Whatcom County Travel Demand Model 2018 - 2019 Update

Project Final Report

Prepared for:
Whatcom Council of Governments

October 21, 2020

Prepared by:

Prepared by:

Caliper Corporation
1172 Beacon St
Newton, MA 02461.

617-527-4700
www.caliper.com

Contents

Chapter 1: Introduction and Motivation for Model Update

This section briefly describes the travel demand prior to the current modeling update effort and the motivation for an update.

2018 Base Year Model

Travel Demand Modeling in the Whatcom County region has had a strong and supportive history throughout the years, with numerous models built for the region in the past two decades. The previous Whatcom Regional Travel Demand Model was developed for the Whatcom Council of Governments (WCOG) by Caliper Corporation to represent a 2010 base year, The Updated Whatcom Model 2014, and was applied to assist WCOG with their regional transportation planning needs. This work was a significant improvement and a complete overhaul to the previous travel demand model with a base year of 2008. The 2018 base year model update pivots off the framework and structure from the 2010 base year with the utilization of a more recent household travel survey to re-estimate the critical model components.

The 2018 model is completely data-driven and utilizes local derived data. Using the most recent household travel survey conducted by Resource Systems Group (RSG) in its entirety, models for Trip Generation, Trip Distribution, Mode Choice, Time of Day Analysis, and Traffic Assignment were all re-visited and re-estimated. The model consists of and generates outputs for four time periods (AM Peak, PM Peak, Mid-day, and Night) throughout a typical spring or fall weekday, providing the WCOG with the ability to analyze potential infrastructure (highway and transit) projects in the context of the time period most affected.

The calibration of the 2018 model and its integrity with respect to replicating the survey is at the highest level and the model produces traffic flows that are highly consistent with observed traffic counts. This 2018 model also provides WCOG with a completely new interface that better facilitates scenario management while retaining and exploiting the excellent visualization capabilities TransCAD is known for.

Motivation for the Model Update

The motivations for a model update are manifold and listed below:

- To harness the latest information derived from the most recent household travel survey, *2018 Whatcom Regional Travel Study*, and apply the data to the model. Also, the new survey data allows us to analyze how travel patterns have changed in the WCOG region in the past several years.

- Another motivation for updating the model was to reflect changes in the roadway network and land use for the region. The network was updated based on documented changes through 2018. Updated traffic counts through 2019 from a variety of sources were also collected for the update. Land use data was updated by WCOG staff with assistance from local jurisdictions to reflect the latest changes in the region.

- In keeping with the latest software, the WCOG model was updated to the TransCAD 8.0 platform. Consequently, the new model uses to the latest procedures and algorithms embedded in TransCAD 8.0 and utilizes the most recent native GISDK code. Advances in the software related to multithreading and more efficient usage of computing resources should yield better running times that will enable WCOG to obtain results in a timely and rapid fashion.

This document describes many of the modeling improvements that resulted in a well calibrated 2018 base year model. Caliper Corporation is pleased to deliver this model to Whatcom and to continually support them in its application to ensure success. We would like to provide a special mention to Lethal Coe at WCOG for his continual dedicated resolve and his relentless excitement and hard work towards developing this quality product. We have full confidence in the updated model and its ability to accurately depict travel in the WCOG region and believe it to be a great tool for assisting staff in prioritizing the future transportation needs for the region.

Chapter 2: Model Framework

The main modeling framework is shown in Figure 2.1 below:

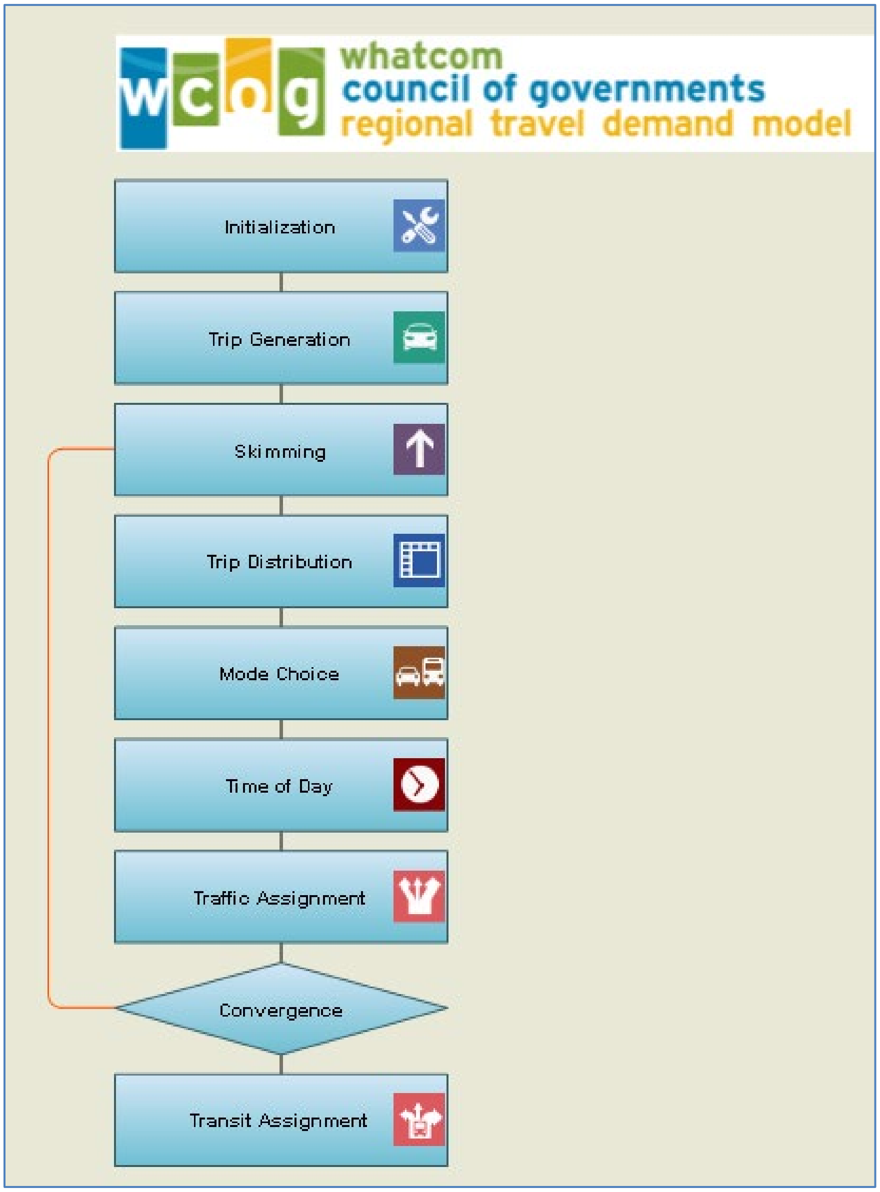

Figure 2.1: 2018 Whatcom Planning Model Flowchart and Interface

The model framework is similar to the 2014 model, with a couple of key differences; the PM peak is now represented as the period from 4 – 6 PM, and the non-motorized trip purposes utilize a more comprehensive path building process that includes considerations for roadway types that are more or less suitable for non-motorized travel. These issues are discussed in the appropriate sections.

The model was developed based on the Household Travel Survey comprising of all of Whatcom County. The model is a traditional four-step travel demand model, with time of day components and a travel time feedback loop structure. A brief summary of the model processes follows:

The highway and transit **initialization routines** process the highway and the route system database. The highway database is processed to make sure that link functional classes, area types and lanes are present for all the links. Based on a lookup table, the link free flow speeds, link capacities and the attributes for the Volume Delay function are filled in.

Links designated for walk are marked in the database and link walking times are computed.

The Route System is attached to the current line layer and transit times on the network links are computed.

The **Trip Generation** algorithm predicts daily productions and attraction by trip purpose. Eight trip purposes are considered in the model (Home-based Work (HBW), Home-based College (HBCol), Home-based School (HBSch), Home-based Shop (HBSho), Home-based Other (HBO), Non-home-based Work (NHBW), Non-home-based Other (NHBO) and Truck Trips (Truck)). For the home-based (HB) trip purposes, the trip production ends are deemed to be the home zones and trip attraction ends are deemed to the non-home zone. For the Non-home-based (NHB) purposes, the trip production is the origin end and the trip attraction is the destination end. The trip productions are based on household trips and the trip attractions are based on employment and enrollment estimates.

Daily Trip Productions rates for the Home-based Work (HBW) purpose are based on the number of workers in the household, the income level of the household, and on the Household or residence region. Daily Trip Production rates for the Home-based Non-work purposes are based on the household size, on the household income type and on the household residence region. The trip making characteristics were found to be different in Bellingham, WA as compared to the rest of the region. Localized variations in the rest of the region were also considered. Trip Production rates for the Non-Home Based purposes and Daily Trip Attractions rates are based on employment by NAICS code (office, industrial, retail, arts employment etc.), school enrollment (for school trips), college enrollment, households and household population. There are no special generators in this model (unlike the 2014 model).

The latest update to the model retains the Truck/Freight model present in the previous model. This model utilizes employment land uses to generate origin and destination trip ends for internal commercial vehicle flows. The methodology is similar to the FHWA Quick Response Freight Model in its implementation, though the Whatcom version uses considerably more land uses. The model stream for the trucks mimics the traditional trip purposes (HBW, HBO, etc.) in that it includes friction factors for a truck-specific gravity model and time of day parameters. The trip rates and parameters used throughout the model were not estimated from the Household Travel survey. The link flows resulting from the truck origin-destination matrices has not been calibrated or validated against any observed truck flow in the region. We believe that it the flow produced by the truck is reasonable.

The daily trip productions and attractions are split into Peak (PK) and Off-Peak (OP) productions and attractions by using splits for each purpose obtained from the survey. The PK period comprises of the AM and the PM peaks and the OP period comprises of the Midday (MD) and Night (NT) periods. External trips are added to the PK and OP trip productions and attractions. Finally, trip balancing is performed for the PK and the OP Production and Attraction tables.

The **Highway Skimming** process generates estimates of zone to zone travel times for the AM and the MD time periods. The link travel times input to the procedure are read from congested AM and MD time fields in the highway network file using the travel times derived from the Method of Successive Averages (MSA) embedded in the assignment functionality. In the case of a feedback run, free flow times are generally input for use in the first iteration.

The **Transit Skimming** is run using the pathfinder skims to generate skims for the AM and MD time period. One of the key inputs to the skim is the origin to parking node input matrix that contain drive times from each of the centroids to the appropriate parking nodes. The drive times used for calculating the skims come from the latest estimate of the AM or MD congested times.

The **Trip Distribution** is based on a doubly constrained gravity model and is applied to generate PK and OP Production Attraction matrices. During the model application, the AM skims are used as a proxy for the PK skims and the MD skims are used as a proxy for the OP period. Gamma function-based Friction factor curves calibrated from the survey are used as inputs to the process.

The **Mode Choice** routine is likewise applied to the PK and OP trip distribution PA matrices. The mode choice is a Nested Logit Model (NLM), with one model developed for each period (PK or OP) and each purpose, excepting the truck purpose. In addition to the TAZ database, the PK mode choice model utilizes AM highway and transit skims and the OP mode choice model utilizes MD highway and transit skims. Several modes are considered during the process including Drive Alone, Carpool, Walk, Bike and Transit modes. The mode choice procedure returns Production-Attraction (PA) trips by purpose, period and mode.

The **Time of Day** procedure is used to further split the PK mode choice output matrices into AM and PM matrices and to split the OP mode choice output matrices into MD and NT matrices. The procedure also converts person trips to auto trips and converts the PA matrices into OD matrices. The time of day procedure yields Auto and Truck OD matrices by the four sub-time periods (AM, PM, MD and NT). Likewise, the transit time of day component (that is outside the feedback loop) generates AM, PM, MD and NT transit OD matrices. External highway trips are added to the Auto/Truck modes.

The **Traffic Assignment** within the feedback loop process assigns the AM and the MD trips onto the network. The assignment is based on the Origin User Equilibrium method using the Bureau of Public Roads (BPR) function. The assignment generates congested AM and MD link travel times using an embedded MSA procedure.

In order to achieve consistency in the travel times used to derive the origin-destination matrix and those output from the traffic assignment stage, there is a **feedback** component in the model, wherein the congested AM and MD link travel times are used to re-compute highway skims and re-run the transit skims, trip distribution, mode choice, time of day and traffic assignment. This process is shown by the feedback arrow in the model. The feedback loop can be run until a fixed-point solution is obtained.

Finally, the PM and MD traffic assignments and the transit assignment for the PK and OP periods are run.

Key Changes to the 2018 Model

This section summarizes the key differences of the Whatcom 2018 planning model compared with the previous model update.

- The 2018 model uses updated demographics derived from the most recent American Community Survey (ACS) Census files using block group level data collected between 2014-2018. The distribution of households by size and income and the distribution of households by income and workers is determined using an innovative population synthesis approach (Chapter 3).
- The PM Peak time period definition in the 2018 model was changed to a two hour period from 4 – 6 PM to better capture the more focused congestion pattern of that period. The AM peak period remains 7 -9 AM. The MD period sandwiches the two peaks and the NT period constitutes the remaining hours.
- The 2018 updated model does not use any special generators. The updated trip attraction models sufficiently explain the attractions and there was no need to have special rates for retail heavy zones.
- Several key parameters such as the network speeds and capacities by functional class were modified.
- The model was calibrated and validated using the most recent counts available (mostly 2017 and 2018), assembled by WCOG staff and derived from various sources.

Model Update Methodology

The update methodology consisted of several stages, given the updated TAZ and network files:

- The first stage consisted of assimilating the latest ACS data and developing a comprehensive routine to generate the household cross tabulations necessary for applying the trip generation model.
- The second stage consisted of fixing and updating some of the input files such as external counts.
- The third stage consisted of processing the travel survey and re-estimating all the model components. This is the most time-consuming component of the update. We cross-referenced the newly estimated models with the previous update to see how things changed between the model updates. This also assists in verifying that we processed the survey correctly.
- The fourth stage consisted of a significant calibration effort to match observed trip patterns and observed counts. This was a highly iterative process with several adjustments to the various models, model re-runs and discussion with WCOG staff.
- The final stage of the calibration focused on the transit modeling with an aim to match overall boardings by period, boarding at key stations and park and ride observed usage.

Chapter 3: Data Preparation

This chapter details the development of the land use data for 2018, specifically the household cross tabulations and describes briefly the work performed by Caliper and WCOG staff towards developing the updated TAZ and network files.

Land Use Data Generation

The key land use inputs are the household and the employment variables. The household classification in the 2018 model required for the trip generation were the tabulation of households by household size and household income and the tabulation by household income and number of workers in the household. The table below shows the various fields that need to be populated:

Household Income	**Household Size**			
	1	**2**	**3**	**4+**
Low : [0, $24,999]	1HHLINC	2HHLINC	3HHLINC	4HHLINC
Medium Low: [$25,000, $49,999]	1HHLMINC	2HHLMINC	3HHLMINC	4HHLMINC
Medium: [$50,000, $74,999]	1HHMINC	2HHMINC	3HHMINC	4HHMINC
Medium High: [$74,999, $99,999]	1HHMHINC	2HHMHINC	3HHMHINC	4HHMHINC
High: [$100,000,)	1HHHINC	2HHHINC	3HHHINC	4HHHINC

Table 3.1: Household Income by Size Variables

Household Income	**Number of Workers in the Household**			
	0	**1**	**2**	**3+**
Low : [0, $24,999]	0WLINC	1WLINC	2WLINC	3WLINC
Medium Low: [$25,000, $49,999]	0WLMINC	1WLMINC	2WLMINC	3WLMINC
Medium: [$50,000, $74,999]	0WMINC	1WMINC	2WMINC	3WMINC
Medium High: [$74,999, $99,999]	0WMHINC	1WMHINC	2WMHINC	3WMHINC
High: [$100,000,)	0WHINC	1WHINC	2WHINC	3WHINC

Table 3.2: Household Income by Household Workers Variables

Generation of Household Cross Tabulations

Figure 3.1 below shows the methodology for the 2010 model using a population synthesis approach.

