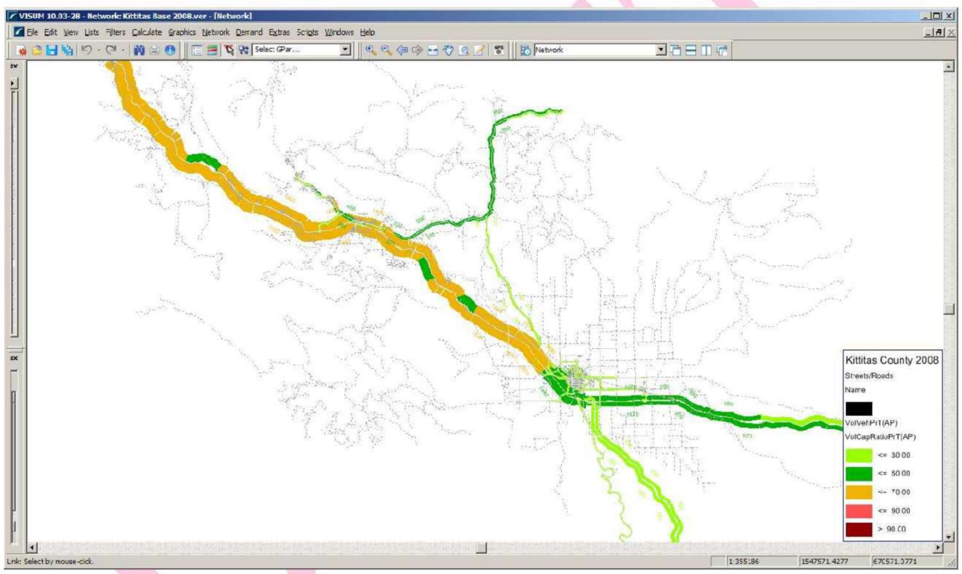
APPENDIX E TRAVEL DEMAND DOCUMENTATION

Kittitas County

Transportation Model Documentation



Prepared for

Kittitas County, Washington

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Introduction

This document provides a summary of the process and the parameters used to update and develop the transportation model for Kittitas County. This model is intended to represent base year conditions for 2008. Also discussed is the methodology used in providing forecasts for the years 2030 for use in recommendations with the Kittitas County Plan and to evaluate other proposed improvements. The knowledge of the procedure used to develop the models and the forecasts is important for the future application of the models.

This model, for use by Kittitas County, will assist in the development and evaluation of future transportation improvement projects.

PTV America developed this 2008 Kittitas County model from the Kittitas County transportation model developed in 2005 and updated for the City of Ellensburg in 2007. The Kittitas County model was completed in August of 2005 and was developed by PTV America in conjunction with Valerie Southern, Transportation Consultant, LLC, and Garry Struthers and Associates, Inc. and in cooperation with Kittitas County. The 2005 Kittitas County model was based upon models for Kittitas County, Ellensburg, and CleElum/Roslyn from various earlier years. These models were developed between 1994 and 2000 using the TMODEL software package.

These previous models were converted into the VISUM software package for ease of data transfer. The new Kittitas County model network was built from NAVTEQ data. The NAVTEQ data is network definition data used in many mapping software including Mapquest, Microsoft Streets and Trips, and used for onboard vehicle navigation systems. The data includes all streets and roads (including names) and data on lanes, speeds, and turn restrictions so it can be used for routing. For purposes of the Kittitas County model this data was further enhanced with data from the previous models, data from the road deficiency reports, and field review. The data was further refined as more detailed parcel level land use data was provided for the 2008 Kittitas County model.

This transportation planning model is a representation of Kittitas County, roadway transportation facilities and the travel patterns using these facilities. The model contains inventories of the existing roadway facilities and of housing, shopping, employment, and other land use in the area. These inventories, along with model "rules" are used to generate traffic volumes for all roadways within the model. These forecast volumes are compared with current traffic counts. When the model matches the traffic counts within acceptable ranges of error, the model can then be used to test future year scenarios. These scenarios may be changes in number of housing units, employment quantities, travel behavior patterns, or roadway improvements. The transportation planner, using the transportation planning model, can project future traffic volumes without the cost of building inappropriate roadways or waiting for traffic congestion to severely impact travelers.

The 2008 Kittitas County model was developed with version 10.03+ of VISUM, part of the PTV Vision Suite of software. Most importantly, this version of the model was updated in 2009 with updated base year land use inventory and forecasts supplied by Kittitas County, new traffic count data supplied by Kittitas County and the City of Ellensburg. This update included review of the network and forecasts involving Kittitas County staff.

This document describes the methodology that PTV America, Inc. (PTV) and Kittitas County staff used to develop the model. Because modeling is a complex process, much of the theory, terminology, and concepts are also discussed.

The Modeling Process

A transportation planning model is constructed with the purposes of forecasting traffic and operating conditions. The model is first calibrated to replicate existing or base-year travel patterns. The model inputs are then modified to represent future conditions, making it possible to project traffic volumes. This gives transportation planners and engineers the ability to determine the impact of different roadway or land use scenarios on the traffic network. This, in turn, allows the professional to evaluate economic decisions on potential capital improvements and then make appropriate plans. One such use of these models is to test several forecast conditions.

Model Area Identification

The modeling process begins by determining the area to be modeled. The Kittitas County model includes major roadway facilities within the Kittitas County boundaries, including all cities. When the county model was developed, detail within the City of Ellensburg and to some extent within the Cle Elum area was included so that the model could be later refined for use by the cities. Because the model was developed with the NAVTEQ data set as its basis, the model also includes rail and trail transportation links and other points of interest such as rivers and lakes. The model area with traffic analysis zone boundaries is shown in Figure 1.

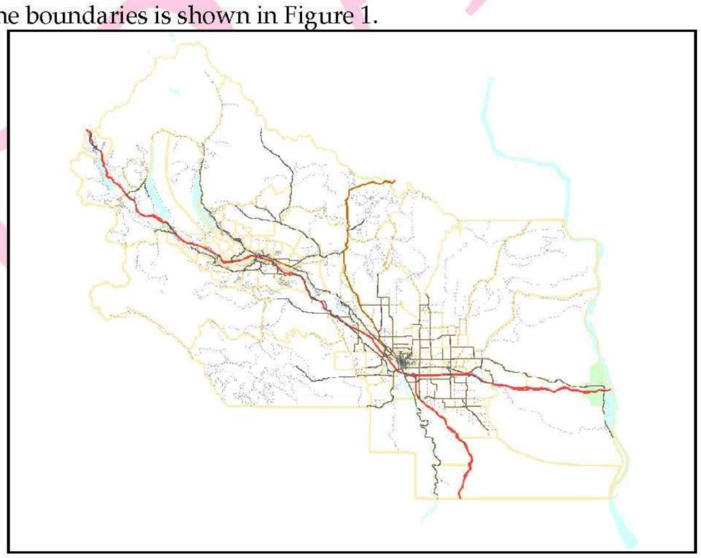


Figure 1 - Model Area with TAZ Structure

The Kittitas County model encompasses the entire county and includes all of the roadways classified as collector or greater within the county. The included network is described in more detail later in this document. The original network was based upon the cities' and county's roadway functional classification maps as determined by Kittitas County staff. Additional streets or roads were added based upon the judgment of the Kittitas County staff. Roadways included in the Kittitas County model are shown in Figure 2. It is important that the model include the major roads leading in, out, and through Kittitas County because these have an impact on traffic within Kittitas County.

