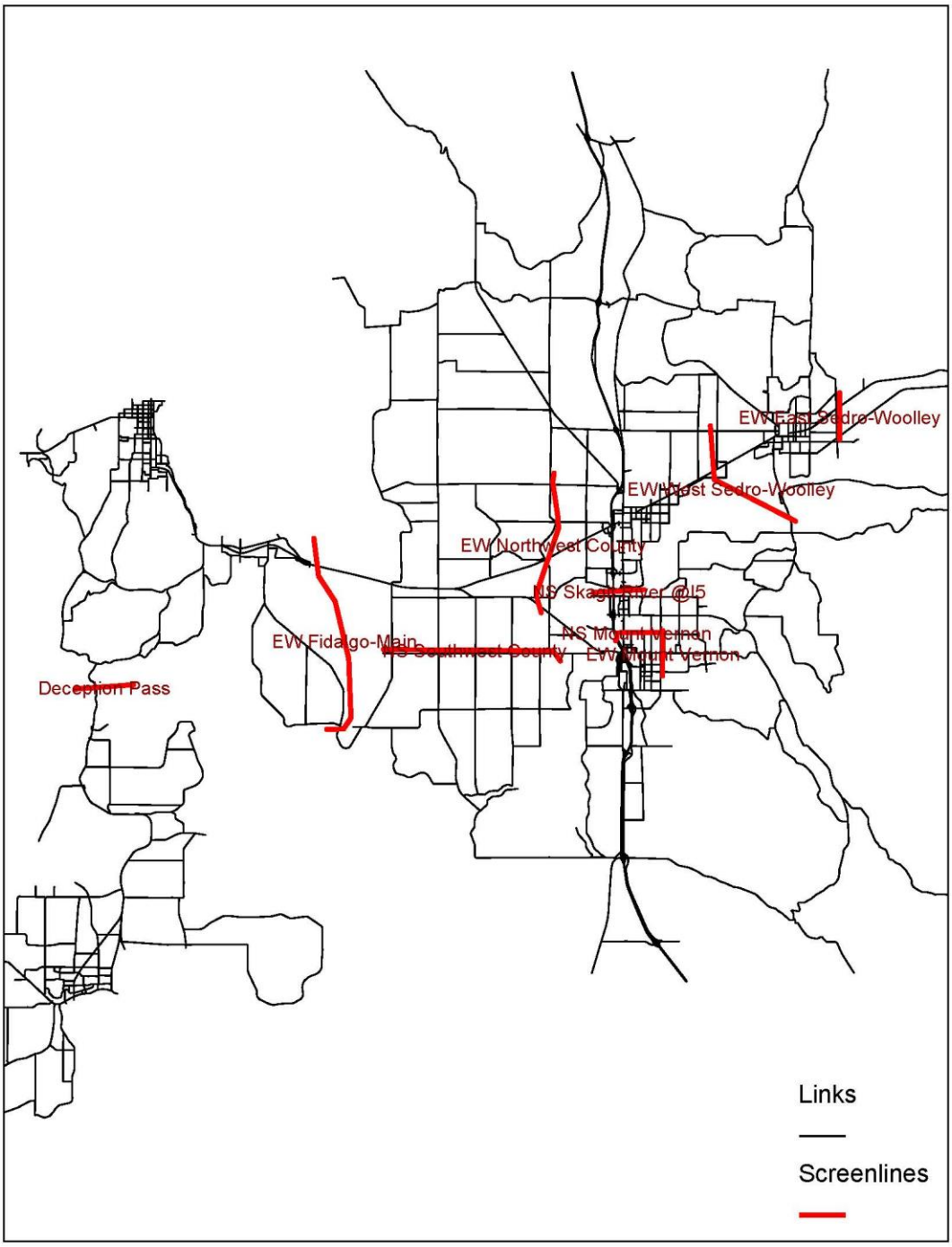

FIGURE 3: SCREEN LINES IN SKAGIT COUNTY MODEL

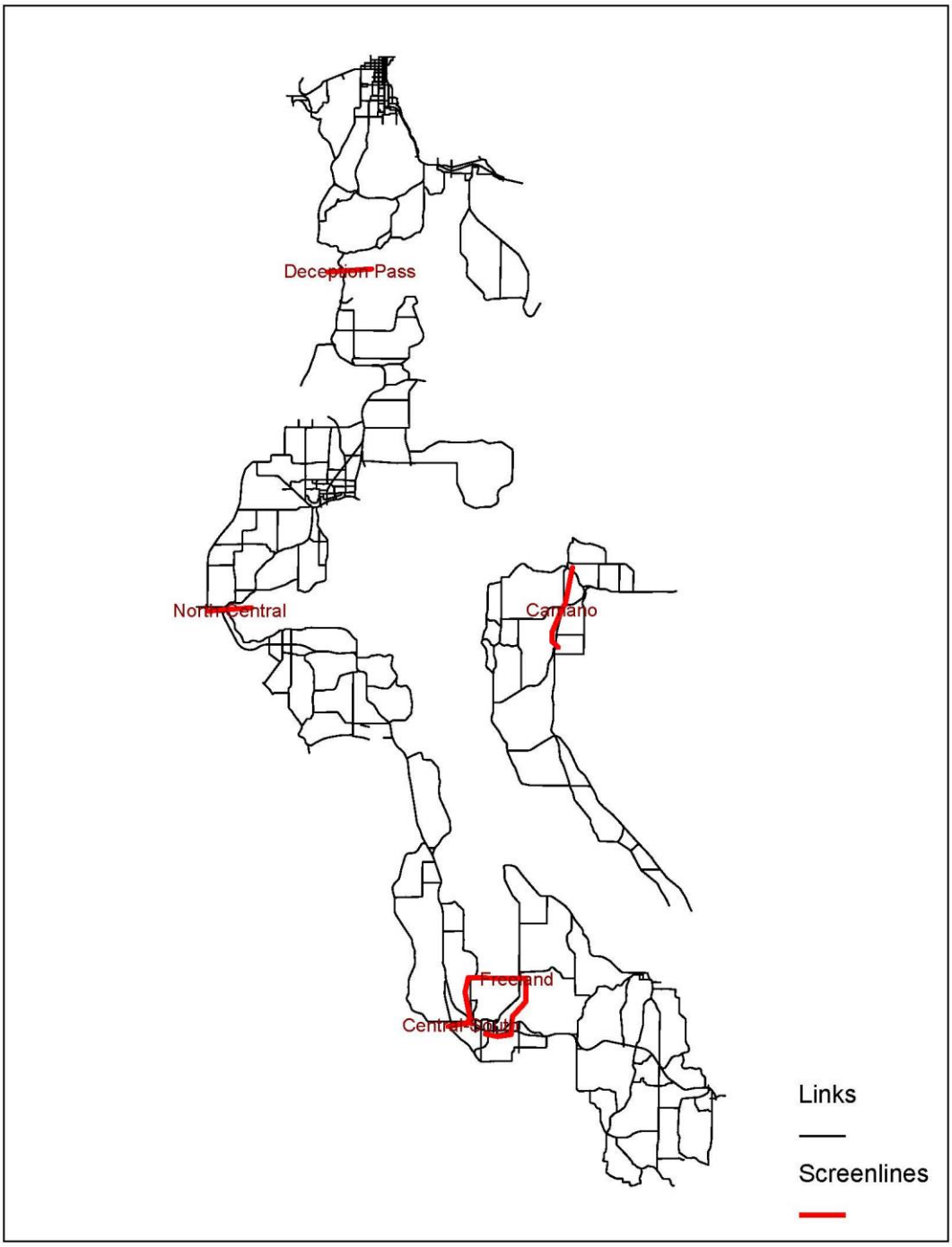

FIGURE 4: SCREEN LINES IN ISLAND COUNTY MODEL

As shown in Table 4, all but one screen line in Skagit County performed within an acceptable difference of 22 percent. The east-west screen line in the City of Mount Vernon had much lower volumes than what the counts would suggest. Given other screen lines were within targets, this may suggest a localized issue within the model, such as incorrect Mount Vernon land use inputs or poor traffic count quality. Given model travel patterns throughout Skagit County, these results were considered acceptable.

	Southbound			Northbound			Both Directions		
	Model[1]	Count[2]	Diff[3]	Model	Count	Diff	Model	Count	Diff
North-South Movements									
Deception Pass	634	695	-10%	650	645	1%	1284	1340	-4%
North/Central Boundary	519	475	8%	479	530	-11%	998	1005	-1%
Central/South Boundary	443	440	1%	405	485	-20%	848	925	-9%
	Inbound/Westbound			**Outbound/Eastbound**			**Both Directions**		
East-West (Inbound-Outbound) Movements									
Freeland Cordon	1214	1350	-11%	1313	1450	-10%	2527	2800	-11%
Camano Central	1263	1210	4%	649	530	18%	1912	1740	9%

TABLE 5: SCREEN LINE RESULTS - ISLAND COUNTY MODEL

1. Represents the sum of all model volumes crossing the screen line in that direction
2. Represents the sum of all count volumes crossing the screen line in that direction
3. Represents to percent difference between the count and model volumes. Percent difference maximums vary by volume and are based on guidance from *Travel Model Validation and Reasonableness Checking Manual* (FHWA, 2010), but generally anything less than 22 percent is acceptable.