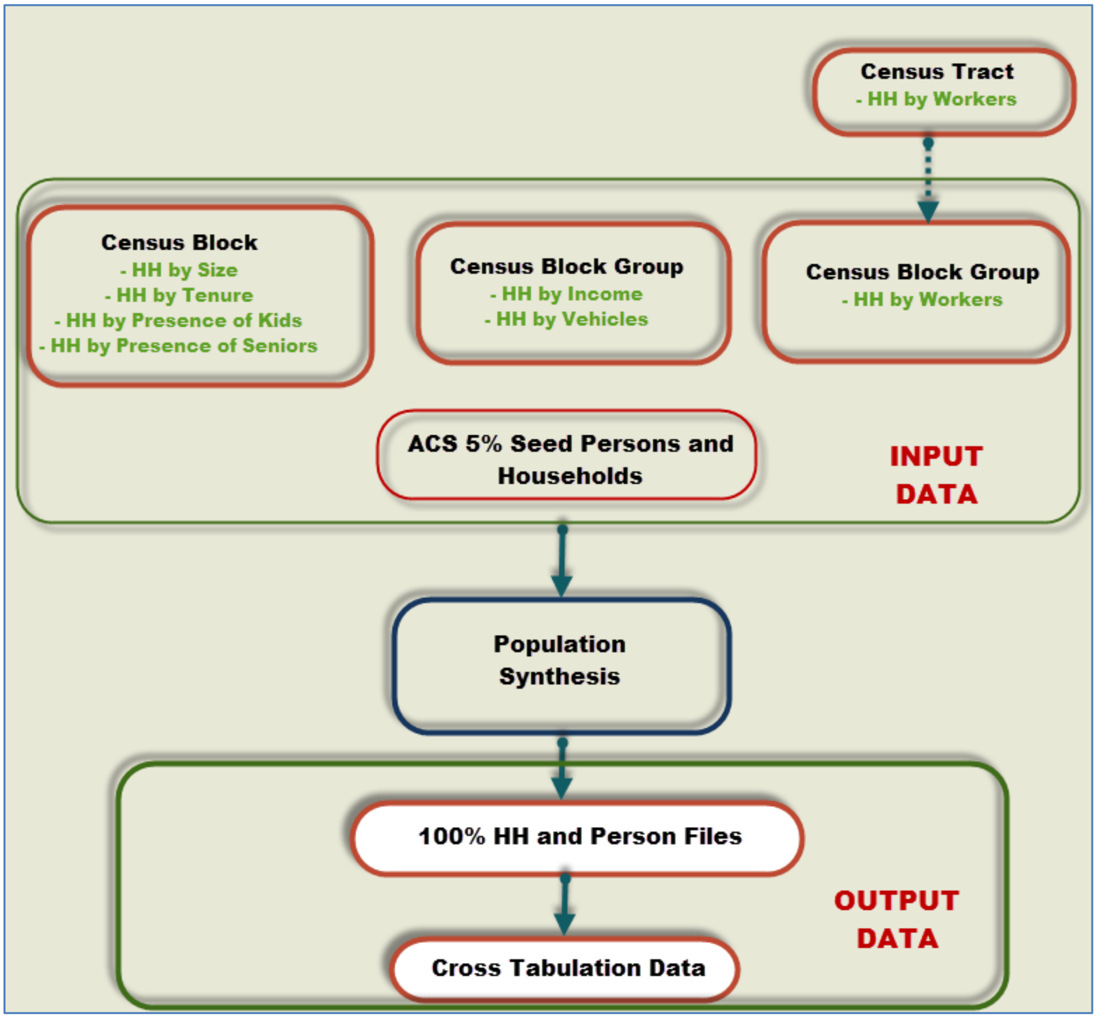

Figure 3.1: Generation of Land Use Cross Tabulation

The methodology involved the use of the TAZ geography, the census 2010 block, ACS block group and tract data and data from the ACS 5% (2014-2018) Public Use Microdata Sample (PUMS) household and person sample. The technique used was a nested population synthesis approach using the ACS 5% PUMS Household and Person data as the seed. Control totals from various levels of geography used in the synthesis are shown in Figure 3.1 (highlighted in green). Particularly, control totals of Households by Household size were supplied from the Census 2010 block data, control totals of Households by Income were supplied from the ACS block group data and control totals of Households by Household Workers were supplied using the ACS tract data. The tract data was first disaggregated to block group data before being used in the population synthesis algorithm.

After running the population synthesis procedure, a 100% population and household database sample was generated for the Whatcom region that has a similar distribution as the ACS 5% seed but also matches the appropriate marginal totals at the various census geography levels. The following output fields are generated.

- Household Output Fields:
    - Household ID
    - Census Block ID,
    - Census Block Group ID,
    - HH Size,
    - Number of Vehicles in the Household
    - Number of workers in the Household
    - Income category
    - Tenure,
    - Presence/Absence of kids in the household.
    - Presence of one or more seniors in the household.
- Population Output Fields:
    - Household ID
    - Age
    - Class of Worker
    - Employment Status
    - Sex
    - Education
    - Is Student?
    - Race

The output of the population synthesis resulted in 95,244 Household records. Particularly, the household attributes after being aggregated to the TAZ level will be fairly accurate and can be confidently used for the planning model. After the aggregation, the key land use cross tabulations for the Whatcom County region are shown below (i.e. All TAZ's):

Household Income					
	1	2	3	4+	All
< $24,999	12.4%	5.6%	2.7%	2.4%	**23.1%**
$25,000 to $49,999	7.3%	8.2%	2.4%	3.6%	**21.5%**
$50,000 to $74,999	4.5%	9.3%	2.9%	4.7%	**21.4%**
$75,000 to $99,999	1.3%	5.0%	2.7%	3.5%	**12.5%**
> $100,000	1.6%	10.4%	3.1%	6.4%	**21.5%**
All Income	**27.1%**	**38.5%**	**13.8%**	**20.6%**	**100.0%**

Table 3.3: Household Income by Size Distribution

Household Income	Number of Workers in the Household				
	0	1	2	3+	All
< $24,999	12.4%	7.9%	2.4%	0.4%	**23.1%**
$25,000 to $49,999	6.2%	9.6%	4.8%	0.9%	**21.5%**
$50,000 to $74,999	5.2%	8.8%	6.0%	1.4%	**21.4%**
$75,000 to $99,999	2.0%	3.9%	5.3%	1.2%	**12.5%**
> $100,000	3.7%	6.0%	9.5%	2.3%	**21.5%**
All Income	**29.5%**	**36.3%**	**28.0%**	**6.2%**	**100.0%**

Table 3.4: Household Income by Household Workers Distribution

For the future year forecasts, the synthesis can be re-run using available Household marginals at any available levels of geography.

Traffic Analysis Zones (TAZ) Update

WCOG staff redefined the TAZ so that roads and natural barriers are used as boundaries using the 2010 census blocks layer. TAZ have a smaller geographical area in city limits and urban growth areas and larger in rural areas. The TAZ structure for the 2018 model has 995 internal zones and 8 external zones. This is a reasonable increase in the number of TAZs with respect to the 2014 model due to land use changes and future growth projections. This more disaggregate representation helps in the prediction of productions and attractions and also facilitates better centroid connector placements and consequently a more accurate traffic assignment.

After review of the external zones, Caliper and WCOG staff decided to use the same external zone configuration as in the 2014 model. A figure of the TAZ layer along with the classification by Minor Civil Division (MCD) is shown in Figure 3.2

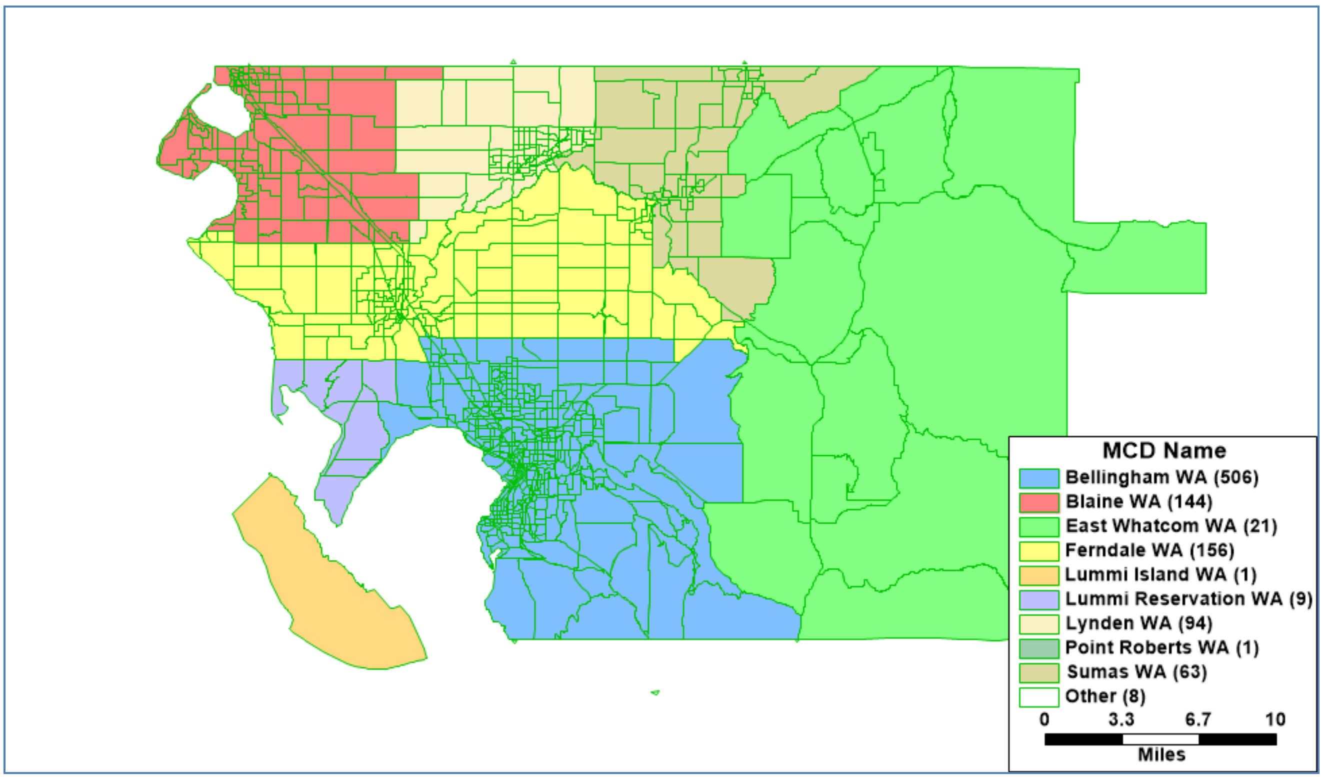

Figure 3.2: 2018 Base Year TAZ

Roadway Network Update

A geographically accurate highway network was developed in 2008 from existing GIS data sources, including centerlines and aerial photographs, and then updated for the 2014 model update. WCOG staff deliberated on the placement of centroids and connectors and established very good databases for planning applications.

For this model update, WCOG staff adjusted the 2014 base year network to reflect the additional zones in the land use, new roadway features, changes to roadway attributes, and the placement of the connectors. The network was also updated based on comments from the local jurisdictions (functional Class, number of lanes, additional roads not previously modeled and area type). WCOG staff also collected traffic counts from local jurisdictions. WCOG staff later identified some gaps where future traffics counts will be beneficial when validating the model.

As before, there are several primary types of links in the Whatcom network. These include highways, ramps, major and minor arterials, major and minor collectors, transit only links, and centroid connectors. Based on the area type of the network links, further classifications within these link types are made, since links in the rural regions typically have greater speeds. These additional classifications also exhibit significant variance in the available capacity for the link. The values of speed and capacity based on link type and area type are illustrated in Table 3.5. These values have been updated during the current calibration effort, especially with regard to the hourly capacity for road classifications of collectors and lower. The updated values are shown in the table 3.5. In addition, certain local sections of a particular road experience changes in speeds and sometimes have a posted speed that is quite different from the speed determined from the table. In such case, these speeds on certain local sections of the roads were over-ridden to match posted speeds.

Type	Class	AreaType	Speed	Lane Capacity
1	Freeway	1 - Urban	65	1800
1	Freeway	2 - Suburban	67.5	2000
1	Freeway	3 - Rural	70	2200
2	Major Arterial	1 - Urban	33	900
2	Major Arterial	2 - Suburban	37	1000

2	Major Arterial	3 - Rural	45	1100
4	Minor Arterial	1 - Urban	30	800
4	Minor Arterial	2 - Suburban	35	900
4	Minor Arterial	3 - Rural	40	1000
5	Major Collector	1 - Urban	28	700
5	Major Collector	2 - Suburban	31	750
5	Major Collector	3 - Rural	37	800
6	Minor Collector	1 - Urban	25	700
6	Minor Collector	2 - Suburban	30	750
6	Minor Collector	3 - Rural	35	800
7	Ramp	1 - Urban	30	900
7	Ramp	2 - Suburban	30	1000
7	Ramp	3 - Rural	30	1100
9	Centroid Connector	1 - Urban	25	9999
9	Centroid Connector	2 - Suburban	25	9999
9	Centroid Connector	3 - Rural	25	9999

Table 3.5 Speed and Capacities by Functional Class

During the initialization phase of the model, the free flow speeds are assigned based on the above classification and the over-riding speeds are applied. The lane capacity is obtained from the above table, multiplied by the number of lanes and a capacity reduction factor to yield the hourly capacity. A map of the network is shown in Figure 3.3.

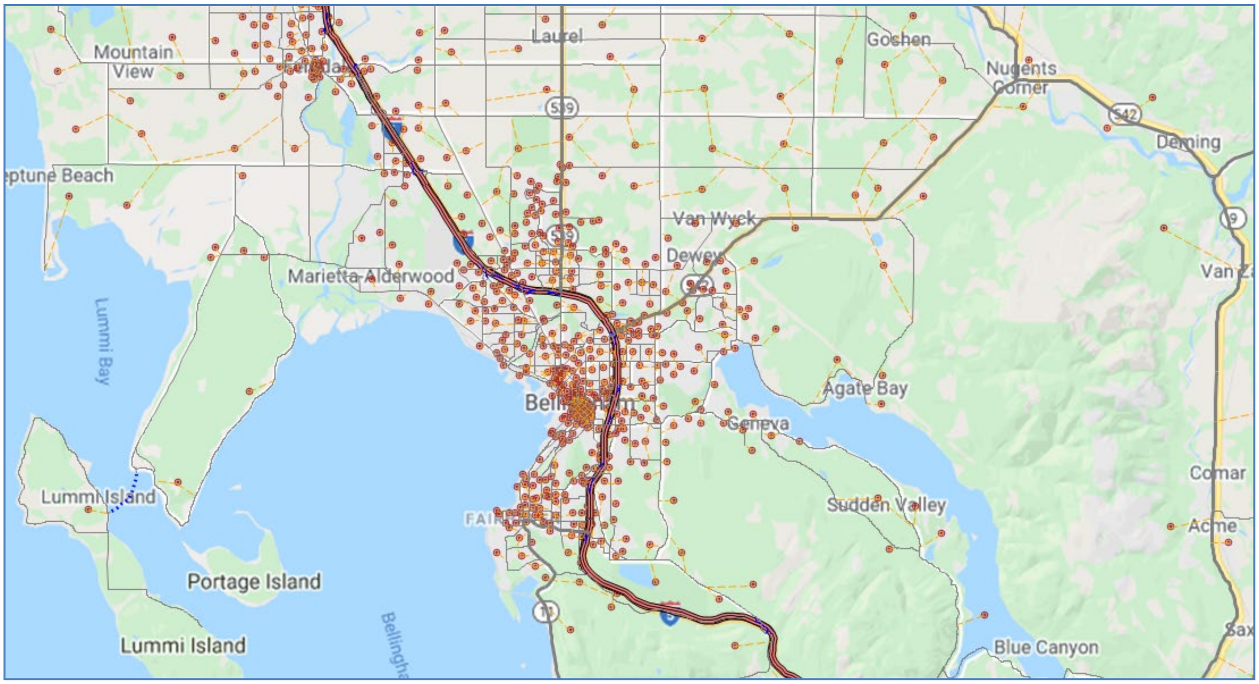

Figure 3.3: 2018 Base Year Highway Network

Transit Network Update

Utilizing the Whatcom roadway network as the underlying geography, Whatcom staff and Caliper Corporation developed a geographically accurate Transit Network during the previous model update. This transit network provides an inventory of available routes and stops. Since the highway network changed during this round of the update, the transit network was appropriately modified to fit the line geography.

As in the previous update, we utilize the same route system for each time period of the model (AM Peak, PM Peak, Off-Peak, and Night) and select only the applicable routes and attributes for that period from which to build the transit network. Stop locations at near/far side of intersections and mid-block locations are also geographically represented. Proper geographic placement of stops helps facilitate better replication of transit accessibility behavior through walking. The travel time between stops in the transit network is a function of the highway travel times between the stops. The transit travel time on a link is assumed to be 1.2 times the highway travel time.

The current park and ride stations in the Whatcom area were re-examined and based on the usage of the parking lots, three parking stations were employed in the model, namely: Lincoln Creek, Ferndale Transit Center and Lynden Transit Center.