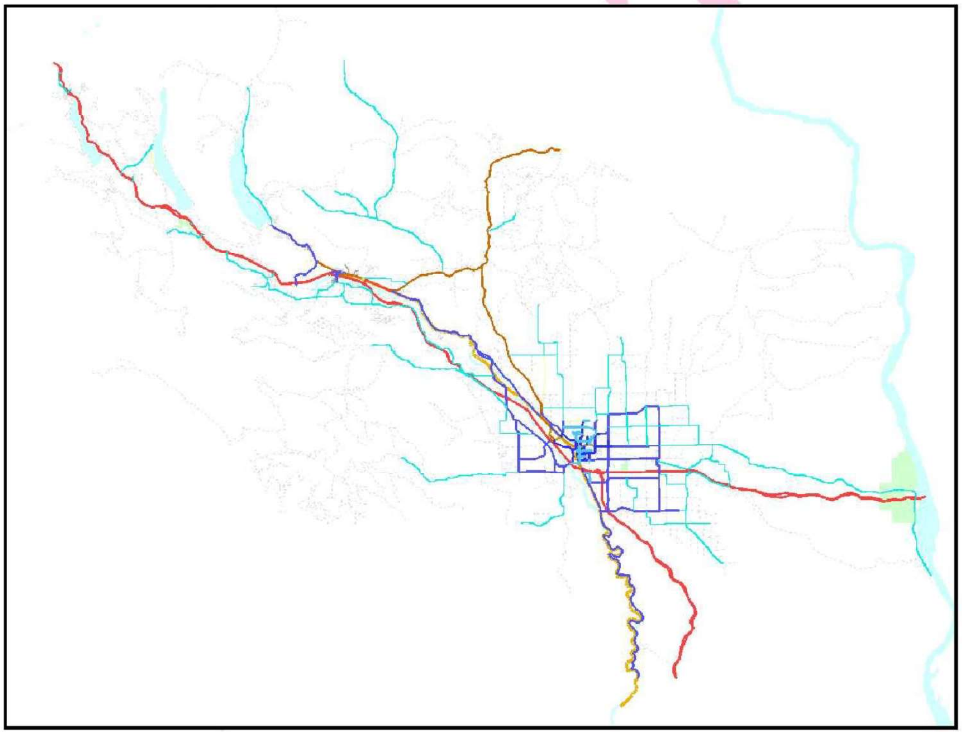


Figure 2
Kittitas County Model Network

The model Traffic Analysis Zones, also known as TAZs are areas with points where trips begin and end. These are used to inventory all of the land use or attributes that generate traffic. For the previous modeling efforts, Kittitas County supplied a TAZ system that was developed previously by county staff. For the 2008 Kittitas model, the TAZ system was reviewed and revised. Traffic Analysis Zones were subdivided in growth areas and other locations to match the detail of the network. The TAZ system used for the model was shown in Figure 1.

Two types of zones were used: *internal and external*. *Internal zones* can consist of a single parcel, a group of like land uses, or a gathering of local land uses separated by natural, physical, or political boundaries. Several factors are considered to find the best zonal design. The primary factor is related to the results expected of the model. It may be logical to place the zone in a way that groups all land uses bounded by network roadways. The second factor is how the available land use information is geographically described. Because the land use data was derived from the Kittitas County parcel layer, the TAZ structure could be defined to best match the transportation system. The Kittitas County model now consists of 300 internal zones.

External zones account for all vehicle trips that enter and leave the model area. Depending upon the desired results, it may be logical to place an external zone on each roadway that leaves the network. In other cases, local traffic conditions may establish a need to tie together several exiting roadways into a single zone so that the external destination of the trip can be simulated. For the Kittitas County model, it was decided that the external zones would be placed at the following locations:

External Zone	Location
1000	I-90 West
1001	SR 97 North
1002	I-90 East
1003	I-82 South
1004	SR-821 South

Data Collection and Coding

After the model area has been identified, the collection and entry of the necessary data to run the modeling program begins. There are two primary components to be entered: network and travel characteristics. The network data includes: roadway (link), intersection (node), turn movement penalty, link delay functions, and node delay functions. Roadway or link data includes traffic count data for links and turning movements at key intersections. Travel characteristic data includes the land use inventory, trip generation rates, external volume data (volumes entering, exiting, and traveling through the model area), and trip length frequency distributions. PTV America conducted a field review of major facilities within the county including some locations with Kittitas County staff.

Upon completion of data collection, development of the model's mathematical "rules" began by coding the information and readying it for entry into VISUM. Essentially all entered data is numeric. Each entry, such as speed limits for links, capacities for nodes, and collected land use data, is used by the model to estimate network or street volumes. The VISUM software contains many equations and algorithms that help the traffic volume computation process. Therefore, given the amount of data in the transportation planning model, it is advisable to group like data together and assign uniform values. For example, link and node capacities are assumed to be uniform for links and nodes of similar classifications and types throughout the model area. In actual practice, these capacities are unique to the location and road conditions. The method for developing these "blanket" values is considered part of the model's rule-building process.

Calibration

After all data has been collected, coded, and entered in the VISUM program, the calibration process begins. In this task, the data and the model rules are refined so that the model closely simulates existing travel patterns and volumes on the roadway network. Calibration is performed by conducting a series of simulation runs and evaluating the results. The calibration is considered complete when the results of the simulation runs are statistically similar to the traffic count volumes and other measures of travel behavior.

Distribution and *assignment* are the two steps undertaken during a typical model simulation run. *Distribution* is the process of allocating trips between various zones within the network. The product of the distribution is a trip table that lists the number of trips between the model's zones. The distribution for this model was computed with the VISUM/TMODEL form of the gravity model.

Application of the gravity model in transportation modeling is derived from earlier work with economic interaction through a study of social physics. The idea, simply put, is that more interactions (between different zones) take place when the cost of interacting is less. As with the physics of gravitation between masses, it has been found that many human interactions can be related to the distance or cost between interactors using a negative exponential function.

In the Assignment portion of the simulation run, the distributed trips on the trip table are assigned to possible paths between each zone. The assignment uses an algorithm known as "equilibrium" assignment. This algorithm assigns traffic to each path between each zone such that the travel time for each path between each path is statistically equal.

Each model run consists of multiple feedback loops from trip assignment to trip distribution. The skim matrix of travel time between zones is fed back after each assignment into the trip distribution. The skim matrix is then averaged (weighted more heavily towards the current iteration) between the previous iterations' skim matrix with this iteration's skim matrix This method of skim matrix averaging and feedback loops produces more stable results and more accurately represents the impact on travel distributions from travel times. This allows the distribution to change as travel times increase or change between zones. Trips will distribute to other zones which are easier to reach or not as congested as reflected in the skim matrix.

This model also used Multi-Point Assignment (MPA). Traditionally all trips begin or end at the zone centroid, a point in the center of the zone. In reality, trips begin at driveways, parking lots, and other places in the zone. MPA allows the modeler to define the access points for each zone. These were assigned equally for each connector, except in cases where the access would be different. For speed of the model run, the MPA function is turned off during the iterative distribution and assignment portion, and then once the final trip matrices are established, MPA is turned back on for a highly refined assignment.

The series of calibration simulation runs involves review of the assumptions used to construct the model. In the distribution portion of the simulation, the exponents to the distance function of the gravity model are examined. During the assignment portion of the simulation, the assumptions for link speeds, capacities, and delay parameters are studied. Between each run, different parameters are evaluated and necessary adjustments made to the "rules" so that the desired results (i.e., calibration) are reached.

Before any adjustments to the Kittitas County model parameters were made, they were justified either through the collected travel pattern data or the judgment of PTV America and their experience with transportation planning models and travel conditions throughout the model area.

Model Forecasts

The fourth and final step to modeling is future scenario travel forecasting. With a working calibrated transportation planning model, different land use and/or roadway projections can be entered to produce forecast results on the roadway network. Before the actual forecast can begin, this question must be raised: Are the rules established in calibration still applicable to future scenarios?

Only professional judgment can answer this question. Most rules that are questioned will involve the roadway characteristic assumptions (speed, capacity, number of lanes, etc.) and should not require any model re-calibration. To complete the forecasts, the appropriate link, node, land use and/or through trip table file is changed by entering the future scenario data.

After the forecast evaluation is complete, it is possible to make recommendations for the study area and test each recommendation to analyze its effectiveness on the roadway network. VISUM can compute link volume changes due to modifications in capacity, land uses, roadways, etc. These types of VISUM tools are a valuable resource for decision makers and transportation professionals in determining the most effective solutions for mitigating existing and potential roadway congestion. For this study, different sets of proposed improvement projects were coded into the model and tested. Each of these scenarios was evaluated with Kittitas County Staff. Furthermore, Kittitas County Staff was trained in use of the model so future alternatives can be rapidly evaluated.

Background Data and Modeling Assumptions

The primary goal of this transportation planning model is to simulate the PM peak hour of travel on the roadway network in Kittitas County. In order for this simulation to be effective, it is important to obtain all transportation related data for that peak hour (a "snapshot" of time). It was also decided that the traffic model would replicate a 2008 weekday evening (PM) peak-hour.