As shown in Table 5, all screen lines within Island County performed within an acceptable difference of 22 percent, based on recommendations in the *FHWA Manual*. Given overall model travel patterns, these results were considered acceptable.

5.2 LINK VOLUME ANALYSIS

The analysis of roadway link volumes compares roadway model volumes to actual traffic counts, by direction, for all locations where actual traffic counts are provided. Two common link volume statistics were reviewed to evaluate the model validity: Percent Root-Mean-Square-Error (RMSE) and R-squared or "goodness of fit".

Percent RMSE was calculated by roadway group to understand model behavior on key facilities. Percent RMSE is essentially the average of all the link-by-link percent differences—a good statistic to understand percent difference variability on links of a particular functional class. Table 6 shows the percent RMSE results for the different roadway groups during each respective time period. Generally, results below 40 percent RMSE are considered acceptable. In Island County, both state highways and arterials were below this 40 percent threshold. In Skagit County, state highways were below the 40 percent threshold but arterials were just above. This is likely due to the same isolated issues in Mount Vernon that also pushed screen line differences above targets. Collector and local roadways were above this threshold, however they typically have lower volumes that make the 40-percent target more challenging to achieve consistently.

R-squared indicates how well the model volumes represent the actual traffic counts. If model volumes exactly matched the actual counts, the R-squared value would be 1.00. For both county models, the overall model R-squared was 0.94 or greater which is within guidelines from the *FHWA Manual*.

	Skagit County Model			Island County Model		
	RMSE[1]	R-squared[2]	Difference[3]	RMSE	R-squared	Difference
State Highways	17%	0.96	13%	18%	0.88	13%
Arterials	41%	0.75	29%	38%	0.79	26%
Collectors/Local	63%	0.74	42%	44%	0.89	29%
Total	27%	0.96	19%	26%	0.94	18%

TABLE 6: LINK VOLUME STATISTICS

1. Percent Root-Mean-Square-Error (RMSE) refers to the percent difference on an average link-by-link basis.
2. R-squared indicates how well the model volumes represent the actual traffic counts. If model volumes exactly matched the actual counts, the R-squared value would be 1.00.
3. Refers to the percent difference on a total volume basis (sum total of all links).

Based on the data shown in Table 6 the SCOG model link-by-link variability (Percent RSME and R-squared) was considered acceptable. Maximums were established based on guidance from *FHWA Manual*. Link analysis scatterplots are shown in Figures 5 and 6.

5.3 DISTRIBUTION CHECKS

Distribution checks relate to how the model is distributing and assigning trips through the model. The following types of distribution checks were performed for both county models.

AVERAGE TRIP LENGTHS

The average trips lengths for the main trip types (HBW, HBO, and NHB) were compared back to trip length information in the *2008 North Sound Travel Survey* (NuStats, April 2009). For the Skagit County Model, average trip lengths were 20, 15, and 13 minutes for the HBW, HBO, and NHB trips, respectively. For the Island County Model, average trip lengths were 22, 15, and 12 minutes for the HBW, HBO, and NHB trips, respectively. These trip lengths were within 10 percent of the trip length information in the *2008 Travel Survey*.

SELECT-LINK AND SELECT-ZONE ANALYSIS

Select-link and select-zone refers to isolating a roadway or TAZ and flagging only those trips on the model network that are associated with that link or zone. This can identify problems with trip generation, trip distribution, and/or trip assignment model parameters. Select-link and select-zone analysis was performed at key roadways and TAZs to test the reasonableness of the model. This included major bridges, external TAZs, and major employment centers. For the SCOG model this process resulting in adjustments to external distribution parameters and improved network coding (nodes, links, and centroid connectors).