Each route is coded with several attributes used in transit skimming and assignment. These include headways for the all the periods and the fare for each route. A map of the transit routes is shown in Figure 3.4.

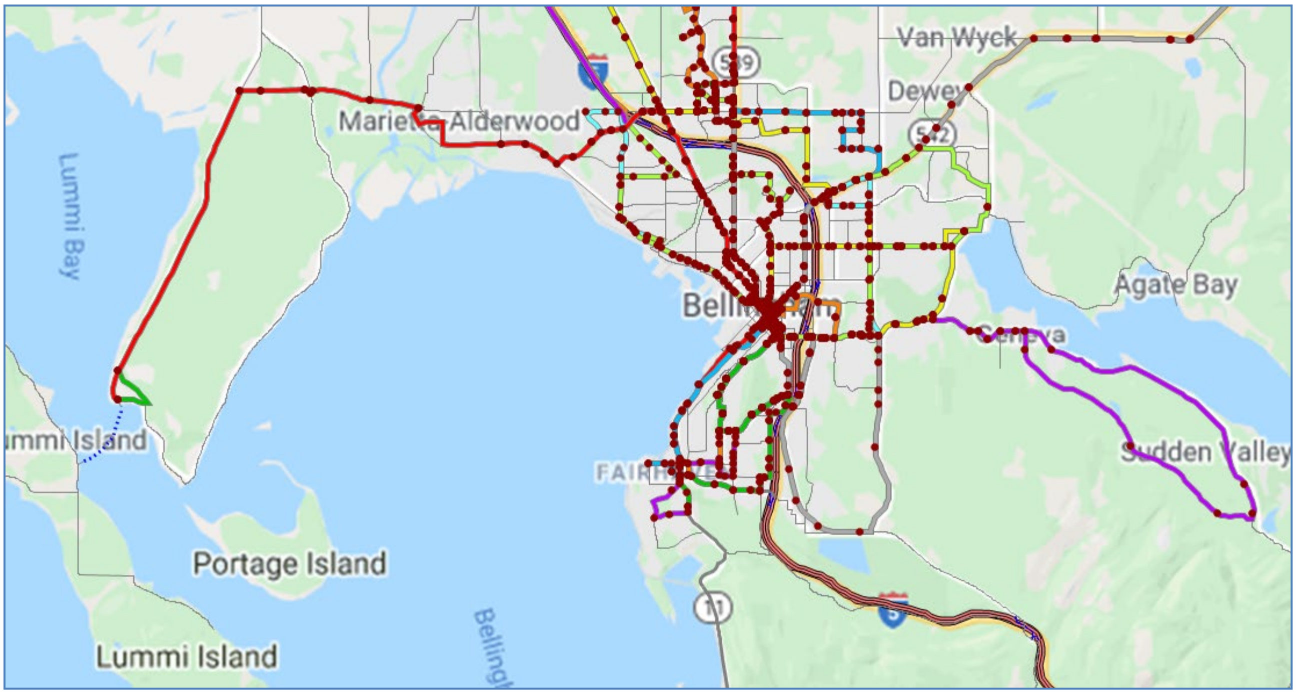

Figure 3.4 2018 Whatcom Transit Route System

Highway Network Skimming

The highway skimming process has been unaltered since the previous update. Below is a description of the procedure, as in the previous model document.

At several stages in the travel demand modeling process centroid to centroid (zone to zone) measures of travel time or other costs must be computed. The process of computing the shortest path between any origin-destination pair is often referred to as skimming. Skimming is a critical process in any travel demand model and greatly influences the model results. Thus, it is imperative to be able to compute skims accurately. The Whatcom model requires highway skims as inputs to the Trip Distribution and the Mode Choice modules.

As described in the model summary, the trip distribution and mode choice models are performed for the Peak (PK) and the Off-peak (OP) periods. The PK periods comprise of the AM and the PM sub-periods and the OP period comprise of the Midday (MD) and Night (NT) sub-periods. The measures of zone to zone skims are necessary for the PK and the OP periods. Given that the trip distribution generates a Production and Attraction matrix and given the definition of trip ends used in the model, it was determined that the AM period skims be used as a proxy for the PK period skims and that the MD period skims be used as a proxy for the OP period skims.

The initial estimate of the trip distribution is completed using skim values based on free-flow travel times derived from free flow speeds on the links. During the calibration phase of the Whatcom model, a feedback model was performed in which congested times derived for the highway network from the highway assignment are passed back to the skimming process to garner a better estimate of the trip distribution model. Several feedback runs were performed to determine congested link travel times for the AM and the MD period. For the base year model, these congested link travel times are populated in the highway database and are used to start the model, eliminating the need to run additional feedback iterations.

It would be remiss not to mention that skimming is subject to several constraints that must be accounted for in the network settings. These include the representation of prohibited turns in the highway network and the prohibition of paths to utilize centroid connectors except to gain access to or egress from the main network. All the network turn prohibitions were examined and modified as necessary. Finally, a measure of the intrazonal trip travel times is obtained based on the travel times to the nearest neighbor to each zone.

Transit Network Skimming

Additional inputs to the mode choice procedure are transit skims for the PK and the OP period. The process of computing the transit skims in the Whatcom model is analogous to that of the highway, although it is often the case that in addition to travel time, other attributes such as fare, walk access time, and initial wait time are needed for input into the mode choice model and must be kept track of during the skimming process. For the transit network, skimming is tightly bound to the network settings which greatly influence the paths utilized in the skimming. Further, the path building methodology and the fact that the cost to traverse the transit network is comprised of many weights applied to both the transit and non-transit elements (e.g. walk access and egress), often find more than one viable path between any OD pair. During this update, the transit parameters were examined and modified as warranted.

For the parking nodes, given the capacity of the nodes and the transit usage, it became clear that the park and ride mode was only being utilized by the population in the vicinity of the parking node. Therefore, for each parking node, a series of network bands were used to identify potential zones within a mile of the transit parking node. Only these zones were allowed access to the parking and the appropriate centroids corresponding to these zones were assigned the parking node information. Various other criteria were experimented with during the calibration process but the chosen 1 mile radius condition yielded the most logical result in terms of the observed park and ride utilization.

An Origin to Parking Node time matrix is developed based on the latest congested travel times to the eligible centroids and this is used as an input in the transit network settings. As in the case of highway skimming, the transit skimming in the Whatcom model is performed for the AM and the MD sub-periods. The Pathfinder transit algorithm developed by Caliper is used to generate zone to zone transit paths. A detailed description of this method is described in the TransCAD Travel Demand Modeling book.

Unlike the previous update of the model, the transit skims are also now part of the feedback loop. This is mainly motivated because of the fact that the origin to parking node skims are determined from the latest estimate of the congested times. Therefore, it makes sense to include this procedure and also the transit skims as part of the feedback loop. During the calibration phase, it was determined that including the transit skims in the feedback loop yielded better results in terms of transit ridership and usage. Further, this did not affect the convergence of the model feedback.

Non-motorized (Walk and Bicycle) Network Skimming

For the walk skims, a distanced based cost is used using a constant walking speed of 2.5 miles per hour. The walk network is built from a selection of links that are eligible for walking, which generally includes most links with sidewalks and excludes freeways. The maximum trip length is 1.5 miles.

For the bike skimming, the maximum trip length is 10 miles. The travel times are derived using a bike facility class, a link attribute that denotes whether the link is bike-friendly. Links denoted as bicycle class 1 (dedicated bike lane) use a speed of 12 mph, class 2 (designated bike route) use 10 mph, and all other links use 7.5 mph. Similar to walking, bicycles are restricted to certain functional classes.

Chapter 4: Trip Generation

The trip generation module in the updated Whatcom planning model predicts daily production and attractions for each of the 8 trip purposes (Home-based Work (HBW), Home-based College (HBCol), Home-based School (HBCH), Home-based Shopping (HBSho), Home-based Other (HBO), Non-Home-based Work (NHBW), Non-Home-based Other (NHBO) and Truck trips (Truck)). The trip generation further splits the daily productions and attractions into Peak (PK), encompassing the AM (7-9) and PM periods (4-6), and Off-peak (OP), Mid-day and Night, trip productions and attractions, adds external trips and balances the PK and OP tables.

The main difference to the previous model update is that all the models have been re-estimated following the update to the survey. Trip rates are somewhat similar to the previous model estimation, thus increasing the confidence and permitting us to make some minor simplifications to some previous micro-level adjustments performed in the 2014 model. The various model components are discussed below:

Trip Production Models

After a brief analysis using the updated survey, the current cross classifications for the trip productions were updated to explain the trip production behavior adequately. As in the 2014 model, all purposes other than NHBW and NHBO use a cross-classification approach for the trip rates, whereas the NHBW and NHBO trip productions use regression models. Trip production rates are also varied by the geographic region. One set of rates were developed for the city of Bellingham, WA and another set for the rest of the region.

Trip Production Rates for Home Based Trips

The trip rates were generated from the survey database using the weights in the survey. Certain classifications that did not have an adequate sample size were merged with other classifications appropriately. In certain instances, the trip rates across various regions also had to be combined due to sample size constraints. The production rates include trips from Whatcom County to external zones.

Tables 5.1 and 5.2 show the trip production rates for the HBW purpose and these are based on household income and number of workers in the household. Out of 995 internal zones, 443 zones are within the city limits of Bellingham, WA.

Household Income	Number of Workers in the household			
	0	1	2	3+
Less than $25,000	-	1.13	2.12	5.33
$25,000–$49,999	-	1.20	2.41	5.33
$50,000–$74,999	-	1.28	2.48	5.33
$75,000-$99,999	-	1.41	2.43	5.40
$100,000 and more	-	1.43	2.11	5.40

Table 5.1: HBW Trip Production Rates for Bellingham, WA

Household Income	Number of Workers in the household			
	0	1	2	3+
Less than $25,000	-	0.72	1.57	4.27
$25,000–$49,999	-	1.05	2.18	4.27
$50,000–$74,999	-	1.38	1.93	4.27
$75,000-$99,999	-	0.95	2.81	4.70
$100,000 and more	-	0.75	2.02	4.70

Table 5.2: HBW Trip Production Rates for rest of region

Tables 5.3 to 5.10 show the trip production rates for the home-based non-work purposes (excluding trucks) for Bellingham and the rest of the region. These rates are based on the cross-classification of household income by household size.

HBCol Trip Rates

Household Income	HH Size			
	1	2	3	4+
Less than $25,000	0.13	0.56	0.36	0.00
$25,000–$49,999	0.13	0.62	0.00	0.22
$50,000–$74,999	0.00	0.07	0.03	0.00

$75,000-$99,999	0.00	0.00	0.43	0.23
$100,000 and more	0.00	0.00	0.00	0.23

Table 5.3: HBCol Trip Production Rates for Bellingham, WA

Household Income	**HH Size**			
	1	**2**	**3**	**4+**
Less than $25,000	0.00	0.04	0.02	0.04
$25,000–$49,999	0.00	0.01	0.04	0.04
$50,000–$74,999	0.00	0.00	0.00	0.19
$75,000-$99,999	0.00	0.00	0.00	0.19
$100,000 and more	0.00	0.00	0.41	0.19

Table 5.4: HBColTrip Production Rates for rest of region

HBSch Trip Rates

Household Income	**HH Size**			
	1	**2**	**3**	**4+**
Less than $25,000	-	0.32	0.62	0.00
$25,000–$49,999	-	0.18	0.62	2.69
$50,000–$74,999	-	0.07	0.62	1.51
$75,000-$99,999	-	0.03	0.81	2.34
$100,000 and more	-	0.03	0.34	1.68

Table 5.5: HBSch Trip Production Rates for Bellingham, WA

Household Income	**HH Size**			
	1	**2**	**3**	**4+**
Less than $25,000	-	0.00	0.29	0.00
$25,000–$49,999	-	0.07	0.29	1.41
$50,000–$74,999	-	0.03	0.29	1.73
$75,000-$99,999	-	0.03	0.22	1.91
$100,000 and more	-	0.02	0.24	2.11

Table 5.6: HBSch Trip Production Rates for rest of region

HBSho Trip Rates

Household Income	HH Size			
	1	2	3	4+
Less than $25,000	0.46	0.86	0.44	2.02
$25,000–$49,999	0.36	1.05	0.45	2.02
$50,000–$74,999	0.39	0.81	0.71	1.14
$75,000-$99,999	0.24	0.94	1.21	1.14
$100,000 and more	0.55	0.63	0.72	1.14

Table 5.7: HBSho Trip Production Rates for Bellingham, WA

Household Income	HH Size			
	1	2	3	4+
Less than $25,000	0.17	0.67	0.29	0.92
$25,000–$49,999	0.47	0.97	0.17	0.92
$50,000–$74,999	0.37	0.57	0.30	1.21
$75,000-$99,999	0.25	0.38	0.16	1.21
$100,000 and more	0.24	0.73	0.30	1.21

Table 5.8: HBSho Trip Production Rates for rest of region

HBO Trip Rates

Household Income	HH Size			
	1	2	3	4+
Less than $25,000	1.23	3.62	3.20	6.97
$25,000–$49,999	1.40	1.83	5.82	6.97
$50,000–$74,999	1.15	2.12	3.69	6.97
$75,000-$99,999	1.28	2.59	3.35	6.61
$100,000 and more	1.45	2.82	2.44	6.61

Table 5.9: HBO Trip Production Rates for Bellingham, WA

Household Income	HH Size			
	1	2	3	4+
Less than $25,000	1.12	1.68	4.71	5.12
$25,000–$49,999	1.59	3.48	3.64	5.12
$50,000–$74,999	1.00	2.80	2.34	5.12
$75,000-$99,999	1.10	3.25	5.38	4.87
$100,000 and more	1.42	2.15	2.60	4.87

Table 5.10: HBO Trip Production Rates for the rest of the region

In all of the trip rates above, it must be noted that the number of lower income households in the county with size greater than 3 is negligible.

Trip Production Rates for Non-Home Based Trips

The trip production rates for the NHBW and NHBO purposes are based on regression equations developed from the survey data and the land use variables. The NHBW and NHBO trips in the survey were aggregated based on the Origin TAZ. The aggregated dataset was then joined to the land use database and regression equations were developed using the employment and enrollment variables as the independent variables. Based on the new survey weights, several regression models were experimented. The models are presented in Table 5.11

Variable	NHBW_P	NHBO_P
Total Households	0.204	0.530
Total Population		2.955
Total Employment		1.496
Educational Employment	0.525	
Finance, Insurance, Real Estate Employment	0.361	
Services Employment	0.474	
Retail Employment	0.639	
Wholesale Employment	1.308	
Other Employment	0.699	
College Enrollment	0.110	
Total School Enrollment		0.280

Table 5.11: NHBW and NHBO Production Rates

One final note is that all production rates for the Point Roberts region are set to 0.

Trip Attraction Models

Trip attraction models are typically developed based on employment estimates, school and college enrollment, total households and household population. The same methodology as in the 2014 model update was used. The trips in the survey were aggregated using the attraction zone to yield an estimate of the number of trips by purpose attracted at each zone. This is the dependent variable for the regression equation.

There are two main issues with estimating such attraction models. First is the fact that not all the zones are represented or covered well enough by the survey respondents. Thus there could be two identical zones with similar employment but for some reason the chosen survey sample yields very few attractions for one of the zones. Including both these zones in the regression could skew the model results. Secondly, the eventual model applied should have no constant, since the presence of one will imply attractions for zones where there is no employment/enrollment. These limitations require several iterations and experiments. However, it is to be noted that since most of the purposes are balanced to productions, we only care about the relative attractions in each zone and thus the adjustment may not be that crucial in the final analysis. The regression equations are shown in Table 5.13

Variable Description	HBW	HBSch	HBSho	HBCol	HBO	NHBW	NHBO
Household Population					0.310		0.250
Total Households						0.209	
Total Employment					0.455		
Educational Employment	1.844	0.423				1.355	0.108
Finance, Insurance, Real Estate Employment	0.624				1.343	0.737	2.276
Services Employment	1.067				0.767	0.324	1.274
Government Employment	0.596					0.841	
Manufacturing Employment	1.271					0.467	
Retail Employment	0.467		3.666		1.219	0.335	7.700
Wholesale Employment	2.175					1.041	
Telecommunications Employment	1.312						
Construction Employment							
Agricultural Employment							
Other Employment	1.236					0.493	
Mining Employment							

Grade School Enrollment		1.016			0.902		
Middle School Enrollment		0.946			0.768		
High School Enrollment		1.174			0.607		
College Enrollment		0.038		0.188			0.139
Total School Enrollment							0.577

Table 5.13: Trip Attraction Rates

Truck Productions and Attractions

The North Sound Travel survey did not contain truck trips. The truck trip production and attraction models from the previous version of the Whatcom model were retained (Table 5.15).