The following section describes the various data used to develop the model. It is subdivided into two sections corresponding to the two primary components of a transportation planning model:

- network characteristics
- travel characteristics data.

NETWORK CHARACTERISTICS DATA

After establishing the model area, the existing model was reviewed and updated. All roadways classified as collector or greater throughout Kittitas County were included. As noted previously, the network was reviewed by Kittitas County Staff and some additional network facilities were added. Data is encoded to describe both the links and the nodes. A link is a vector that describes connectivity between two nodes. A node is an end point of a link. Typically, a node can be an intersection or an intermediate point between intersections.

This model was developed using the geographically accurate NAVTEQ data set. Much of the data was already coded. This data was refined during the model development process.

Roadway (Link Data)
After establishing the model area, the existing model was reviewed and updated. In expanding the model, all roadways classified as local street or greater throughout the study area were included.
Data attributes entered for the link layer in VISUM:

- Link Type
- TSys (Transport System)
- One- or Two-way Direction
- Number of Lanes
- Capacity
- Length
- Design Speed (or posted speed limit)
- TWLTL (Two-Way Left Turn Lanes)

Link Type
Link Type is used to describe the functional classification of the network links for the Kittitas County model. The Type numbering corresponds to the FHWA roadway classification numbering system. Link Delay functions are coded to operate with these link types. It is important to code future network revisions with the correct link classifications. Link types in the model are shown described in Table 1 and shown in Figure 3.

Please note that there is no link type for centroid connector as VISUM has a special layer for centroid connectors and thus they are not coded as links. Link type 99 was used to denote the John Wayne Trail. Other links are in the model for future use but if they are not given a Type number they have not been "activated" for use in the model.

Table 1
Link Type Class
2008 Kittitas County Transportation Planning Model

Type Number	Facility Type
1	Interstate Principal Arterial (Rural Freeway)
2	Principal Arterial (Rural)
3	Freeway Ramps
6	Minor Arterial (Rural)
7	Major Collector (Rural)
8	Minor Collector (Rural)
9	Local (Rural)
11	Interstate Principal Arterial (Urban Freeway)
12	Expressway Principal Arterial (Urban)
14	Principal Arterial (Urban)
16	Minor Arterial (Urban)
17	Collector (Urban)
19	Local (Urban)
99	Trail

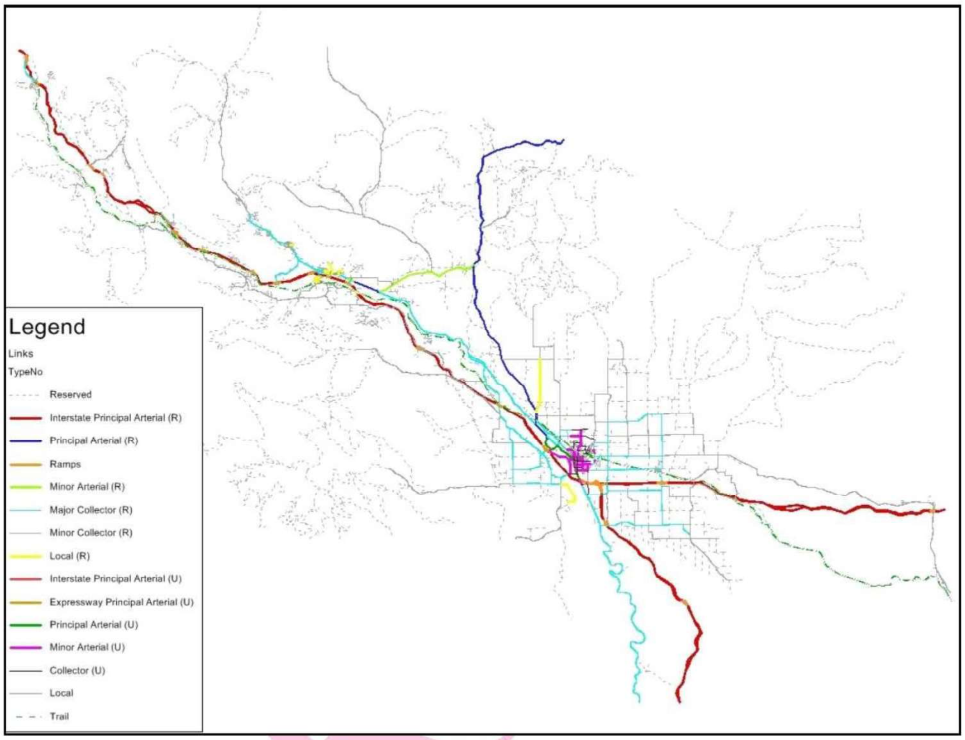


Figure 3
Kittitas County Link Types

TSys

VISUM permits the specification of Transportation Systems or TSys for short. Because the network was constructed from the NAVTEQ data, only the model links (those classifications specified with a Type 1-19 were given the ability to carry Cars and Trucks. All of these links permitted both Cars and Trucks. However, trucks were assumed to be equal to four (4) passenger car units (PCU) for capacity and delay computations. This higher value was used to reflect the situations where trucks are operating on steep grades or, when in urban areas, have a lot of starts and stops, making the impact of a truck greater. Therefore, truck assignments were kept separate from the car assignments. It is important during the testing of scenarios that the proper TSys is activated for new links as well as for turns.

Although transit was not explicitly analyzed as a part of this study, a TSys for Bus was also created for future use.

One- or Two-way Direction

All links were checked for one- or two-way entry. Interstate 90 and Interstate 82 were coded as pairs of one-way links in VISUM. Typically, freeways segments in modeling are split into a pair of one-way links so that the difference in capacities and directional splits can be modeled appropriately. On and off ramps for these facilities were also coded as one-way links.

A one-way link is entered in VISUM by permitting only the car and truck transportation systems (TSys-Car and TSys-Truck) to move in one direction and not the other.

Number of Lanes

This attribute is used in the VISUM model run to assign capacities to network links. It is also used for display and for entering intersection geometry in VISUM. All model links were checked for accuracy with this designation. Number of lanes per direction is shown as Figure 4.

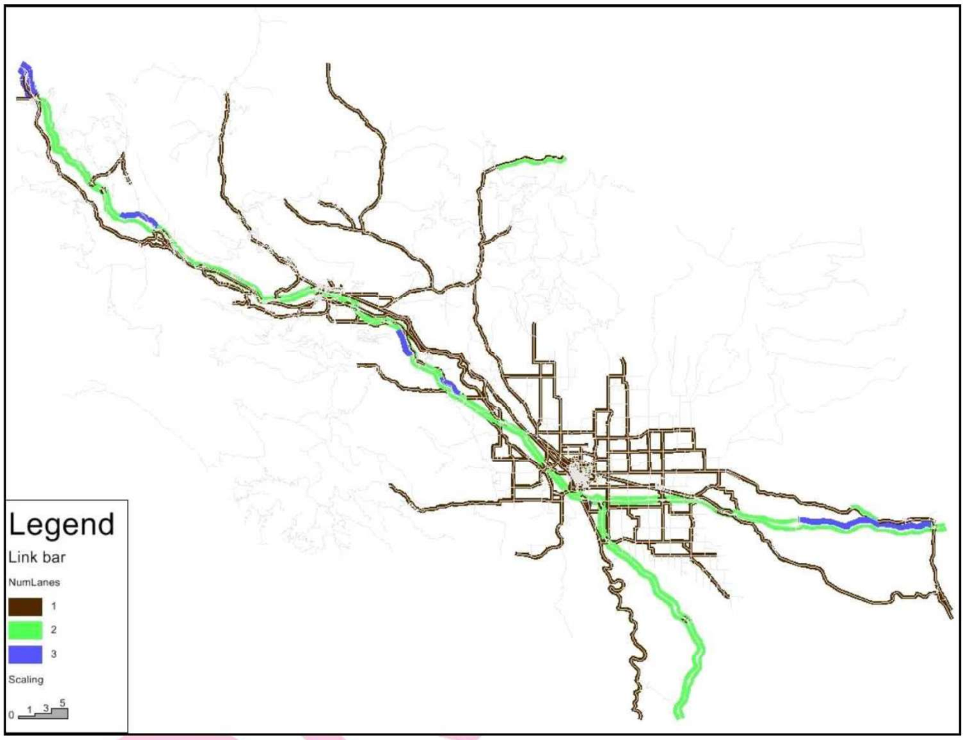


Figure 4
Kittitas County Number of Lanes

Capacity
Capacity is entered in terms of vehicles per hour per lane (vphpl) for each link, directionally. For the Kittitas County model, capacities were based upon Special Report 209 "Highway Capacity Manual", Transportation Research Board, National Research Council, Washington, D.C. 1985, updated 1994, and PTV America experience with other models.