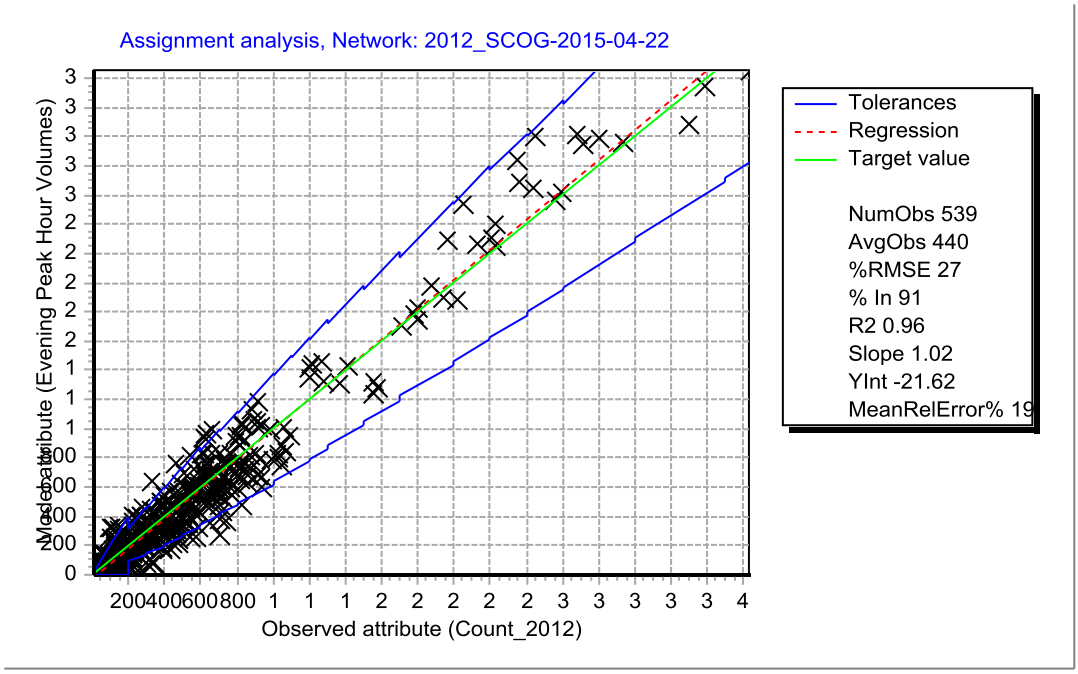

FIGURE 5: LINK ANALYSIS SCATTERPLOT - SKAGIT COUNTY

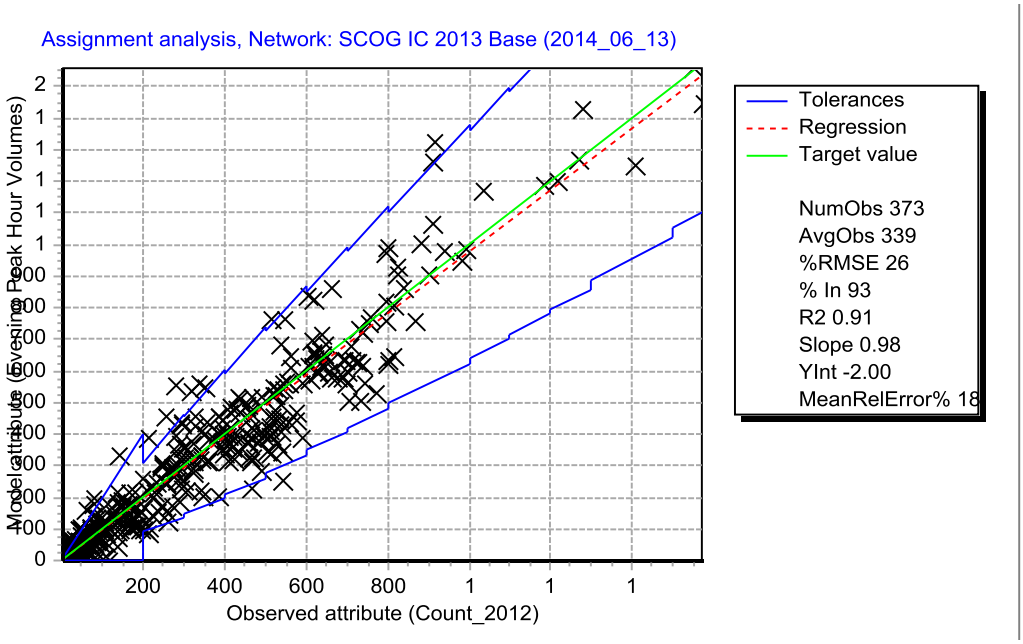

FIGURE 6: LINK ANALYSIS SCATTERPLOT - ISLAND COUNTY