Variable Description	Truck Production	Truck Attraction
Total Households	0.1	0.319
Educational Employment	0.253	0.114
Finance, Insurance, Real Estate Employment	0.262	0.305
Services Employment	0.262	0.305
Government Employment	0.253	0.114
Manufacturing Employment	0.762	0.433
Retail Employment	0.623	0.076
Wholesale Employment	0.792	0.19
Telecommunications Employment	0.733	0.646
Construction Employment	0.717	0.375
Agricultural Employment	0.829	0.587
Mining Employment	0.912	67.802

Table 5.15: Truck Production and Attraction Rates

Special Generators

There are no special generators in the updated 2020 model. During the previous update, the number of trips attracted around primary retail centers such as malls and shopping complexes could not be adequately explained by the attraction models. However, the attraction models from the updated survey explain the trips around major retail zones well enough to not warrant any special treatment.

Daily Productions and Attractions

The applied productions and attractions are shown in Table 5.16 below:

Purpose	Model Productions	Model Attractions	Survey Trips
HBW	132,018	110,606	117,534
HBSho	40,177	34,278	39,660
HBSch	70,828	56,152	57,646
HBColl	10,229	5,673	10,688
HBO	293,507	190,553	252,172
NHBW	70,505	76,464	104,082
NHBO	236,013	249,587	340,508
Truck	59,007	69,431	**none reported**

Table 5.16: Total Daily Productions and Attractions by Purpose

The production and attractions numbers seem to be within reasonable 10% limits and match the survey trips as well.

Productions and Attractions by Time Period

The Whatcom model is based on two distinct periods Peak (PK) and Off-peak (OP). Further the PK period is sub-divided into the AM peak (7 AM and 9 AM) and the PM Peak (4 PM and 6 PM). Likewise, the OP period is sub-divided into the MD period (9 AM and 4 PM) and the night period NT (6PM until 7 AM the following day). For each purpose, the peak and off-peak trip splits were obtained from the survey as below:

Purpose	Model Productions	Model Attractions
HBW	14.47%	13.95%
HBSch	4.40%	4.32%
HBSho	7.76%	7.08%
HBColl	1.12%	0.72%
HBO	32.17%	24.04%
NHBW	7.73%	9.65%
NHBO	25.87%	31.48%
Truck	6.47%	8.76%

Table5.17: Peak and Off-peak percentages by Purpose

External Trips

Trips from external zones that use the Whatcom network are obtained as inputs to the model. The eight entry/exit points (used in the 2014 model) were found to be sufficient.

TAZ	External Station
1001	I-5 Southern External
1002	I-5 Northern External
1003	SR-543 Northern External
1004	SR-539 Northern External
1005	SR-9 Northern External
1006	SR-11 Southern External
1007	SR-9 Southern External
1008	SR-542 Eastern External

Table 5:18: List of External Stations

The external trips from each of these locations are available as Origins and Destinations (Entry and Exit) vehicle trips for the AM, MD, PM and the NT time periods as shown in Table 5.19. Entry trips are those trips that enter Whatcom County (EI Trips) and exit trips are those that leave Whatcom County (IE trips). This data was assimilated with great care from the latest count information including border crossing counts.

TAZ	AM Entry	AM Exit	MD Entry	MD Exit	PM Entry	PM Exit	NT Entry	NT Exit	Through Trips Pct	Truck Trips Pct
1001	2,409	3,143	10,274	10,958	4,098	3,621	7,448	6,671	3.80%	10.28%
1002	660	442	3,165	2,683	942	1,027	1,579	1,895	24.20%	0.00%
1003	650	485	2,736	2,730	810	1,017	1,724	2,266	19.10%	22.19%
1004	193	128	894	782	230	279	312	432	6.30%	22.48%
1005	252	201	1,201	1,125	380	413	564	692	14.50%	12.42%
1006	46	82	411	449	206	156	271	232	0.80%	7.40%
1007	78	160	346	479	186	135	292	364	2.80%	29.77%
1008	36	36	180	180	52	52	92	91	0.01%	0.00%

Table 5.19: Vehicle Traffic Counts at External Stations

Each station also has the percentage of through trips and truck trips. As a first step to incorporating them into the model, the AM and PM Entries and Exits were added to the PK Productions and Attraction tables respectively and the MD and the NT external Entries and Exits were added to the OP Productions and Attraction tables respectively. The through trip percentage was subtracted from each of the vehicle counts before this process.

Trip Balancing

All purposes except the Home-based School (HBSch) trips were balanced to productions. The HBSch purpose was balanced to attractions. In each case, the external productions and attractions are left untouched.

The balanced total productions and attractions for the PK and the OP period are listed below:

Purpose	Peak Trips	Off-Peak Trips
HBW	58,616	73,402
HBSch	7,453	26,824
HBSho	24,405	46,423
HBColl	1,857	3,816
HBO	59,300	234,207
NHBW	14,536	55,968
NHBO	47,605	188,408
Truck	8,740	50,268

Table 5.20: Peak and Off-peak total balanced trips by purpose

In general, the trips during the Off-Peak period are greater than the trips during the Peak period.

Figures 5.1 and 5.2 give a sense of the daily trip productions and attractions within Whatcom County. In general, the trip productions in Bellingham are higher than the rest of the County.

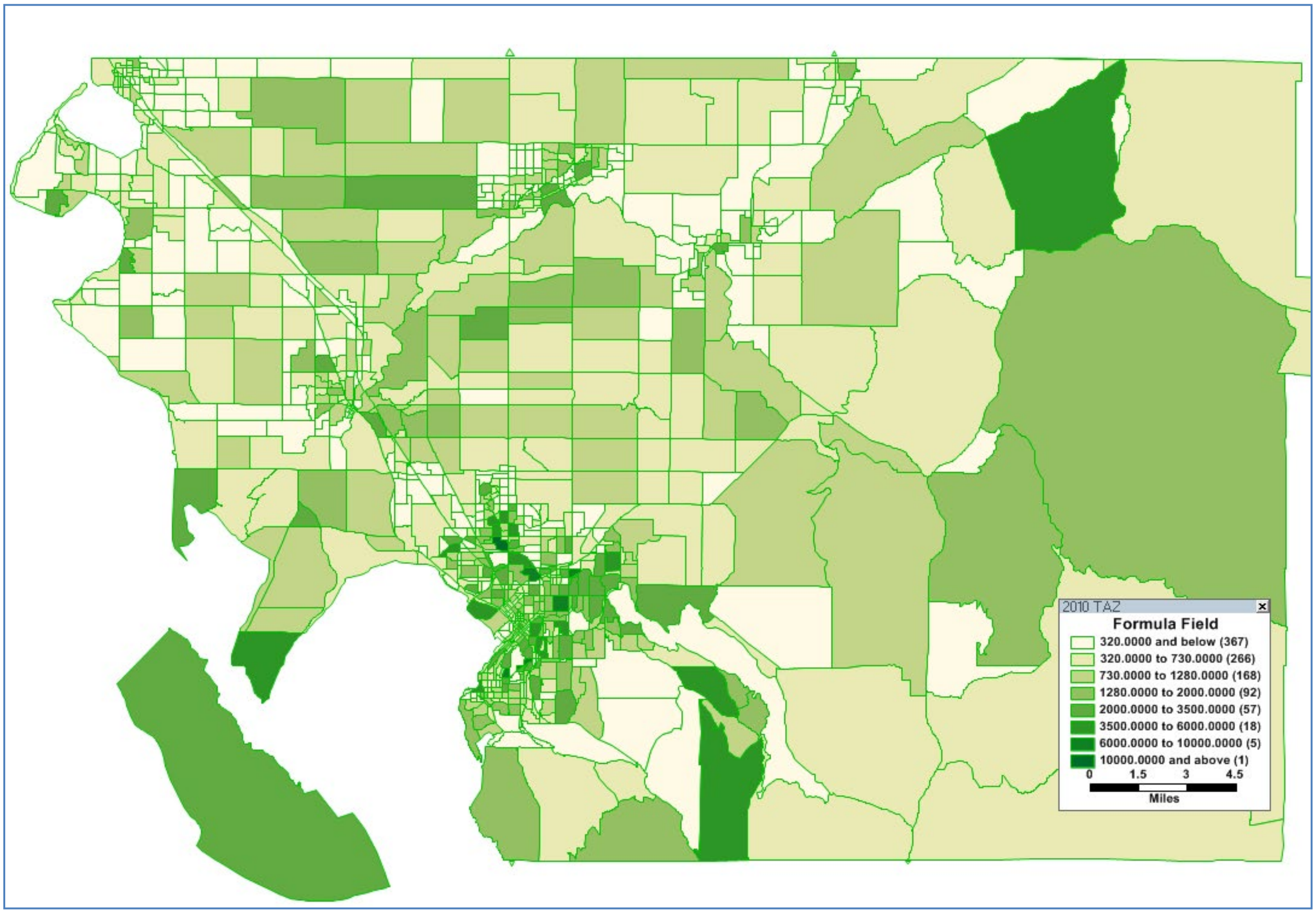

Figure 5.1: Daily Productions in Whatcom County

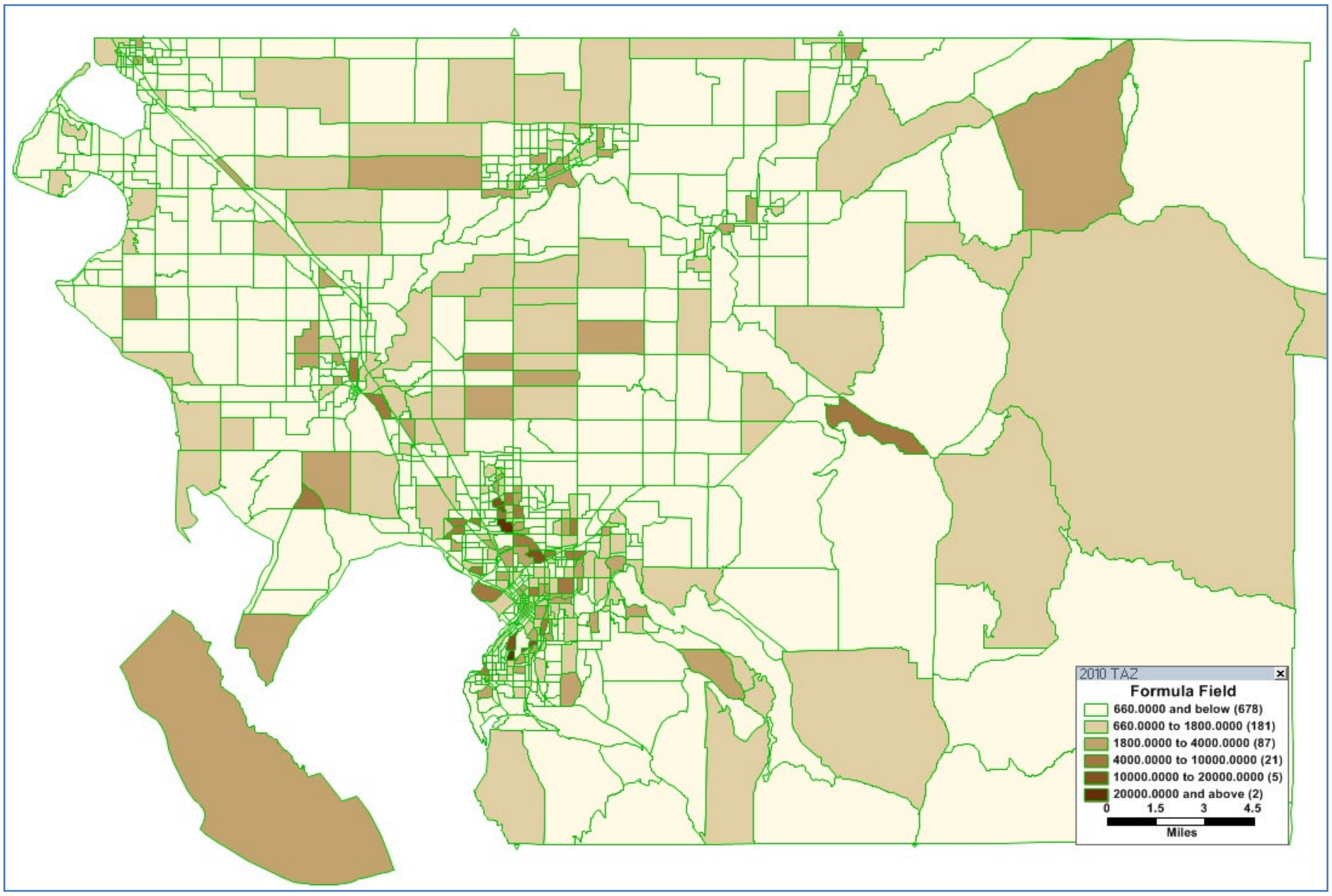

Figure 5.2: Daily Attractions in Whatcom County

Chapter 5: Trip Distribution

The trip distribution in the Whatcom Model is a double constrained gravity model using gamma function friction factor curves. The trip distribution is applied for the PK period and the OP period. Some salient features of the distribution procedure as repeated from the 2014 documentation are:

- The PK Trip Distribution is performed using the PK Balanced Production and Attraction table output from the trip generation, the congested AM Skim times and PK friction factor curves calibrated for each trip purpose.
- Likewise, the OP Trip Distribution is performed using the OP Balanced Production and Attraction table output from the trip generation, the congested MD Skim times and OP friction factor curves calibrated for each trip purpose.
- For each purpose, the tolerance of the gravity procedure was set to 0.001 with a maximum of 1000 iterations.
- While performing the trip distribution, no trips were distributed from external zones to external zones. In other words, external productions were allocated only to internal zones and external attractions were constrained to be produced from internal zones. Note that the through trips were already removed in the trip generation stage.
- A through trip matrix was generated using a Fratar scaling procedure, one for the PK and another for the OP trips. This matrix is added to the trips prior to the traffic assignment.
- The outputs of the trip distribution procedure are a PK Production Attraction (PA) matrix containing one matrix core for each purpose and an OP Production Attraction (PA) matrix containing one matrix core for each purpose.

Friction Factor Calibration

To properly apply the gravity model, friction factor curves need to be calibrated for each purpose for both the peak (PK) and the off-peak (OP) periods. The calibration is done to ensure that the average trip length frequency for each purpose is similar to the observed trip lengths from the travel survey. Matching the trip length (or time) ensures that the frequency of trips by travel time is as observed in the survey.

During the previous model calibration round, curves based on the Gamma functio below were used to fit curves for every trip purpose:

$$f = a.t^{-b}.e^{-ct}$$

, where f is the trip frequency, t is the travel time and a, b and c are parameters that were calibrated.

It was observed during the 2014 calibration phase that the trip lengths obtained using the previous friction factor curves were close to the updated survey trip lengths. The factor parameters used in the gravity model are shown below.

Peak-Period Friction Factors

Purpose	a	b	c
HBW	18344.44	0.12	0.11
HBSch	17688.70	0.56	0.11
HBSho	6515.28	0.14	0.17
HBColl	35779.05	2.43	-0.01
HBO	108474.19	0.90	0.10
NHBW	14371.89	0.13	0.17
NHBO	20535.48	-0.94	0.37

Table 6.1: Gamma Parameters for Peak Periods

Off-peak Period Friction Factors

Purpose	a	b	c
HBW	5016.80	-1.46	0.32
HBSch	12933.53	0.39	0.13
HBSho	11096.57	-0.75	0.29
HBColl	337420.54	3.69	-0.08
HBO	55543.42	-0.15	0.17
NHBW	45683.17	0.26	0.19
NHBO	202361.49	0.19	0.23

Table 6.2: Gamma Parameters for Off-peak Periods

During the calibration phase, the tail region of the above gamma curve (e.g., the longest travel time) was made to drop sharply to discourage long duration trips for some of trip purposes, such as school trips.

Truck Friction Factors

The truck friction factors were retained from the previous model as shown in Table 6.8

Time	a	b	c
t < 8	2411.28	0.4992	0.2887
t >= 8	22000	0.6	0.01

Table 6.3: Truck Gamma Parameters

Based on the equations shown, friction factor tables for the PK and the OP trip distribution matrices were filled and used as inputs to the model.

External Trips

In the trip generation stage, the through trip count at each of the external stations was obtained for the PK and the OP period. Using the percentage of trucks at each external station, these counts were further split into auto and truck counts. Using a seed distribution of through trips (from the previous version of the Whatcom model), a growth factor (or Fratar) method was applied to generate the auto and truck through trip matrix. This matrix is added immediately before the traffic assignment step.