The capacities are used for both model operation and network analysis. In the context of model operation, the capacities are used in conjunction with link speeds, link lengths, and speed-delay functions to derive a realistic travel speed to be used in the distribution of travel and the derivation of appropriate travel routes. In the context of network analysis, the capacities are used to identify deficiencies and recommend improvements. In both cases, it is desired that the capacities used in the model be as accurate and realistic as possible. These capacities were modified slightly during model calibration to better match local conditions. These were further revised during the 2009 update based upon the new traffic count and land use data, including adding 200 vehicles per hour per direction for links with Two-Way Left Turn Lanes. Table 2 represents the capacities used for the model.

Table 2
Link (Roadway) Type/Capacities
2005 Kittitas County Model

Link Type	Facility Type	Capacity (vphpl)
1	Interstate Principal Arterial (Rural Freeway)	2000
2	Principal Arterial (Rural)	1200
3	Freeway Ramps	1200
6	Minor Arterial (Rural)	1200
7	Major Collector (Rural)	1000
8	Minor Collector (Rural)	800
9	Local (Rural)	600
11	Interstate Principal Arterial (Rural Freeway)	2000
12	Expressway Principal Arterial (Urban)	1600
14	Principal Arterial (Urban)	1400
16	Minor Arterial (Urban)	1200
17	Collector (Urban)	800
19	Local (Urban)	600
99	Trail	NA

Length

In VISUM, all lengths are automatically calculated. The program will calculate lengths for each link during data entry and any subsequent future modifications. After the link lengths were calculated for the Kittitas County model, link lengths were checked to confirm that the function was working properly. Typically in a model for a county that has relatively long travel times on the externals the external link lengths are adjusted. For this model, the additional travel times in and out of the model area were coded into the centroid connectors. The model scale is set in the Network Parameters section. This assures that whenever a link is added, re-shaped, or a node is moved, the link length will be recalculated using this scale.

Design Speed

Link speeds are entered in VISUM in miles per hour. Speeds have a direct influence on the computation of travel times during simulation runs. Generally, posted speed limits are entered into the program during the initial data entry phase. However, posted limits do not always accurately depict the free-flow conditions on the roadway. For example, some state highways have 65 mph speed limits in urban areas that are often ignored. Conversely, some locations may have posted limits greater than what can be achieved (e.g., arterials in fully developed areas with numerous driveways and signalized intersections).

Speeds were entered from the NAVTEQ data and then updated with data from the previous models, the data collected during other portions of this study, and during the field review.

TWLTL

Links are coded with locations with Two-Way Left Turn Lanes (TWLTL). This adds 200 vehicles per hour to the capacity. This should be coded for both directions of a link.

Link Delay Coefficients

Travel time on each individual link typically increases as the traffic volume on the link approaches capacity. Current research has shown that the amount of travel time increase depends on the functional classification of the link as well as the region and the behavior of the drivers using that link. VISUM offers the ability to adjust the travel time increases on the link as the volume-to-capacity (V/C) ratio changes by functional classification of the link. This feature was used during the calibration process.

During calibration analysis, both link operating speeds and total (including both link and node delays) operating speeds can be analyzed. This differential analysis is used to adjust both the link and node delay coefficients. The final values used in the model calibration are shown in Table 3. These values are similar to others used in central Washington and are based upon experience with travel behavior in this area. The form of the equation is shown as:

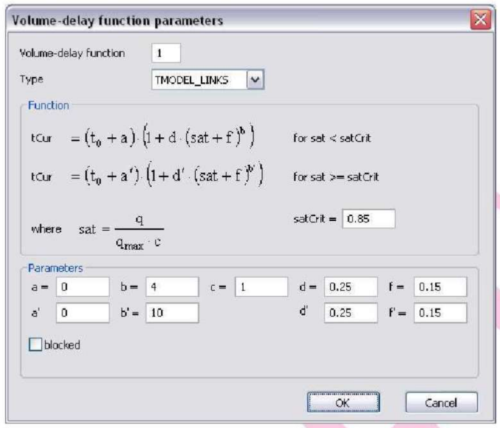


Table 3
Link Delay Coefficients
2008 Kittitas County Transportation Planning Model

Link Type	V/C < SatCrit			SatCrit	V/C => SatCrit		
	d	b	f		d′	b′	f′
1	0.25	4.0	0.05	0.95	0.25	10.0	0.05
2	0.25	4.0	0.15	0.85	0.25	10.0	0.15
3	0.25	4.0	0.15	0.85	0.25	10.0	0.15
6	0.25	4.0	0.25	0.75	0.25	10.0	0.25
7	0.25	4.0	0.25	0.75	0.25	10.0	0.25
8	0.25	4.0	0.25	0.75	0.25	10.0	0.25
9	0.25	4.0	0.25	0.75	0.25	10.0	0.25
11	0.25	4.0	0.15	0.85	0.25	10.0	0.15
12	0.25	4.0	0.15	0.85	0.25	10.0	0.15
14	0.25	4.0	0.25	0.75	0.25	10.0	0.25
16	0.25	4.0	0.25	0.75	0.25	10.0	0.25
17	0.25	4.0	0.25	0.75	0.25	10.0	0.25
19	0.25	4.0	0.25	0.75	0.25	10.0	0.25

INTERSECTION NODE DATA

Data entered for each node include the following:

- Type
- Node Capacity Factors
- Capacity
- TMODEL Special Delay Links (SDLs)
- Base Delay
- Turns

Node Type
The node classifications were coded in the model dependent upon the intersection control. Table 4 lists the node types. These were modified from the previous model structure to represent current practice.

Table 4
Node (Intersection) Type
2008 Kittitas County Transportation Planning Model

Node Type	Description
1	Not an Intersection
4	Freeway Ramp Terminal – Merges
5	Freeway Ramp Terminal – Diverges
10	All-way Stop
11	Partial Stop
20	Signal
21	Signal not at network intersection
30	Roundabout

Node Capacity
Using Capacities at all nodes is one of VISUM's three options to model delays based upon traffic congestion at the intersections. This feature has been incorporated into the Kittitas County model so that delays at these critical points on the network can be

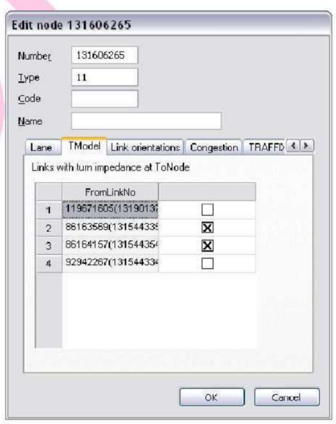
modeled to reflect the impacts upon traffic flow patterns. For the 2008 Kittitas County model, VISUM calculates node capacities using the following node equation:

Node Capacity = K1 + K4 * (Entering Link Capacity)

Node capacities for the Kittitas County model use the K1 and K4 constants. K4 was used to simulate the effect that a green time-to-cycle length (G/C) ratio has at an intersection. For modeling purposes, it was assumed that when similar link types classes meet, the G/C ratio is fairly even, and as the roadway meets lesser class roadways, the green time, or G/C ratio increases on the major facility. This effect is reflected in the increasing values of the K4 constant as the difference in entering link types or classifications is more disparate. When there are less than three (3) intersection legs, the K4 constant is increased by .05 to reflect the impact of a smaller number of conflicts. When there are five (5) or more intersection legs, the K4 constant is decreased by .05 to reflect the impact of more conflicts, which take green time, at the intersection. For shape nodes of Type 1 and Ramp Diverge nodes of Type 5 a K4 value of 1.0 should be used.