Trip Distribution Results

The trip distribution produces a PK and an OP Production Attraction (PA) matrix. Each matrix has eight cores, one for each trip purpose and contains the zone to zone trips. The total number of trips allocated for each purpose and period matches the balanced productions and attractions for that purpose and period.

The model trip times are shown in table 6.9 below. Note that trips from external to internal zones (XI) and internal to external zones (IX) trips are also included in this estimation. In general, there is no significant difference between the trip lengths in the PK and in the OP period. These number match the trip length from the updated survey using the final skim matrices.

Purpose	Avg Trip Time PK (min)	Avg Trip Time OP (min)
HBW	11.8	10.7
HBSch	10.3	10.4
HBSho	10.5	10.5

HBCol	8.7	8.5
HBO	9.0	10.4
NHBW	9.5	8.1
NHBO	7.0	6.4
Truck	17.5	16.5

Table 6.4: Model Trip Times (including IX and XI trips)

The average trip lengths are shown in Table 6.10

Purpose	Avg Trip Dist PK (miles)	Avg Trip Dist OP (miles)
HBW	8.3	7.5
HBSch	6.9	7.0
HBSho	7.4	7.4
HBCol	5.7	5.6
HBO	6.2	7.1
NHBW	7.2	6.0
NHBO	4.7	4.3
Truck	13.1	12.0

Table 6.5: Model Trip Lengths (including IX and XI trips)

The output PA matrices from the trip distribution are input to the mode choice procedure.

Chapter 6: Mode Choice

The mode choice module in the Whatcom model was estimated and is applied for the PK and the OP trip distribution matrices.

An extensive mode choice modeling effort including model specification, estimation, calibration and application were done in the 2014 model update. During the current phase of the modeling effort, the mode choice estimations were revisited numerous times and the models were modified. Further, the mode choice utility Alternate Specific Constants (ASC's) were adjusted several times during the calibration process to match regional survey shares.

In general, the same mode choice tree structure as developed in the 2014 model update was retained. Some experimentation with the tree structure was nevertheless done but the current structure yielded a better fit. Several new explanatory variables were introduced to capture transit mode share and will be discussed appropriately. The next section shows the estimated mode choice models after the adjustment of the ASC's to match regional shares. Key differences with respect to the previous model update are pointed out. For a detailed description of the technique of mode choice model estimation, please refer to the 2014 model document[1].

Mode Choice Model Set

Table 7.1 summarizes the modes deemed available for each purpose. Mode choice estimation is obviously not done for Truck trips.

Mode	HBW	HBSch	HBColl	HBSho	HBO	NHBW	NHBO
Drive Alone (DA)	√	√	√	√	√	√	√
Carpool (CP)	√	√	√	√	√	√	√
Bike	√	√	√	√	√	√	√
Walk	√	√	√	√	√	√	√
Transit	√		√	√	√	√	√
School Bus		√					√

Table 7.1: Availability of Modes by Trip Purpose

It should be noted that the School Bus mode appears only in the HBSch and NHBO purposes. Further the mode choice alternatives for a given purpose are the same between PK and OP periods.

HBW Peak Model Tree

In the diagrams below, the θ parameter indicates that there is a co-efficient associated with the logsum term from the sub-tree below. The symbol **C** indicates the presence of an alternative specific constant (ASC).

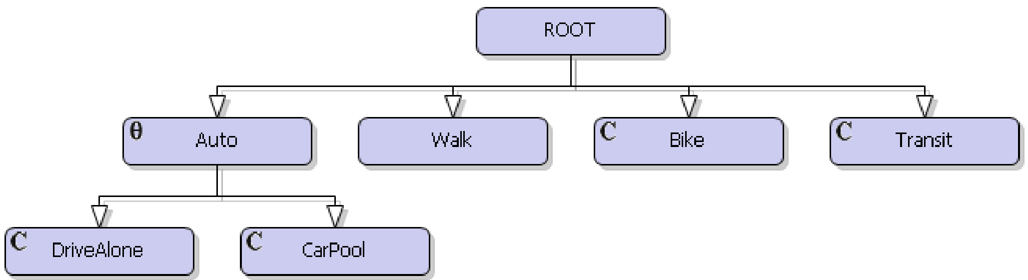

Figure 7.1: HBW Peak Mode Choice Tree Structure

HBW Peak Model Utilities

$\theta_{Auto} = 0.876$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	1.2421	1				
ASC_CP	-0.5687		1			
ASC_Bike	-0.4049			1		
ASC_Walk					Base	
ASC_Transit	-2.0842					1
B_IVTT	-0.0005	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.2: HBW Peak Mode Choice Model Specification

HBW Off-peak Model Tree

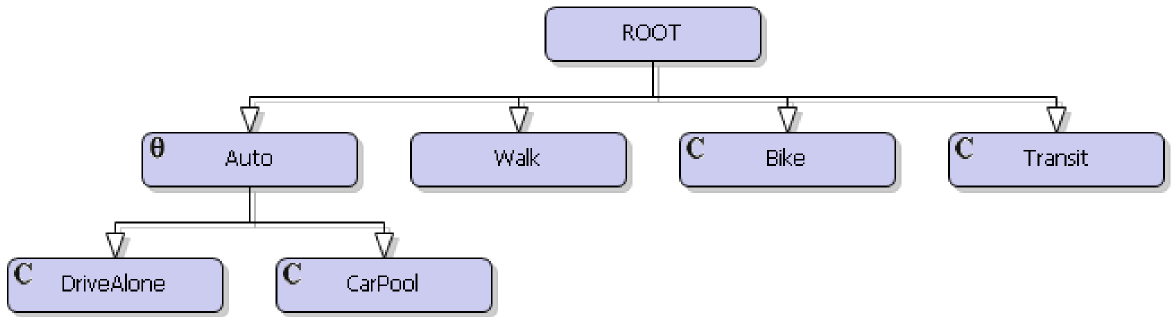

Figure 7.2: HBW Off-peak Mode Choice Tree Structure

HBW Off-peak Model Utilities

$\theta_{Auto} = 0.932$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	1.5104	1				
ASC_CP	-0.4095		1			
ASC_Bike	-0.6405			1		
ASC_Walk					Base	
ASC_Transit	-1.9697					1
B_IVTT	-0.0003	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.3: HBW Off-peak Mode Choice Model Specification

HBSch Peak Model Tree

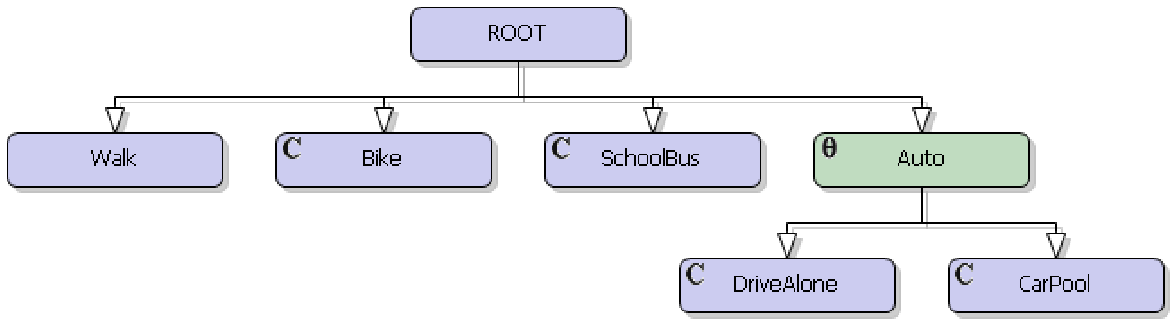

Figure 7.3: HBSch Peak Mode Choice Tree Structure

HBSch Peak Model Utilities

θ_Auto = 1.00

Coefficient	Value	DA	CP	Bike	Walk	School Bus
ASC_DA	-2.6562	1				
ASC_CP	-0.1199		1			
ASC_Bike	-2.5291			1		
ASC_Walk					Base	
ASC_School Bus	-2.0035					1
B_IVTT	-0.0032	Auto_Time	Auto_Time	Bike_Time	Walk_Time	Auto_Time

Table 7.4: HBSch Peak Mode Choice Model Specification

HBSch Off-peak Model Tree

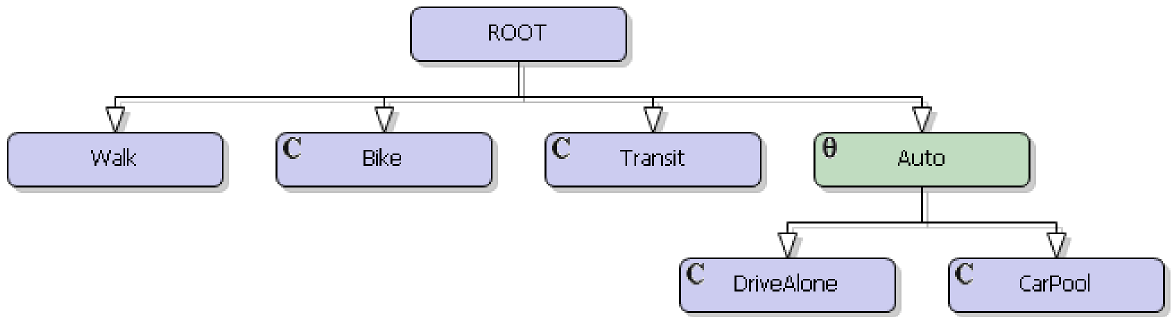

Figure 7.4: HBSch Off-peak Mode Choice Tree Structure

HBSch Off-peak Model Utilities

θ_Auto = 1.00

Coefficient	Value	DA	CP	Bike	Walk	School Bus
ASC_DA	-3.3619	1				
ASC_CP	-1.0185		1			
ASC_Bike	-2.8348			1		
ASC_Walk					Base	
ASC_School Bus	-2.6613					1
B_IVTT	-0.0036	Auto_Time	Auto_Time	Bike_Time	Walk_Time	Auto_Time

Table 7.5: HBSch Off-peak Mode Choice Model Specification

HBCol Peak Model Tree

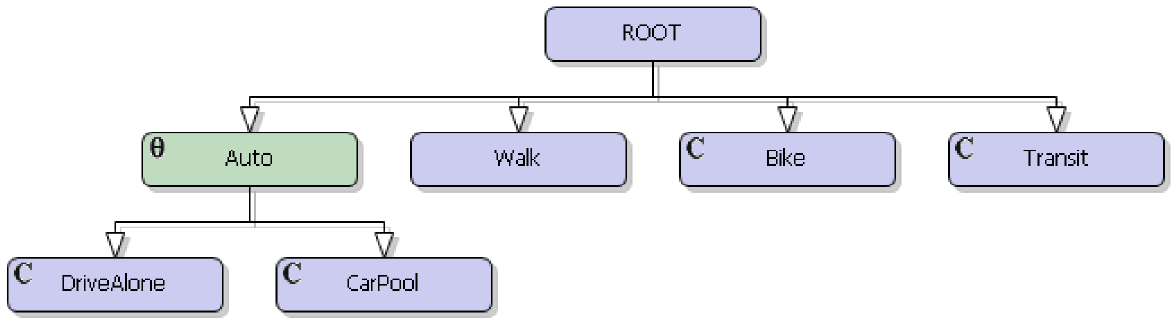

Figure 7.5: HBCol Peak Mode Choice Tree Structure

HBCol Peak Model Utilities

$\theta_{Auto} = 1.00$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	-3.5225	1				
ASC_CP	-4.7811		1			
ASC_Bike	-3.4202			1		
ASC_Walk					Base	
ASC_Transit	-4.7528					1
B_IVTT	-0.0022	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.6: HBCol Peak Mode Choice Model Specification

HBCol Off-peak Model Tree

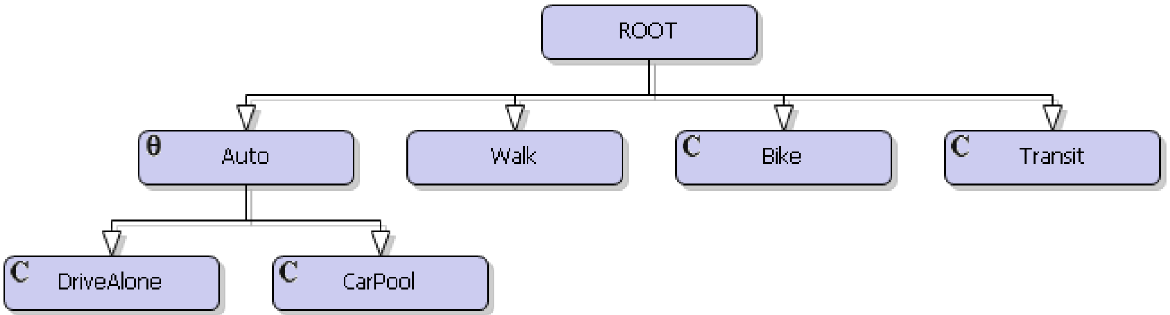

Figure 7.6: HBCol Off-peak Mode Choice Tree Structure

HBCol Off-peak Model Utilities

$\theta_{Auto} = 0.724$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	-2.839	1				
ASC_CP	-4.039		1			
ASC_Bike	-3.9513			1		
ASC_Walk					Base	
ASC_Transit	-4.1571					1
B_IVTT	-0.0022	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.7: HBCol Off-peak Mode Choice Model Specification

HBSho Peak Model Tree

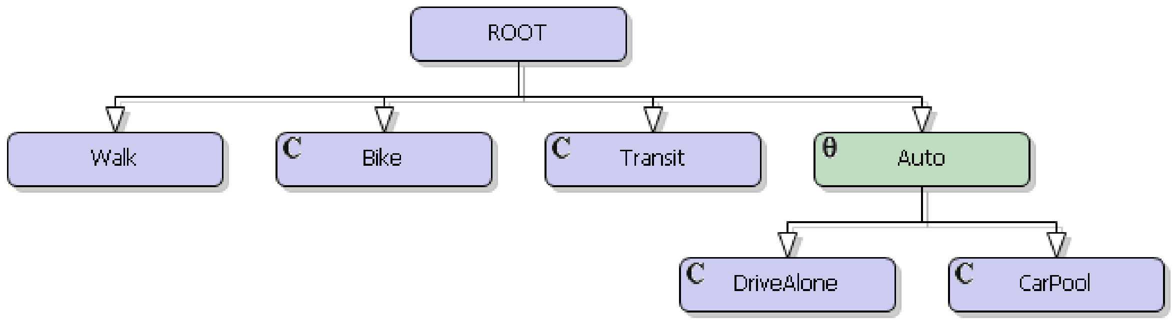

Figure 7.7: HBSho Peak Mode Choice Tree Structure

HBSho Peak Model Utilities

θ_{Auto} = 1.00

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	-1.0042	1				
ASC_CP	-1.3713		1			
ASC_Bike	-2.8338			1		
ASC_Walk					Base	
ASC_Transit	-4.6975					1
B_IVTT	-0.0028	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.8: HBSho Peak Mode Choice Model Specification

HBSho Off-peak Model Tree

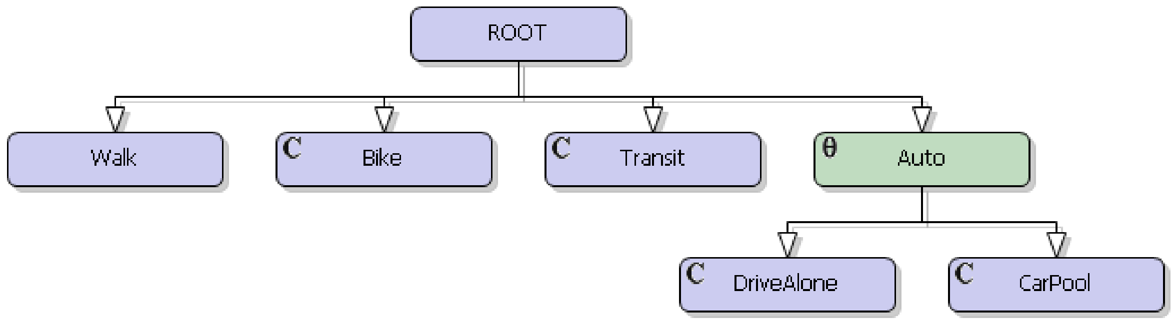

Figure 7.8: HBSho Off-peak Mode Choice Tree Structure

HBSho Off-peak Model Utilities

$\theta_{Auto} = 1.00$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	-0.6459	1				
ASC_CP	-0.9858		1			
ASC_Bike	-4.0544			1		
ASC_Walk					Base	
ASC_Transit	-4.0615					1
B_IVTT	-0.0014	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.9: HBSho Off-peak Mode Choice Model Specification