Special Delay Links (SDLs)

Another special feature in VISUM (and previously in TMODEL) is the ability to model intersections under STOP or YIELD control. SDLs at a node denote which link(s) are under two- or three-way STOP or YIELD control. If an intersection is a four-way STOP, then no SDLs are entered. SDLs are coded using the node dialog box with the TModel tab.



SDLs work in the VISUM model run. As traffic is loaded onto the network, the program calculates Volume-to-Capacity (V/C) ratios at each node. Intersection delay is calculated using the V/C ratio (more on how the program calculates the delay is presented in later sections of this report). If SDLs are specified at the nodes, then any delay calculated during the simulation run is assigned to the special delay link(s) approaching the node to simulate a STOP or YIELD condition. Under a four-way STOP condition, delay is experienced on all four legs and no SDLs are entered for this condition.

All nodes were checked to insure that SDLs were coded where appropriate for partial way stop controlled intersections.

Base Delay

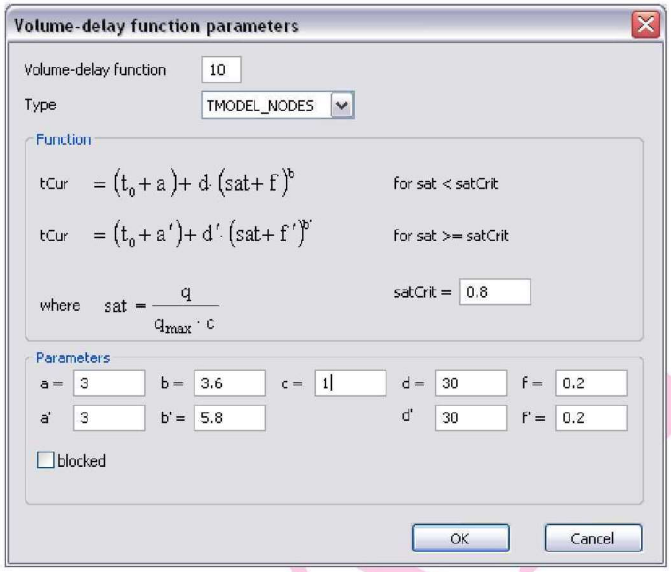
Additional delay, called t0 in VISUM, can be added to an intersection if a known condition exists. These conditions could include an all red condition at a signal, pedestrian phases, or a node representing a railroad crossing. No additional base delays have been used in the Kittitas County model.

Turn Penalty

At some locations on a network it may not be possible to execute a certain turn movement or there can be a capacity constraint due to the drivers' perception of restricted sight distance or other potential safety concerns. If a movement is not allowed, then the transportation system car is removed from the turning movement layer in VISUM. Turns were restricted as necessary. At left turns at stop and signal controlled nodes, a base delay, or t0, of 6 seconds was added. These same left turns were given a capacity of 250 vehicles per hour so the turn delay would increase as the volume of the left turn increased.

Node Delay Coefficients

The delay caused by different types of intersection control must be defined to reproduce the delays that drivers perceive. The resultant extra travel time is dependent upon the volume-to-capacity ratio (V/C) and varies by Type of the nodes. These use the TMODEL_Nodes equation as shown in this dialog box:



The final values used are shown in Table 5.

Table 5
Node Delay Coefficients
Kittitas County 2008 Transportation Planning Model

Node Types	V/C < SatCrit				SatCrit	V/C => SatCrit			
	D	b	f	a		d′	b′	f′	a′
1, 5	0	0.01	0	0	0	0	0	0	0
4	30	3.80	0.15	0	0.85	30	5.80	0.15	0
10	30	3.60	0.20	3	0.80	30	5.80	0.20	3
11	30	3.60	0.20	3	0.80	30	6.00	0.20	6
20, 21	30	3.60	0.20	1.2	0.80	30	5.00	0.20	1.2

LAND USE AND TRAVEL CHARACTERISTICS

The central point of each traffic analysis zone (TAZ), where trips begin and end on a transportation planning model network, is called a zone centroid. Zone centroids are at the center of a zone which consists of a variety of land uses bounded by either the roadway network or other geographic or municipal boundaries. The TAZ system was established from a TAZ system originally developed by Kittitas County staff. This TAZ system was revised slightly to disaggregate into smaller zones in the Suncadia and CleElum UGA area. A graphic of the TAZ boundaries is shown as Figure 1.

The Kittitas County model consists of two zone types: internal and external. Internal zones were those zones within the model area. Internal zones have associated land use data that is used to generate origins and destinations. External zones were placed along roadways entering and leaving the Kittitas County model area. Land use is not associated with external zones; rather the traffic volumes coming in and out of the area are used to describe the origins and destinations for these zones.

During this model update, a number of zones were disaggregated to allow a finer granularity of traffic assignment. The majority of the disaggregated zones were in the areas surrounding Cle Elum. As a part of this zone reorganization, the zone numbering scheme was modified throughout the network to a more intuitive numbering scheme. In general, the zone numbers in each area increase from west to east and from north to south. A record of the old zone numbers can be found within a user-defined attribute of each zone called "OLDZONENO". The new numbering scheme is as follows:

Zones	Area
1 to 71	Internal Zones - representing the Ellensburg Area.
100 to 179	Internal Zones - representing the Cle Elum-Roslyn Area.
200 to 272	Internal Zones - representing the Upper Kittitas County Area excluding zones from the Cle Elum-Roslyn Area.
300 to 313	Internal Zones - representing the Lower Kittitas County Area excluding zones from the Ellensburg Area.
400 to 461	Internal Zones – representing the Range Area of Kittitas County.
1000 to 1004	External Zones - representing the entry/exit points from the model area.

Data for each land use variable, such as numbers of dwelling units, employees, etc. is required for each TAZ. This data is required for the base year calibration as well as for each forecast scenario. When this was not available, various procedures were used to derive this data.

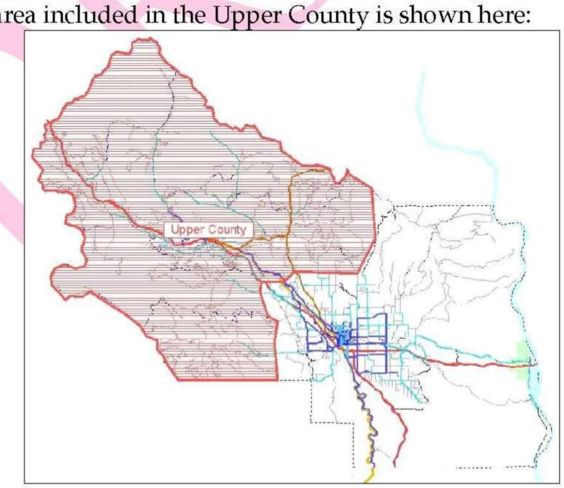
Summary of the Procedures for Compiling Kittitas County Land Use

The Kittitas County land use data was updated using data from multiple sources for both the base year and the forecast scenarios. The transportation model requires not only numbers of dwelling units but also levels of employment, as measured by floor area, by type of employment and can also include other types of land use not specifically related to dwelling units or employment.

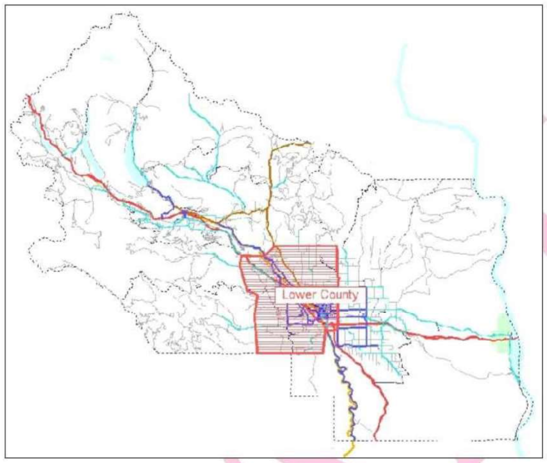
Internal Zone Data

The residential land use was further divided into residential categories for Upper County, Lower County, and Range to allow for more accurate trip generation. Much of the residential in the Upper County is vacation or recreational property and hence has a lower average trip generation rate. The Agriculture/Forestry/Mining classification was also divided to differentiate by trip generation as well. Typically irrigated agriculture has higher trip generation than range land.