HBO Peak Model Tree

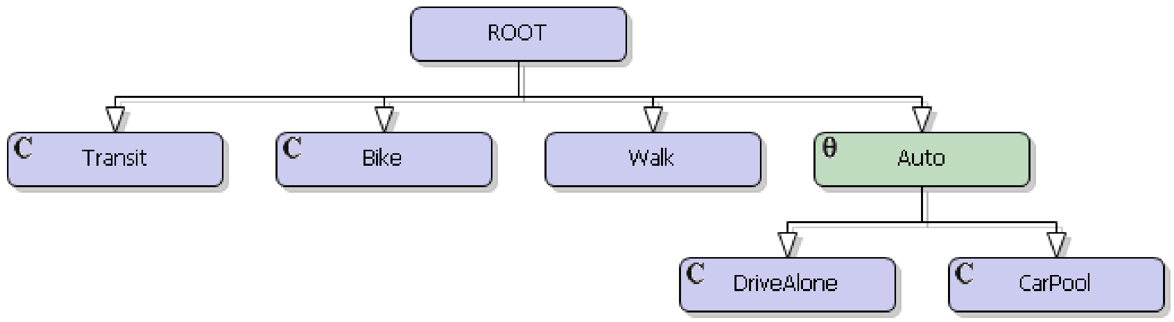

Figure 7.9: HBO Peak Mode Choice Tree Structure

HBO Peak Model Utilities

$\theta_{Auto} = 1.00$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	-2.2923	1				
ASC_CP	-1.9167		1			
ASC_Bike	-3.9912			1		
ASC_Walk					Base	
ASC_Transit	-6.7292					1
B_IVTT	-0.0024	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.10: HBO Peak Mode Choice Model Specification

HBO Off-peak Model Tree

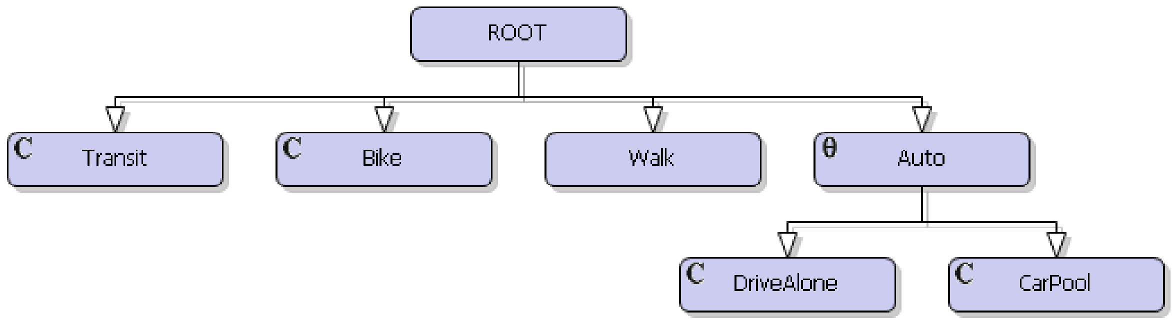

Figure 7.10: HBO Off-peak Mode Choice Tree Structure

HBO Off-peak Model Utilities

$\theta_{Auto} = 0.589$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	-1.1317	1				
ASC_CP	-1.0446		1			
ASC_Bike	-2.9955			1		
ASC_Walk					Base	
ASC_Transit	-4.6019					1
B_IVTT	-0.0015	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.11: HBO Off-peak Mode Choice Model Specification

NHBW Peak Model Tree

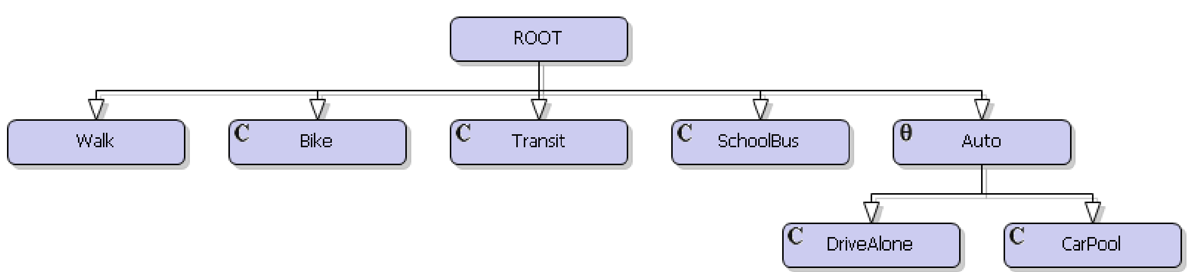

Figure 7.11: NHBW Peak Mode Choice Tree Structure

NHBW Peak Model Utilities

θ_Auto = 0.283

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	1.6128	1				
ASC_CP	1.0417		1			
ASC_Bike	-1.7107			1		
ASC_Walk					Base	
ASC_Transit	-0.5604					1
B_IVTT	-0.0002	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.12: NHBW Peak Mode Choice Model Specification

NHBW Off-peak Model Tree

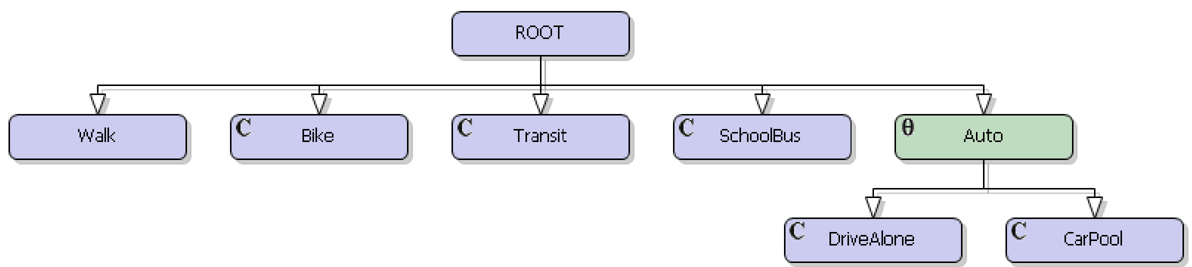

Figure 7.12: NHBW Off-peak Mode Choice Tree Structure

NHBW Off-peak Model Utilities

$\theta_{Auto} = 1.00$

Coefficient	Value	DA	CP	Bike	Walk	Transit
ASC_DA	-0.0574	1				
ASC_CP	-1.9154		1			
ASC_Bike	-2.9493			1		
ASC_Walk					Base	
ASC_Transit	-2.642					1
B_IVTT	-0.0012	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time

Table 7.13: NHBW Off-peak Mode Choice Model Specification

NHBO Peak Model Tree

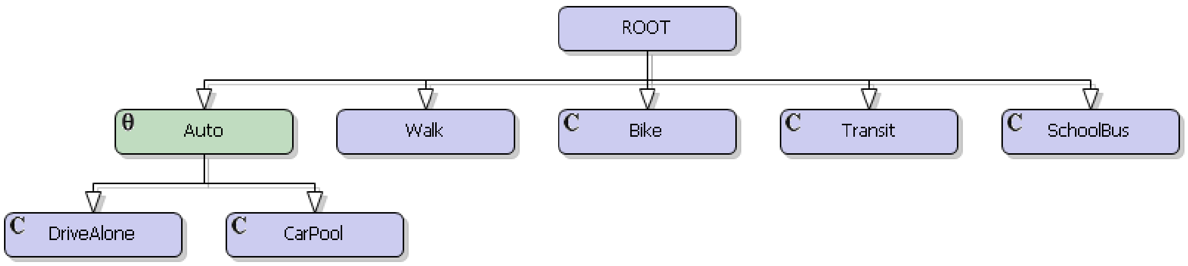

Figure 7.13: NHBO Peak Mode Choice Tree Structure

NHBO Peak Model Utilities

θ_Auto = 1.00

Coefficient	Value	DA	CP	Bike	Walk	Transit	School Bus
ASC_DA	-0.5265	1					
ASC_CP	-0.4606		1				
ASC_Bike	-2.7093			1			
ASC_Walk					Base		
ASC_Transit	-2.9415					1	
ASC_School Bus	-5.6434						1
B_IVTT	-0.0944	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time	Auto_Time

Table 7.14: NHBO Peak Mode Choice Model Specification

This model changed from the previous update in that some dummy variables were no longer needed. The transit availability matrix was able to adequately explain the observed shares without the special treatment of the zones.

NHBO Off-peak Model Tree

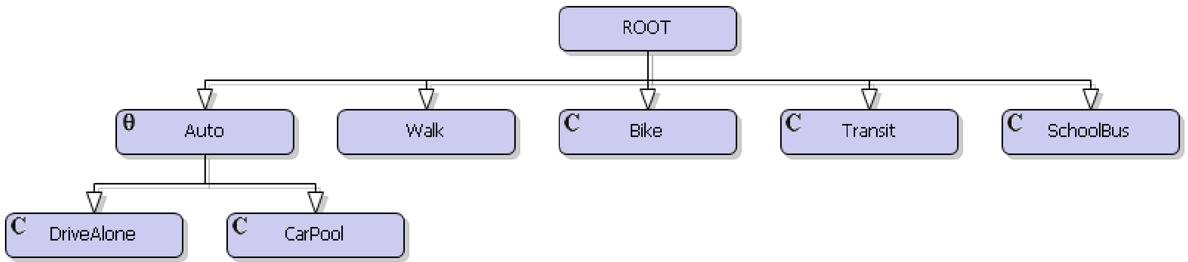

Figure 7.14: NHBO Off-peak Mode Choice Tree Structure

NHBO Off-peak Model Utilities

θ_Auto = 0.535

Coefficient	Value	DA	CP	Bike	Walk	Transit	School Bus
ASC_DA	-1.0111	1					
ASC_CP	-0.9856		1				
ASC_Bike	-3.602			1			
ASC_Walk					Base		
ASC_Transit	-3.7864					1	
ASC_SchoolBus	-6.5549						1
B_IVTT	-0.1055	Auto_Time	Auto_Time	Bike_Time	Walk_Time	IVT_Time	Auto_Time

Table 7.15: NHBO Off-peak Mode Choice Model Specification

Application of Mode Choice Models

The mode choice models are applied to the outputs of the trip distribution stage. Specifically, the PK mode choice model is applied to the PK PA matrix in conjunction with the PK highway and transit skims and using appropriate variables from the TAZ layer. For all the models, the walk mode is unavailable if the walking skim distance is greater than 1.5 miles, the bike mode is deemed unavailable if the skim distance is greater than 10 miles. The transit availability is determined by the transit skim settings and outputs. Missing transit skim values for an OD pair indicate lack of transit availability. Drive and Carpool modes are always available. The Drive Alone and Carpool trips components are output to the Auto matrix, the Walk and Bike components are output to the Non-Motorized matrix, the transit components are output in the transit matrix and all other modes (school bus) are output to the *Other* matrix.

The above process was likewise applied to the OP period (using OP skims and TAZ attributes).

Comparison of Survey and Model Mode Shares

Tables 7.16 and 7.17 compare model and survey shares by purpose, for the peak and Off-peak periods respectively. The tables indicate a reasonably close match to the survey shares. In general, it was difficult to match walk shares for the peak period and due to the availability variable, increasing the walk ASC beyond any value had no effect. It was similarly difficult to allocate between walk and bike shares but the combined non-motorized share match the survey very well.

The percentage of transit trips for the NHBO purpose for both the Peak and Off-Peak period is lower than the survey share. Initially the ASC for transit was adjusted to exactly replicate the transit survey shares. However, this resulted in an unreasonable number of transit trips and the total boardings from the transit assignment were significantly greater than the observed boardings provided by the Whatcom Transit Agency (WTA). Therefore, the transit totals were lowered to better match the WTA data.

The Mode Choice module is not applied to the IX (Internal External) and XI (External Internal) trips because these matrices were created using auto and truck counts at the external stations.

Purpose	DriveAlone	CarPool	Walk	Bike	Transit	SchoolBus
HBW Model	76.44%	9.67%	2.10%	10.03%	1.76%	-
HBW Survey	76.33%	9.66%	3.74%	7.70%	2.58%	-
HBSch Model	5.57%	70.33%	9.24%	4.17%	0.00%	10.69%
HBSch Survey	5.62%	70.99%	8.98%	3.41%	0.15%	10.85%
HBCol Model	33.26%	9.45%	24.64%	23.18%	9.47%	-
HBCol Survey	30.12%	8.56%	36.10%	14.52%	10.70%	-
HBSho Model	50.76%	35.16%	7.38%	5.71%	0.98%	-
HBSho Survey	51.16%	35.37%	7.95%	3.31%	2.21%	-
HBO Model	30.37%	44.22%	21.11%	4.09%	0.21%	-
HBO Survey	33.97%	49.29%	13.04%	2.48%	1.21%	-
NHBW Model	77.86%	10.37%	3.29%	2.63%	5.84%	-
NHBW Survey	74.23%	9.93%	6.11%	2.22%	7.51%	-
NHBO Model	45.32%	48.41%	1.74%	1.39%	2.57%	0.56%
NHBO Survey	39.86%	42.58%	10.26%	3.16%	3.68%	0.47%

Table 7.16: Comparison of Peak Mode Choice Shares by purpose

Purpose	DriveAlone	CarPool	Walk	Bike	Transit	SchoolBus
HBW Model	79.90%	10.19%	0.89%	7.42%	1.60%	-
HBW Survey	76.33%	9.66%	3.74%	7.70%	2.58%	-
HBSch Model	6.06%	63.14%	12.11%	6.47%	0.00%	12.21%
HBSch Survey	5.62%	70.99%	8.98%	3.41%	0.15%	10.85%
HBCol Model	43.35%	8.26%	26.10%	10.37%	11.91%	-
HBCol Survey	30.12%	8.56%	36.10%	14.52%	10.70%	-
HBSho Model	54.30%	38.65%	4.29%	1.36%	1.39%	-
HBSho Survey	51.16%	35.37%	7.95%	3.31%	2.21%	-
HBO Model	39.26%	45.52%	8.21%	5.99%	1.02%	-
HBO Survey	33.97%	49.29%	13.04%	2.48%	1.21%	-
NHBW Model	70.35%	10.97%	12.12%	3.36%	3.18%	-
NHBW Survey	74.23%	9.93%	6.11%	2.22%	7.51%	-
NHBO Model	43.89%	46.04%	5.77%	1.32%	2.42%	0.56%
NHBO Survey	39.86%	42.58%	10.26%	3.16%	3.68%	0.47%

Table 7.17: Comparison of Off-peak Mode Choice Shares by purpose

Chapter 7: Time of Day Procedure

The Whatcom model update has a time of day component that splits the PK PA and the OP PA matrices obtained after the mode choice procedure into sub-period (AM, PM) and (MD and NT) OD matrices respectively. These are then input to the traffic and transit assignment. The onset and duration of each time period were obtained by plotting the various trips from the survey by departure hour. A plot of trips (all purposes) by departure hour is shown in Figure 8.1 below:

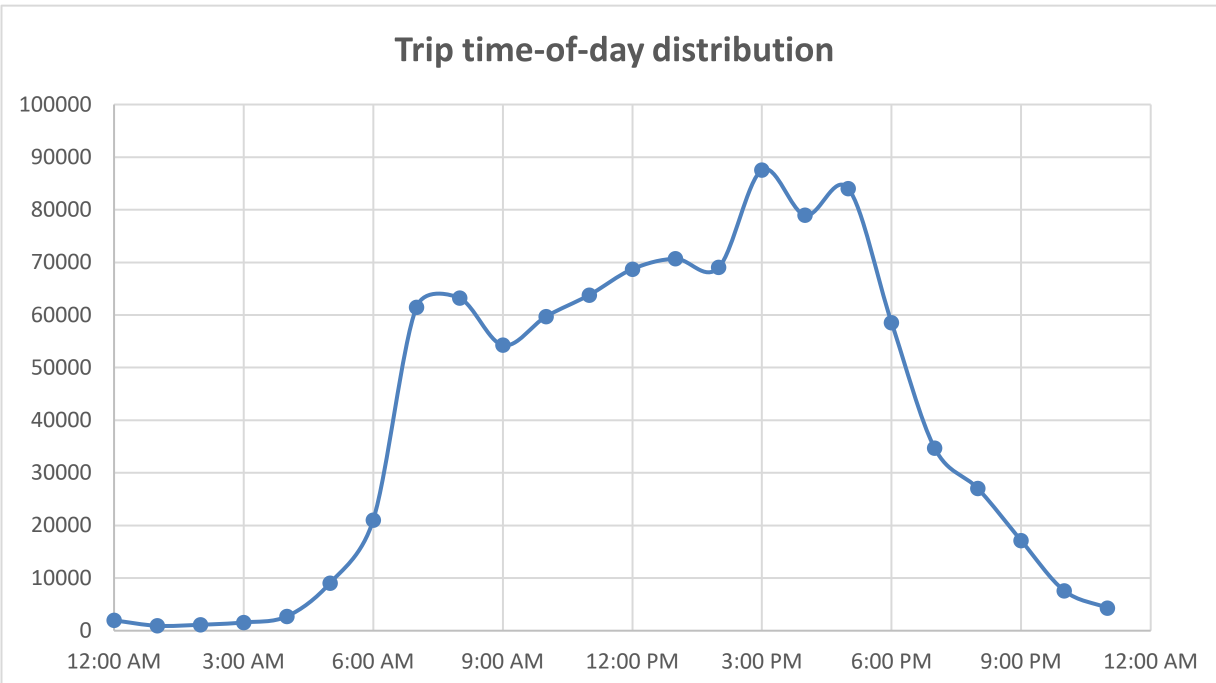

Figure 8.1: Time of Day Distribution

Based on the figure, we designated the four time periods; AM Peak, Mid-day (MD), PM Peak and Night (NT) as follows:

AM – 7 AM to 9 AM; MD – 9 AM to 4 PM; PM – 4 PM to 6 PM and the NT containing the rest of the hours

As in the previous model, the time of day departure and return rates were constructed from the survey, using the above time period definitions. It is worthwhile to note that for any hour (or period), the appropriate OD matrix can be obtained by multiplying the departure rate with the PA matrix and adding to this the product of the return rate multiplied by the transpose of the PA matrix. In the case of converting carpool trips, this result is further multiplied by the appropriate carpool occupancy rate in order to obtain vehicle trips. The salient features of the time of day procedure are:

- The time of day departure and return rates are developed separately for the auto and transit modes. For each case, PK and OP **hourly** departure and return rates were obtained.
- The **Auto** time of day procedure is applied on the PK and OP mode choice auto matrices by purpose. The PK Auto time of day procedure operates on the PK Auto matrix (that contains PK drive alone and carpool trips by purpose) and the OP Auto time of day procedure operates on the OP Auto Matrix (that contains OP drive alone and carpool trips by purpose).
- Likewise, the **Transit** time of day procedure is applied on the PK and OP mode choice transit matrices by purpose.
- The PK time of day procedure (both auto and transit) split the trips into the AM and the PM sub-periods and creates AM and PM OD matrices (auto and transit).
- The OP time of day procedure (both auto and transit) split the trips into the MD and NT sub-periods and creates MD and NT OD matrices (auto and transit).
- During the process, vehicle carpool occupancy rates are used to convert person trips of the carpool auto mode to vehicle trips. The carpool occupancy rates (2+ carpool) for the HBW, HBSch, HBColl, HBSho, HBO, NHBW and NHBO purposes are 2.02, 2.52, 2.05, 2.06, 2.18, 2.05 and 2.11 respectively. These occupancy factors were obtained from the carpool trips reported in the survey. Note that transit OD trips are left as person trips for transit assignment. There is no occupancy factor for Truck Trips.
- The time of day procedure (above) is not applicable to the Internal External (IX) and the External Internal Trips (XI) trips, since the original data was already in OD format. (As mentioned earlier in the mode choice chapter, this is why the mode choice output matrices were zeroed out for IX and XI trips).
- Once the time of day procedure is complete, the IX and XI trips are added directly from the PK and OP trip distribution results into the OD matrices for the appropriate sub-period. (Note that during this procedure, the PK trips had to split into AM and PM trips and the OP trips had to be split into MD and NT trips. These splits were done using the ratios in the External Trips input file).

Time of Day Tables

To develop departure and return rates, trips had to be classified as departure trips or return trips. For the home-based trip purposes, the departure trip occurs from the home end and the return trips is one that is destined to the home end of the trip. For the NHB purposes however, there is no such clear demarcation and hence the total rate was equally split to obtain departure and return rates.

The Auto Peak departure and return rates are obtained by looking at all the Auto trips from the survey that departed during the Peak period. The Auto Off-peak departure and return rates are obtained by looking at all the Auto trips from the survey that departed during the OP period Transit departure and return rates were determined from the transit trips in the survey.

The departure and return rates were developed for hourly intervals but have been aggregated to the respective time periods. Table 8.1 shows the Auto departure and return rates for the peak period.

Purpose	AM_Dep	AM_Ret	PM_Dep	PM_Ret
HBW	53.04%	1.78%	4.82%	40.36%
HBColl	71.77%	1.20%	1.72%	25.31%
HBSch	69.82%	13.86%	3.75%	12.57%
HBSho	11.98%	5.03%	19.69%	63.30%
HBO	27.79%	6.99%	30.40%	34.82%
NHBW	30.83%	30.83%	19.17%	19.17%
NHBO	14.41%	14.41%	35.59%	35.59%
Truck	14.41%	14.41%	35.59%	35.59%

Table 8.1: Peak Auto Departure and Return Rates by Purpose

Some features of the above table are:

- The above departure and return percentages by purpose pertain only to the Peak Period (7 AM to 10 AM and 3PM to 6PM). Note that this lookup table operates only on the PK Auto and Carpool trips from the mode choice.
- The departure percentages sum to 50% and the return percentages sum to 50%, thus constituting 100% of the trips.
- For example, to compute the HBW Drive Alone OD matrix and the HBW Carpool OD Matrix for the AM period, the formulation is:
    - HBW Drive Alone AM OD = 46.1 % of (HBW Drive Alone PA) + 1.0 % of (HBW Drive Alone PA transpose)

- HBW Carpool AM OD = (46.1% of (HBW Carpool PA) + 1.0 % of (HBW Carpool PA transpose)/2.12, where 2.12 is the carpool 2+ occupancy rate for the HBW purpose.

Table 8.2 shows the Auto departure and return rates for the Off-Peak period (10 AM to 3PM and 6PM to 7 AM of the following day). This lookup table operates only on the OP Auto and Carpool trips from the mode choice model.

Purpose	MD_Dep	MD_Ret	NT_Dep	NT_Ret
HBW	24.14%	28.61%	26.03%	21.21%
HBColl	48.83%	43.97%	0.07%	7.14%
HBSch	30.33%	57.35%	5.57%	6.75%
HBSho	26.75%	40.85%	10.27%	22.14%
HBO	32.63%	29.91%	13.33%	24.13%
NHBW	37.77%	37.77%	12.23%	12.23%
NHBO	40.42%	40.42%	9.58%	9.58%
Truck	40.42%	40.42%	9.58%	9.58%

Table 8.2: Off-peak Auto Departure and Return Rates by Purpose

After the PA to OD conversion, the IE (Internal-External) and EI (External-Internal) Auto and Truck trip matrices are added to the respective periods. Previously, the IE and EI trips for the peak and Off-peak periods were generated during the trip distribution and these already contained auto and truck vehicle trips. The AM peak and PM Peak counts at the external stations are used to split the Peak Auto and Truck IE and EI trips into AM and PM matrices, which are then added to the respective OD matrices. Likewise, the Off-Peak Auto and Truck IE and EI trips are split into MD and NT IE and EI trips and added to the respective OD matrices. Finally, the through trip auto and truck matrices are added to the auto and truck OD matrices for each period.

Tables 8.3 and 8.4 illustrate the departure and return rates for the PK and OP transit matrices.

Purpose	AM_Dep	AM_Ret	PM_Dep	PM_Ret
NHBW and NHBO	17.5%	17.5%	32.5%	32.5%

Table 8.3: Peak Transit Departure and Return Rates

Purpose	MD_Dep	MD_Ret	NT_Dep	NT_Ret

NHBW and NHBO	42.4%	42.4%	7.6%	7.6%

Table 8.4: Off-peak Transit Departure and Return Rates

Time of Day Results

The following tables show the auto and transit OD totals by time period and purpose after the Time of Day procedure and before the traffic assignment.

Mode/Vehicle Class	AM OD Trips	MD OD Trips	PM OD Trips	NT OD Trips	Total Trips
Drive Alone	41,543	18,3861	56,241	61,787	**343,432**
Carpool	10,848	73,818	19,093	25,231	**128,990**
Transit	1,414	7,249	1,764	2,026	**12,453**
School Bus	737	3,676	305	460	**5,178**
Walk	6,254	28,934	10,338	9,257	**54,783**
Bike	4,852	15,891	5,657	6,102	**32,502**
Truck	1,841	35,293	4,549	7,472	**49,155**
Auto External	7,572	32,349	11,429	20,841	**72,191**
Truck External	984	4,154	1,460	2,745	**9,343**
Total	**76,047**	**385,225**	**110,836**	**135,921**	**708,029**

Table 8.5: Auto and Truck OD by Time Period

Chapter 8: Assignment

Highway Assignment

The traffic assignment procedure is run for each of the four time periods (AM, PM, MD and NT). If a feedback procedure is employed, then only the AM and MD assignments are run during the intermediate loops. The assignments for all the time periods are executed during the final loop of the feedback process.

The features of the traffic assignment during each loop are as follows:

- The assignment method used in the 2018 updated model is TransCAD's super-efficient Bi-conjugate User Equilibrium assignment run to a relative gap of 1e-5
- The assignment consists of two classes, cars and trucks. Cars are subdivided into two classes, Drive Alone and Carpool, though there are no network characteristics that require this (e.g., HOV Lanes)
- Trucks have a Passenger Car Equivalent (PCE) of 2.0 (e.g., the capacity that a truck occupies on a roadway is assumed to be twice that of a passenger car)
- The assignment employs the Bureau of Public Roads (BPR) delay function

Since the demand is not unform across the assignment period, capacity factors are used to scale the hourly capacity to the time period duration. If the actual number of hours in each Table 9.1 shows how the time period assignments are assembled. For each period, two assignments are done and the results are combined.

Time Period	Assignment 1	Effective Capacity (hours)
AM	7AM-9AM	1.75
MD	9AM-4PM	4
PM	4PM-6PM	1.75
NT	6PM-7AM	5

Table 9.1: Time Period Assignments

Assignment Parameters

The volume delay function (VDF) is the BPR formulation as shown, where v/c represents the volume to the capacity ratio, α and β are delay parameters that vary depending on the type of the link, t_f is the free flow time and t is the congested time.

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

During this update, the alpha and beta values were calibrated to a more detailed level and vary based on both functional class and area type, as shown in Table 9.2 below

Type	Class	Area Type	Hourly Capacity (pcphpl)	Alpha	Beta
1	Freeway	Urban	1800	0.2	5.5
1	Freeway	Suburban	2000	0.175	5
1	Freeway	Rural	2200	0.15	4
2	Major Arterial	Urban	900	1.25	6
2	Major Arterial	Suburban/Rural	1000	1.15	6
4	Minor Arterial	Urban	1100	1	6
4	Minor Arterial	Suburban/Rural	800	1	5
5	Major Collector	Urban	900	1	5
5	Major Collector	Suburban	1000	1	5
5	Major Collector	Rural	700	1	6
6	Minor Collector	Urban	750	1	6
6	Minor Collector	Suburban	800	1	6
6	Minor Collector	Rural	700	1	6
7	Ramp	Urban	750	1	6
7	Ramp	Suburban	800	1	6
7	Ramp	Rural	900	1	6
9	Centroid Connector	All	1000	1	6

Table 9.2; BPR VDF Parameters

The plot of some of the VDF equations is shown in Figure 9.1. The horizontal axis shows the volume to capacity ratio and the vertical axis represents the ratio of congested time to free flow times.

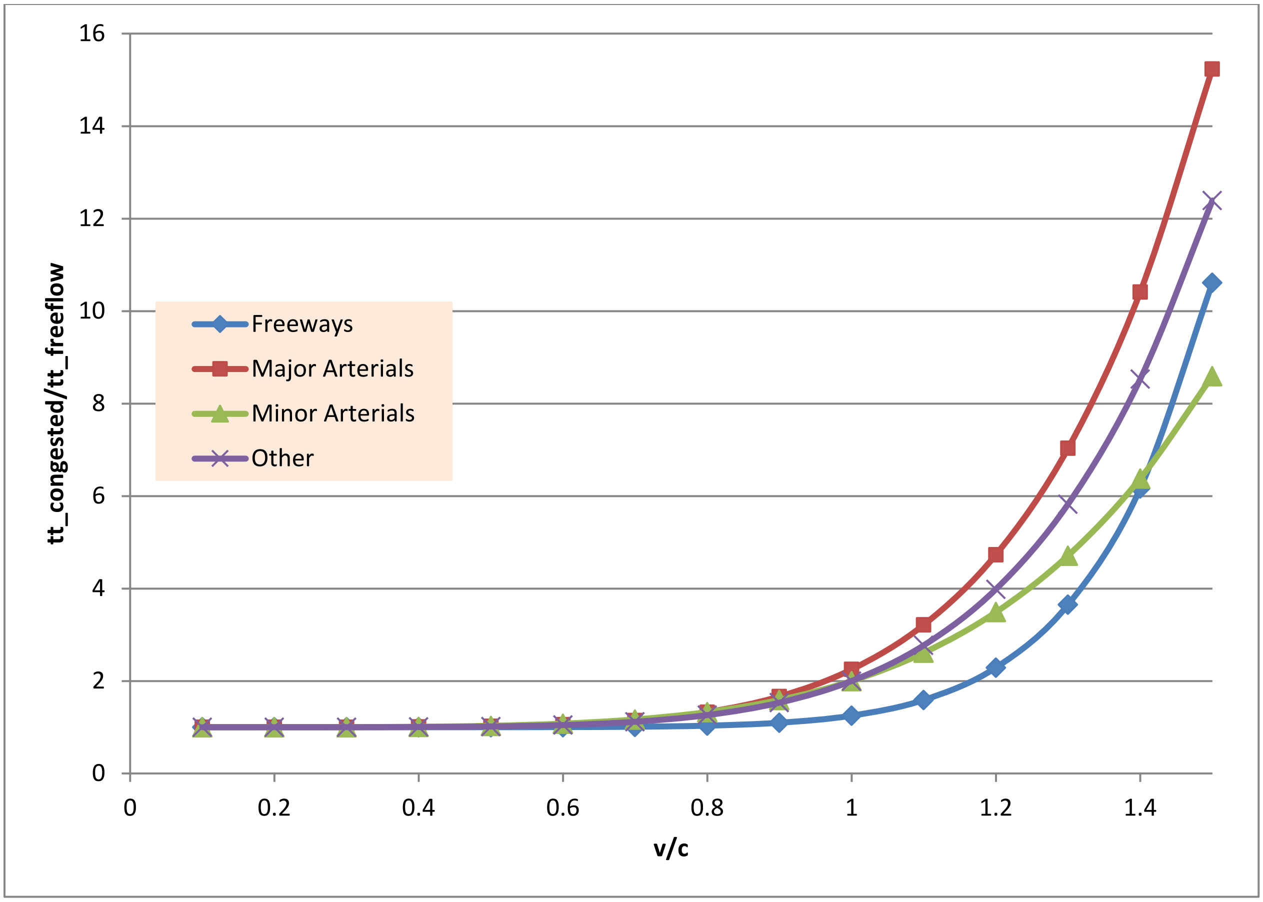

Figure 9.1: Sample Volume Delay Functions by Functional Class

Assignment Results

The traffic assignment results are presented for the four time periods. The congestion plots for each of the time periods are shown in figures 9.2 to 9.5. The assignment results for each period were compared with traffic count data by period and the results are then discussed:

Figure 9.2 shows a scaled symbol and color theme plot where the thickness of each line feature is proportional to the flow on the link and the color theme shows the congestion of each feature (measured using the Volume to Capacity VOC ratio on the link). A red color indicates a high VOC and a green color indicates a low VOC value.