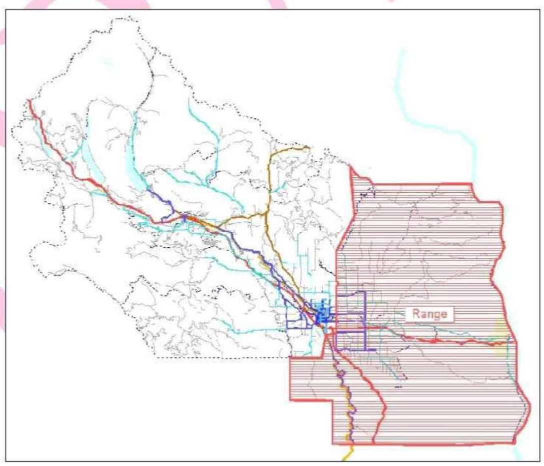
The Upper County area is typically the part of Kittitas County that is West and North of Ellensburg. The area included in the Upper County is shown here:



The Lower County includes the area around Ellensburg. This area is shown as:



The Range area of the county is shown as:



Land Use Detail

For Kittitas County, PTV America analyzed the area with using a variety of sources of information to create a credible database of land use information. This involved using the Kittitas County GIS coverage, inventorying occupancy by land use type, and computing expected numbers of dwelling units, employees, and students. These were compared with previous data and computations.

All land use data was summarized into the following:

LU1 **Single Family Residential** includes those lands occupied by either a single family home, a manufactured home, or a duplex on a single lot. Measured in dwelling units.

LU2 **Multi-Family Residential** uses three or more or more residential units on a parcel of land. Also, this category includes mobile home parks, apartment buildings, and condominiums. Measured in dwelling units.

LU3 **Hotel** includes motel rooms, hotels, and camp areas. Measured in number of rooms or designated camp areas.

LU4 **Retail Trade** includes a variety of uses identified by Kittitas County staff. Retail uses include a broad range of establishments which sell goods directly to the general public, such as restaurants, automotive dealers, home furnishings, food stores or other products. Measured in thousand square feet.

LU5 **Industrial and Manufacturing** includes a variety of uses identified by Kittitas County staff, within a broad range of general or specialty contractors: the production of food, textile, wood, furniture, paper, printing, metal, machinery, electrical and other products; and also includes Transportation, Communication and Public Utilities, such as railroads, trucking and warehouse, air transportation, pipelines, communication towers and electrical, gas and sanitary services. Measured in thousand square feet.

LU6 **Office** are those land uses which are owned, or operated by units of government and provide the administration of public programs, which are identified by Kittitas County staff. Also included are offices with minimal customer traffic. This includes the state patrol. Measured in thousand square feet.

LU7 **FIRES (Finance Insurance Real Estate and Services)** includes a variety of uses identified by Kittitas County staff. Services and offices include banks or other financial institutions, real estate and insurance offices, personal services, such as laundry or cleaning services, business services such as advertising, automotive repairs, amusements, churches, health care, medical, legal services and other assorted services. Measured in thousand square feet.

LU8 **Elementary and Middle Schools** were updated using information obtained from the Washington State Office of the Superintendent of Instruction (OSPI). The website of OSPI listed the number of students that attend each public school during the 2007-2008 school year. Measured in numbers of students.

LU9 **High Schools** were updated using information obtained from the Washington State Office of the Superintendent of Instruction (OSPI). The website of OSPI listed the number of students that attend each public school during the 2007-2008 school year. Measured in numbers of students.

LU10 **College** and University are measured in number of full time equivalent students using data obtained from Central Washington University's website on enrollment during the 2007-2008 school year.

LU11 **Agriculture/Forestry/Mining** generally relate to agricultural production and services without irrigation. Measured in acres.

LU12 **Agriculture-Upper County** is a subdivision of LU11 for those uses in the Upper County area. Typically these include forestry and mining with some limited agriculture. Measured in acres.

LU13 **Agriculture-Lower County** is a subdivision of LU11 for those uses in the Lower County area. Typically these include irrigated agriculture. Measured in acres.

LU14 **Agriculture-Range** is a subdivision of LU11 for those uses in the Range area. Typically these include range and dry agriculture. Measured in acres.

LU15 **Single Family Residential-Upper County** is a subdivision of LU1 for just the zones included in the Upper County area. Measured in dwelling units.

LU16 **Multi-Family Residential-Upper County** is a subdivision of LU2 for just the zones included in the Upper County area. Measured in dwelling units.

LU17 **Single Family Residential-Lower County** is a subdivision of LU1 for just the zones included in the Lower County area. Measured in dwelling units.

LU18 **Multi-Family Residential-Lower County** is a subdivision of LU2 for just the zones included in the Lower County area. Measured in dwelling units.

LU19 **Single Family Residential-Range** is a subdivision of LU1 for just the zones included in the Range area. Measured in dwelling units.

LU20 **Multi-Family Residential-Range** is a subdivision of LU2 for just the zones included in the Range area. Measured in dwelling units.

LU21 **Parks** are those land uses which are open space used for recreation. Measured in acres.

LU22 **Recreation** are those land uses for recreation. Measured in thousand square feet.

LU23 **Medical** are those land uses which are used for hospitals, clinics, or for medical offices. Measured in thousand square feet.

LU24 Wholesale are those land uses which are for wholesale sale or storage. Measured in thousand square feet.

Trip Generation
After the collected land use data was distributed to the model zone system, the number of trips generated by each zone was calculated. This procedure, called trip generation, is a compilation of several mathematical formulas that determine the number of trips produced and attracted to each model zone.

Many transportation engineering projects use the Institute of Transportation Engineer's (ITE) *Trip Generation* report to determine trip generation for proposed projects. Research by ITE has established a series of trip generation rates that, when multiplied by amount of proposed development (e.g., number of dwelling units, employees of commercial or industrial, etc.), produce an estimate of the total number of vehicle trips entering or exiting the development.

While the above application is suitable for many traffic engineering projects, modeling uses a more disaggregate trip generation approach. When a trip distribution model (such as the one used in VISUM) is applied to origins and destinations, different trip *purposes* exhibit different travel *characteristics*. For example, the characteristics of a home-to-work trip are different from a home-to-shopping trip. If trip generation estimates were made simply following just the ITE rates, no distinction could be made. Therefore, it is important that the model generate different trip productions (origins) and attractions (destinations) for different trip purposes so that different travel characteristics can be accounted for in the gravity model.

In its NCHRP reports 187 and 365, the Transportation Research Board (TRB) describes a methodology for trip generation that includes the following trip purposes:

- Home-Based Work (HBW) trips,
- Home-Based Other (HBO) trips, and
- Non-Home-Based (NHB) trips.

These three trip purposes are typically used with most daily transportation models. Because of the spatial structure of the Kittitas County model, it was decided to disaggregate the trip purposes. The Home-Based Work trips were divided into trips between Home-to-Work and Work-to-Home. The Home-Based-Other trips were divided into trips between Home-to-Other and Other-to-Home. By splitting the HBW and HBO trip purposes into their components; this eliminated the possibility of a problem of excessive trips between households. In addition, a Truck trip purpose was added to allow for the explicit generation and tracking of truck trips. Therefore six trip types were used:

- Home to Work (HW) trips,
- Work to Home (WH) trips,
- Home to Other (HO) trips,
- Other to Home (OH) trips, and
- Non-Home-Based (NHB) trips
- Truck trips

PTV America developed the following trip generation factors for use in the model. The base trip generation rates were taken from ITE's *Trip Generation Report*. Factors used to separate the trips into the six purposes and origins-destinations were from NCHRP reports 187 and 365 and experience by PTV America with other studies. The trip generation process used percentage control totals that correspond to data in NCHRP 365 for similar sized areas.

Trip generation rates are set at values during the beginning calibration simulations. As the calibration process is conducted, adjustments are made to the rates to better reflect the known (or base-year) travel conditions. Generated trips are compared with traffic count volumes and modified to match these volumes as closely as possible. During the process the residential and agricultural land uses were disaggregated for better definition of actual trip making characteristics. The total trips generated were adjusted for the three main county areas based upon regression analysis and observation of the behavior of the model with these adjustments. The allocations of the SFDU, MFDU, and AGFM units to the territories

During the update of the model, the trip rates were refined for use in Kittitas County. This involved making incremental changes and comparing the results with the traffic counts in the areas throughout Kittitas County. Trip rates were revised as necessary to achieve improvement of the modeled volumes within Kittitas County. Table 6 presents the final trip generation rates used for the weekday evening peak hour model. Note that land uses one and two are not listed. These are disaggregated into categories 15 - 20. Please note that there are also rates for the "externals" which generate the trips coming in and out of the external locations.

Table 6

Peak Hour Trip Rates for the Kittitas County Transportation Planning Model

			HW		WH		HO		OH		NHB		Truck		Total		
	Land Uses	Units	Orig	Dest	Orig	Dest	Orig	Dest	Orig	Dest	Orig	Dest	Orig	Dest	Orig	Dest	Total
3	Hotel/Motel	Rms	0.011	0.013	0.011	0.013	0.022	0.025	0.022	0.025	0.145	0.170	0.006	0.008	0.216	0.254	0.470
4	Retail	KSF.	0.000	0.037	0.475	0.000	0.000	1.104	1.080	0.000	0.518	0.626	0.086	0.074	2.160	1.840	4.000
5	Ind/Man	KSF.	0.000	0.029	0.209	0.000	0.000	0.043	0.070	0.000	0.093	0.086	0.093	0.128	0.465	0.285	0.750
6	Service/Office	KSF.	0.000	0.051	1.232	0.000	0.000	0.506	1.177	0.000	0.246	0.405	0.082	0.051	2.738	1.013	3.750
7	FIRES	KSF.	0.000	0.050	0.905	0.000	0.000	0.495	0.804	0.000	0.241	0.396	0.060	0.050	2.010	0.990	3.000
8	El/MidSchool	Stud.	0.000	0.003	0.034	0.000	0.000	0.022	0.043	0.000	0.016	0.036	0.003	0.003	0.096	0.064	0.160
9	High School	Stud.	0.000	0.002	0.032	0.000	0.000	0.021	0.041	0.000	0.015	0.034	0.003	0.003	0.090	0.060	0.150
10	College	Stud.	0.000	0.003	0.051	0.000	0.000	0.022	0.066	0.000	0.025	0.035	0.004	0.003	0.147	0.063	0.210
11	Ag/For/Min	Acres	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	Ag-Range	Acres	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
13	Ag-Lower	Acres	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.002	0.001	0.003
14	Ag-Upper	Acres	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
15	SF-Upper	DU	0.010	0.000	0.000	0.163	0.159	0.000	0.000	0.206	0.057	0.051	0.005	0.009	0.231	0.429	0.660
16	MF-Upper	DU	0.005	0.000	0.000	0.089	0.080	0.000	0.000	0.116	0.031	0.031	0.002	0.005	0.119	0.241	0.360
17	SF-Lower	DU	0.016	0.000	0.000	0.233	0.238	0.000	0.000	0.295	0.085	0.074	0.007	0.012	0.346	0.614	0.960
18	MF-Lower	DU	0.009	0.000	0.000	0.144	0.128	0.000	0.000	0.187	0.051	0.051	0.004	0.008	0.191	0.389	0.580
19	SF-Range	DU	0.012	0.000	0.000	0.185	0.181	0.000	0.000	0.234	0.064	0.059	0.005	0.010	0.263	0.488	0.750
20	MF-Range	DU	0.007	0.000	0.000	0.112	0.099	0.000	0.000	0.145	0.039	0.039	0.003	0.006	0.149	0.302	0.450
21	Parks	Acres	0.000	0.001	0.002	0.000	0.000	0.004	0.003	0.000	0.006	0.004	0.000	0.000	0.011	0.009	0.020
22	Recreation	KSF	0.000	0.095	0.401	0.000	0.000	0.788	0.501	0.000	1.042	0.646	0.060	0.047	2.005	1.575	3.580
23	Government	KSF	0.000	0.020	0.392	0.000	0.000	0.102	0.218	0.000	0.235	0.207	0.026	0.010	0.871	0.339	1.210
24	Medical	KSF	0.000	0.046	0.205	0.000	0.000	0.228	0.171	0.000	0.287	0.169	0.021	0.014	0.684	0.456	1.140
25	Wholesale	KSF	0.000	0.010	0.120	0.000	0.000	0.050	0.051	0.000	0.103	0.057	0.068	0.050	0.342	0.168	0.510
26	External-Internal	Trips	0.050	0.000	0.260	0.000	0.150	0.000	0.210	0.000	0.230	0.000	0.100	0.000	1.000	0.000	1.000
27	Internal-External	Trips	0.000	0.050	0.000	0.220	0.000	0.260	0.000	0.200	0.000	0.170	0.000	0.100	0.000	1.000	1.000

In Table 7, a comparison is made between the generation rates used in the Kittitas County model and ITE *Trip Generation Report*.

Table 7
Trip Generation Rate Comparison
2008 Kittitas County Transportation Planning Model

Land Use		Rates used in the Model			ITE Rates		
		Orig	Dest	Total	Avg.	Low	High
3	Hotel/Motel	0.22	0.25	0.47	0.47	0.20	1.69
4	Retail	2.16	1.84	4.00	3.74	0.68	29.27
5	Ind/Man	0.47	0.29	0.75	0.75	0.09	7.85
6	Service/-Office	2.74	1.01	3.75	3.46	0.97	8.86
7	FIRES	2.01	0.99	3.00	2.85	2.82	2.86
8	Elem/Mid School	0.10	0.06	0.16	0.16	0.12	0.30
9	High School	0.09	0.06	0.15	0.15	0.03	0.38
10	College	0.15	0.06	0.21	0.21	0.20	0.43
11	Ag/For/Min	0.00	0.00	0.00	NA		
12	Ag-Range	0.00	0.00	0.00	NA		
13	Ag-Lower	0.00	0.00	0.00	NA		
14	Ag-Upper	0.00	0.00	0.00	NA		
15	SF-Upper	0.23	0.43	0.66	1.01	0.42	2.98
16	MF-Upper	0.12	0.24	0.36	0.62	0.10	1.64
17	SF-Lower	0.35	0.61	0.96	1.01	0.42	2.98
18	MF-Lower	0.19	0.39	0.58	0.62	0.10	1.64
19	SF-Range	0.26	0.49	0.75	1.01	0.42	2.98
20	MF-Range	0.15	0.30	0.45	0.62	0.10	1.64
21	Parks	0.01	0.01	0.02	0.02	0.01	0.03
22	Recreation	2.00	1.58	3.58	3.58	2.95	4.06
23	Government	0.87	0.34	1.21	1.21	1.17	1.22
24	Medical	0.68	0.46	1.14	1.14	0.70	6.94
25	Wholesale	0.34	0.17	0.51	0.51	0.50	0.55

Model rates are comparable but slightly different than ITE rates. Reasons for these differences can be occupancy or, conversely, vacancy, the aggregation of distinct land use types into more general categories, and local variations. Retail rates are based upon a medium size shopping center. Typically a smaller retail establishment will have a higher trip generation to employee ratio than a large shopping mall.

In addition, the ITE national average, or NCHRP 187 and 365 rates, assumes the same trip generation rates at each development. During the actual system peak hour, this is not necessarily the case. For example, one industrial development or office may dismiss their employees during the peak hour, while another, located elsewhere in the model area, will have a slightly earlier (or later) discharge time. Adjustments were made to the 2008 model to reduce trip generation in the residential areas that may have seasonally vacant vacation homes, homes away from the urban areas resulting in lower peak hour trip generation rates, and to increase the generation for retail, office, and service uses. Rates were adjusted slightly for balance between origins and destinations and to account for locations in the model where overall trip generation appeared too high or too low.

The factors were applied to the collected land use information and stored in the origin-destination files in VISUM. These files contain the origins and destination values for all trips generated by all land uses and external zones.

External Zones

Origin and destination totals for external zones were set at the base-year peak-hour traffic volumes. These were based upon data from the previous models and WSDOT data. As with internal zones, traffic generated externally is also apportioned among different trip purposes as show in Table 6. Trips generated by external zones fall into two categories. Traffic that travels from external zone to external zone, or through the network, is called a through trip. These movements are designated as X-X trips in VISUM, which stands for eXternal to eXternal travel. The primary characteristic of these trips is that they travel through the network but do not stop or start within an internal or perimeter zone. In the Kittitas County model the best illustration for this movement is the trip that starts in Seattle and ends in Moses Lake or Yakima without making a stop in the Kittitas County model area.