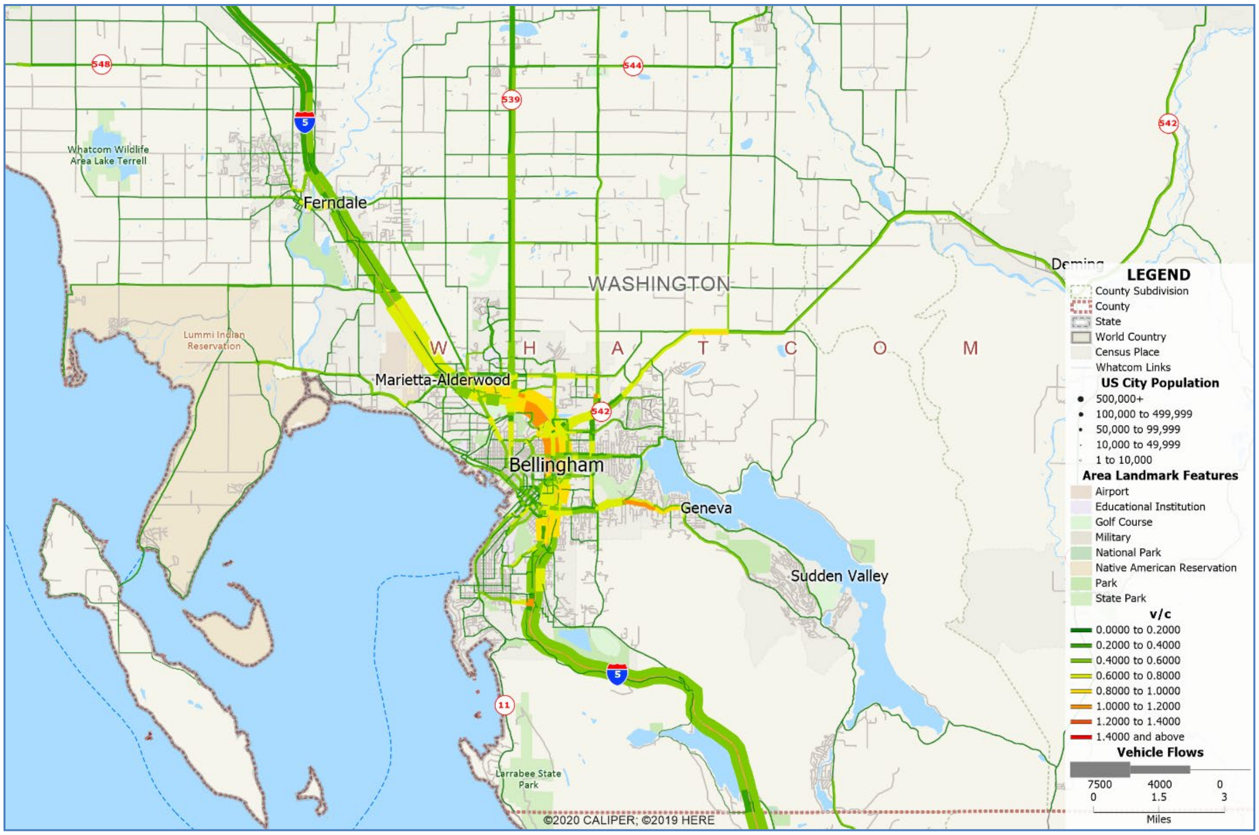

Figure 9.2: PM Flow Map and Congestion Pattern

The PM period congestion pattern shows some congestion along the I-5 corridor in the vicinity of Bellingham and along route 539 (Guide Meridian road). Most of the other locations are not overly congested. Figure 9.3 shows a close-up of the PM assignment in Bellingham.

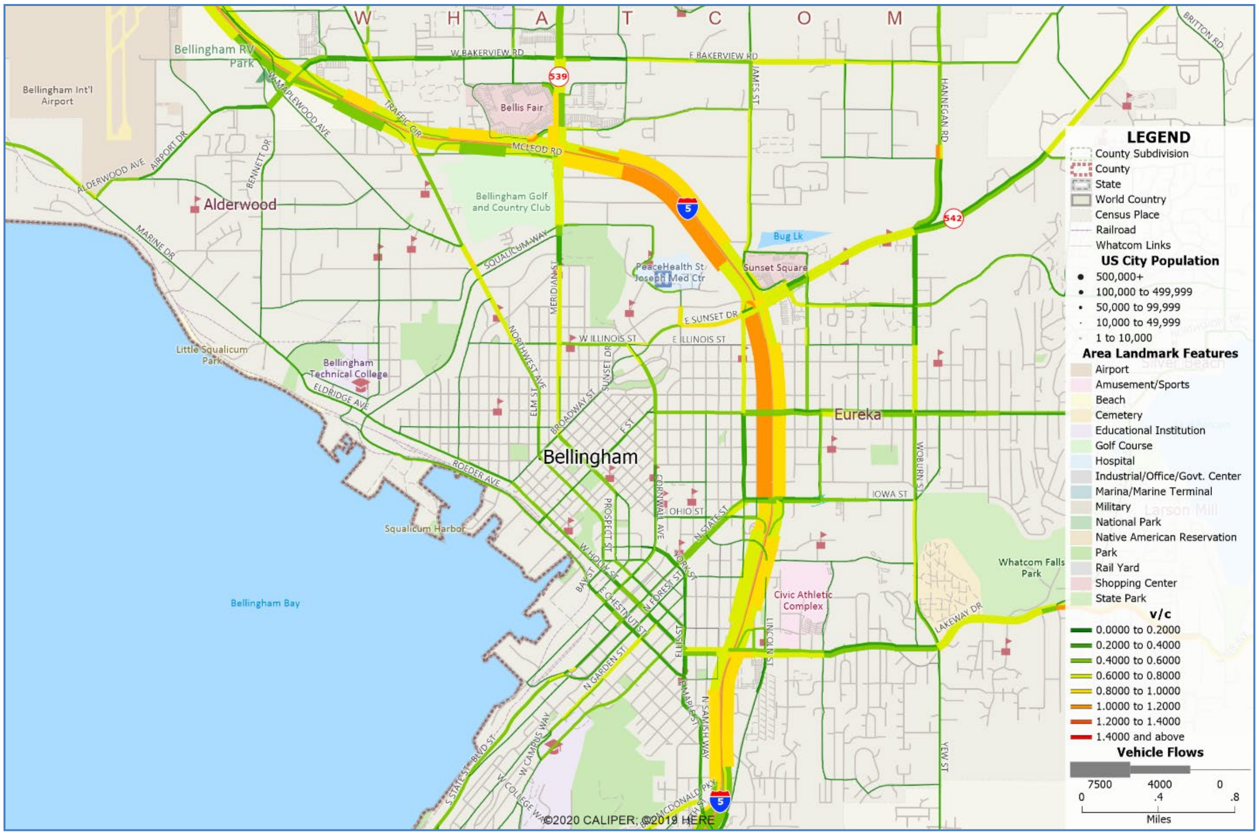

Figure 9.3: Close up of PM Flow Map and Congestion Pattern in Bellingham, WA

Comparison of Assignment Volumes to Traffic Counts

The validity of the model was determined by comparing against ground counts on a time period basis. The counts were pooled together from various sources by Whatcom County staff and provided for one hour intervals. The counts were aggregated to the respective time periods and used to compare against the assignment flows. The assignment flows from all the four periods were added to obtain the daily flows.

Tables 9.3 to 9.7 show the comparison of the flows versus the counts for the daily period and for each of the time periods. The %RMSE, a statistic most helpful in determining how the counts match up with the flows, is shown for all the links and specifically for highway links, ramps, major and minor arterials for each of the time periods.

The Percent RMSE formula is given by:

$$\%RMSE = 100 * \sqrt{\left(\sum_i (Model_i - Count_i)^2 / (Numberofcounts)\right.} \, / \left(\sum_i (Count_i / NumberofCounts)\right)$$

A %RMSE of 40 or below is recommended for all the links. For freeway links, it is generally recommended that the %RMSE be below 20%.

It can be seen from that tables that the RMSE between the flows and the counts clearly satisfy this criteria. Further the %RMSE for highway is well below 12%, indicating an excellent match of the flows to highway counts for all the four periods and for the daily model. These results exceed the standards set forth in national guidance from FHWA. The calibration of the model focused on the Daily and PM Peak periods, though assignment results are available for all four time periods in the model:

Class	# Count Links	Total Flow	Total Count	Pct Diff	RMSE %
All Counts	688	3,241,726	3,377,951	-4.0	**26.9**
Freeways	39	875,564	941,952	-7.0	**12.0**
Major Arterials	241	1,424,666	1,473,427	-3.3	**23.1**
Minor Arterials	215	635,073	657,766	-3.4	**39.4**
Collectors	141	194,576	197,364	-1.4	**50.4**
External Links	14	84,348	85,405	-1.2	**2.0**

Table 9.3: Daily Flow and Count Comparison

Class	# Count Links	Total Flow	Total Count	Pct Diff	RMSE %
All Counts	533	354,016	382,435	-7.4	**33.1**
Freeways	10	31,522	33,205	-5.1	**9.6**
Major Arterials	201	212,315	218,968	-3.0	**26.8**
Minor Arterials	167	73,935	89,273	-17.2	**45.2**
Collectors	103	19,008	23,885	-20.4	**58.9**
External Links	16	72,635	77,420	-6.2	**2.1**

Table 9.5: PM Flow and Count Comparison

In general, both the period assignments and the daily assignments are well calibrated. Figure 9.6 shows a scatter plot of flow versus count for the daily period. As can be seen, a majority of the points lie on the 45 degree line indicating a very good match for the base year.

Vehicle Hours of Travel and Vehicle Miles of Travel

The total Vehicle Miles Traveled (VMT) and the total Vehicle Hours of Travel (VHT) for each of the time periods is shown in Table 9.8

Time Period	Total VMT	Total VHT
AM	503,215	12,051
MD	2,369,916	74,978
PM	716,834	17,742
NT	946,836	21,884
24-hour	4,536,800	126,655

Table 9.8: VMT and VHT by Time Period

Transit Assignment

The transit assignment is performed for the 4 time periods AM, PM, MD and NT and the results are added to give the total boardings for the daily period. During this model update, the Pathfinder assignment in TransCAD was applied. This is a process that combines paths between origin and destination pairs that have similar cost, allowing for a more realistic path choice set than other conventionally applied methods. Please refer to the TransCAD Travel Demand Modeling guide for details on this procedure.

As mentioned earlier, an origin to parking node input matrix is used for the assignment that determines the zones eligible for park and ride access.

The transit validation was done by three main criteria:

- Match Daily, total Boardings and Alightings on the highest ridership routes.
- Match Boardings and Alightings at key stops
- Match Park and Ride usage

After calibration of the transit network setting parameters, some adjustments to the mode choice models, the above goals were sufficiently met. There are 12,453 transit trips in the daily period. This equates to a ridership of 15,851. This is slightly higher than the WTA estimate, which is close to 14,500.

Time Period	Total Boardings
AM	2,053
MD	9,280
PM	2,112
NT	2,406
Daily	15,851

Table 9.9: VMT and VHT by Time Period

Figure 9.7 shows the AM transit flows aggregated to the line layer. A thicker line indicates greater transit flow. As can be seen from the map, the transit flows are greater around Bellingham, particularly in the proximity of Western Washington University (in the south west corner of the map).

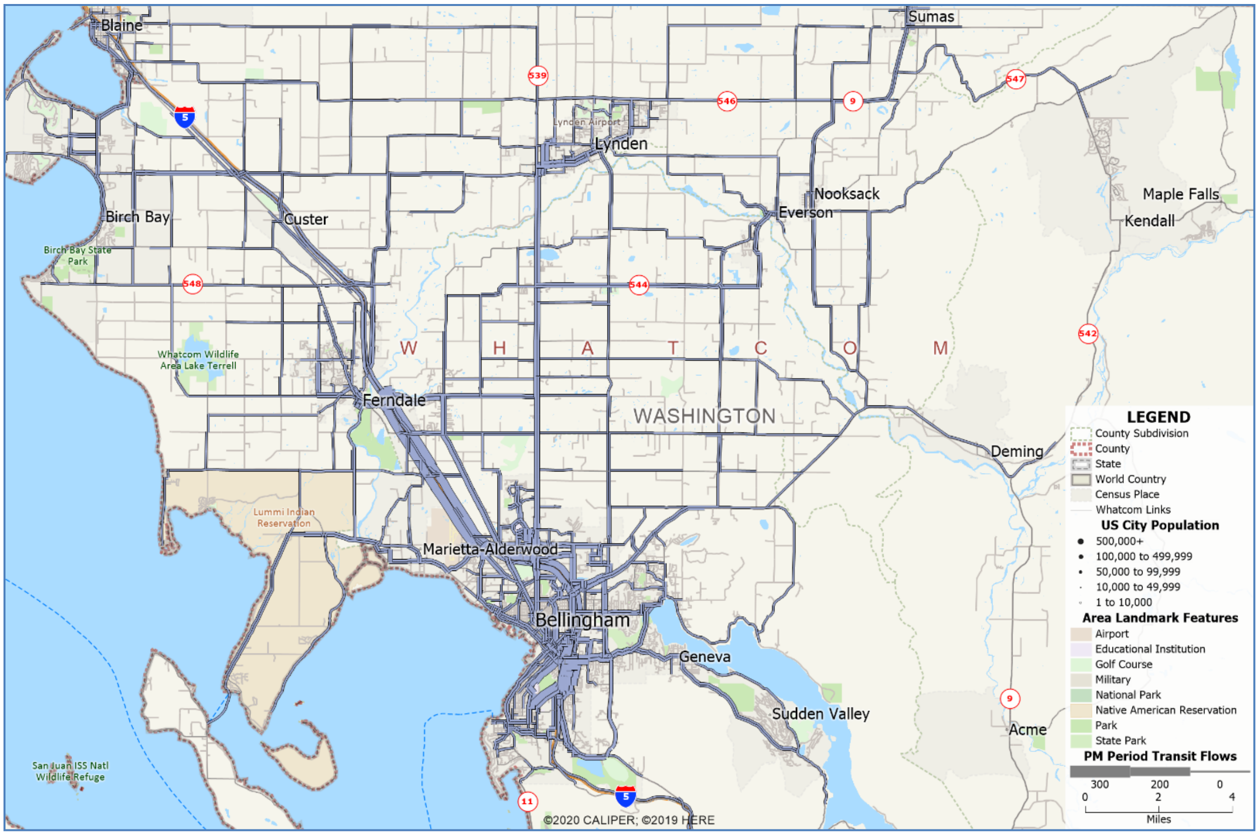

Figure 9.7: Transit Assignment PM Flow Map

Chapter 9: Feedback Loop and Logic

The Whatcom Travel Demand Model utilizes a feedback mechanism option. It is necessary for planning models to incorporate a feedback model to ensure the congested link travel times that result from the assignment algorithm are identical to the link travel times that was used to generate the skims and ultimately derive the trip matrices. The feedback is a fixed point problem.

The Whatcom model generates PK and OP trip ends, performs trip distribution and mode spilt to generate PK and OP trips by purpose and mode. The Time of Day further produces OD matrices by AM, PM, MD and NT periods. Since the trip distribution primarily works on Production and Attraction data, the AM skims is representative of the PK skims. Likewise, the MD skims is representative for the OP skims. The feedback loop hence is designed to achieve consistency in the AM and MD congested link travel times.

Both the highway and transit skimming procedure is run for the AM and the MD period. The highway skims are used for the trip distribution for the PK and OP periods respectively. The mode spilt is then executed, (using the AM highway and transit skims for the PK skim utility terms and the MD highway and transit skims for the OP skim utility terms). The time of day procedure then produces AM, MD, PM and NT OD matrices, out of which the AM and the MD assignment are executed within the feedback loop. The flows from AM assignments in successive feedback loops are smoothed using the Method of Successive Averages (MSA). Likewise an MSA flow vector is generated for the MD trips. These flows are then used to construct MSA link travel times for the AM and the MD periods using the VDF functions. These times are fed back into the AM and MD highway skimming procedure.

Note finally that the PM and the NT assignment and transit assignment are executed only in the final feedback loop.

During the process of calibration, several runs were performed and the base year highway network was eventually populated with the congested link travel times for the AM and the MD periods. A flag in the model allows the user to start the model using these congested times. It is recommended that for the base year scenario, the user utilizes this option and runs through the model steps just once. It is not necessary to run the feedback procedure, unless a change is made to a critical input variable.

It is to be noted that for a new model scenario (such as a future year run) that has different demographics, land use patterns etc., the user start with free flow travel times and runs sufficient feedback loops first to generate the congested times. In the case of a short term scenario run (such as reducing the number of lanes), it may not be necessary to run the feedback. Rather, in this case, it may be useful to code in the network change and simply re-run the traffic assignment. It is left to the judgment of the user to decide when a feedback run is warranted. Typically, for any given scenario, the answer depends on whether OD patterns change and whether travelers will adjust their travel patterns in response to the scenario.

Given a particular scenario that requires feedback loops, it is recommended to perform at least five loops of the feedback process starting with free flow times. There is no harm in running additional feedback loops, such as 10 loops starting with free flow times, especially if testing a scenario with higher than expected demand, though 5 has been deemed sufficient for attaining consistency in travel times in the current configuration.