The second trip type generated by an external zone is the one that begins at an internal zone and ends in an external zone, or vice versa. These trips, often designated as I-X and X-I trips (for Internal to eXternal, eXternal to Internal) can be illustrated by the movement from Ellensburg to Yakima.

Trip distribution is typically only performed for I-I (Internal-Internal), I-X, and X-I trips. The remaining X-X trips are placed in a trip table. This trip table, listing the number of direct movements between zones, is a manual distribution of the X-X traffic based upon some known parameters. External-external traffic is difficult to simulate (or in this case, distribute) with the gravity model. Therefore, the modeling process with VISUM includes a step for "manually" distributing X-X traffic to the external stations.

For this model, the External-External traffic was derived from the previous modeling efforts and then tested in the model. These were revised in this process because several ramps with count data were too high in the model. It was determined that more through trips would reduce these to more reasonable values. The X-X trips were placed in two through trip table matrices, one for Cars and one for Trucks. The Truck matrix was derived using WSDOT ADC counter locations and an average of 25% trucks was used at all external locations except for SR 821 which assumed 10% trucks. The remaining trips associated with the external zone's I-X and X-I movements were added to the trip generation portion of the modeling stream and then combined with the model's origin-destination file for the model runs. The model stream run module used in VISUM automatically adds the manually distributed X-X trips to the trip table created from the origin-destination file during the gravity model distribution process.

Combine Productions and Attractions and Balance

Data from the external traffic zones were combined with the internal zone trips to form a complete origin-destination file for the Kittitas County model. After the I-X and X-I trips were added, origin and destination sums by trip purpose were automatically balanced to the average of the number of productions and attractions to be equal. The trip generation rates were previously checked with land use totals to insure that trips would be balanced. The primary purpose for checking equivalencies was to ensure that for each production or origin generated by the model there was an attraction or destination. (Transportation planning models are closed systems, meaning that every trip on the network must have an origin and a destination.) Care was taken to closely correlate to target percentages by trip purpose from NCHRP 365.

A trip generation rates strategy such as the one used to develop the Kittitas County model internal zone traffic does not always produce balanced origins and destinations. For example, trip generation assumes that every business within the same retail category has the same trip generating characteristic. Retail land uses include different types of development ranging from department stores to restaurants. Furthermore, had a single land use been assumed, such as grocery stores, the departure rates during the PM peak hour would vary from development to development. Therefore, with the methodology there can be some difficulty in producing equal numbers of origins and destinations in the transportation model.

A process must be followed before the first simulation run can be performed to balance the origins and destinations. Any balancing adjustments would be done to the total numbers of trips by trip purpose. First, the total differences by trip purpose were found. Then, the trip generation rates were reevaluated and appropriate changes were made to the trip rates. After this process was completed, the sums were checked for both internal and external zones, all trips were balanced by averaging the trips, and the total productions and attractions by demand strata were ready for initial VISUM distribution and assignment runs.

Calibration

Approach

Calibration is an iterative process and includes upgrading or adjusting entered data, program coefficients, or parameters and assumptions on successive simulation runs until the volumes and traffic patterns produced by the model approximate known volumes within an "acceptable level of error." The acceptable level of error for calibrated model data has been recommended in the National Cooperative Highway Research Program Report No. 255 entitled *Highway Traffic Data for Urbanized Area Project Planning and Design*. The primary premise behind these guidelines is that simulated model data should not significantly differ from actual count data thereby causing inappropriate under- or over-design of roadway facilities. Differences between modeled volumes and actual counts may look significant; however, in everyday practice, these differences should not cause unsuitable roadway facility planning.

There are three significant points to consider. The first is "acceptable level of error" and "How good are the counts?" Given that this is the basis for calibration, are these counts good enough for the process? If some count data is questionable, can the model be asked to simulate a condition better than the condition is known?

Considering these questions, it has been found through experience in modeling that an "acceptable level of error" is directly related to the existing traffic volumes on a certain link. Through the course of calibration, higher volume streets can be expected to have better results. Acceptable limits may be that a 20% error can be expected on heavily used arterials, 40% on primary collectors, and perhaps as high as 200% on little-used rural collectors. Although the latter level of error may seem high, a variation of 200% on little-used roadways may mean a difference of 25 to 100 vehicles, insufficient to cause inappropriate facility planning when the model results are used.

The second point to consider is the adjustment of entered data, program parameters, and model assumptions. After entering all the data and making the initial model assumptions, the simulation distribution and assignment run is made. The desired outcome is that the results will perfectly match all the counts and the model will be calibrated. Usually, though, some data or assumptions (the "rules" of the model) are incorrect. On locating the errors from the distribution and assignment, causes are identified. The rules are reconsidered and adjusted.

Each change in data, parameters, or assumptions represents a refinement or upgrade of the rules. Each refinement **must be backed** by a reason. No changes are made to simply get better volumes. To apply the model to alternate scenarios, especially future year forecasts, each justification must be questioned for its continued application. If the rule still holds for the scenario, then it can be applied. If the rule is not applicable, then adjustments must be made in rules for that scenario.

Finally, it must be emphasized that the simulation being run with the model is one of human interaction with the transportation system. To do this, the program uses the gravity model to simulate the distribution of trips between zones and selects "shortest paths" for the assignment of trips. Human behavior is equated to a series of mathematical formulas that assume that all humans behave logically. While people do not always behave in a logical and rational manner, under most situations these assumptions are valid. Keeping this in mind, the calibration process is carried out.

Model Calibration Process

Essentially, calibration is comprised of three stages. First, working from outside to inside and large to small, all volumes that lead to the outside world through external zones are calibrated. Analyzing the model for general trends of trips is the next step. The third step is to evaluate the individual count locations and individual routes. Changes at any level may affect operations at another stage in calibration. That is, a proper allocation of trips to the right route may affect the general trends. Therefore, the calibration process is one of always looking back and continually monitoring each step until the procedure is complete.

External Zones

In VISUM, zones are differentiated between "internal" and "external." Internal zones are those in which all the land use is known and all generated trips will go to and arrive from other zones in the modeled system. An external zone interacts with other zones in the modeled system and with the external world that surrounds the network. (Traffic count data, collected on the roadway leading in or out of an external zone, is used.) It is impossible to describe fully the land uses outside the modeled area that interact with the internal zones. Therefore, an external zone is described in the model as having origins and destinations to produce the appropriate volume of traffic on the roadways that connect it with the rest of the network.

VISUM automatically adjusts the distribution to match the I-X and X-I origins and destinations at the external zones. It also automatically distributes the proper number of destinations to each zone based upon the values derived during the trip generation process. However, the distribution of those trips within the model can be modified by changing the apparent distance traveled either approaching or departing the model area. These were adjusted to get an expected distribution from the externals.

From these results, analyses are performed and potential changes or upgrades to the entered data are made for the following simulation run. Overall high or low trends can suggest that information needs to be upgraded concerning dwelling units, employment, trip generation rates, and/or gravity model-spatial behavior coefficients. Throughout the calibration of overall trends, each segment of entered data is questioned and necessary changes are made. In addition, ground count data is also scrutinized.

Final Calibration Values

Changes were made to the parameters in an iterative fashion based upon judgment. The final values used in the calibration are the following:

- Car impedance is weighted 0.985 on time and 0.15 on distance.
- Truck impedance is weighted 0.980 on time and .020 on distance
- Iterative distribution and assignment with equilibrium assignment was used. The skim matrix (a measure of travel impedance) was averaged for each iteration for up to 3 iterations after the initial step. Specification of this option meant that the gravity model distributions are based upon recalculated travel impedances in subsequent assignments.
- Table 8 illustrates the gravity model exponents set at the following:

Table 8
Gravity Model Parameters
2008 Kittitas County Transportation Planning Model

Trip Purpose	Beta Exponent	Alpha Exponent	Constant
HW	2.00	-0.2	100
WH	2.00	-0.2	100
HO	2.70	-0.2	100
OH	2.70	-0.2	100
NHB	2.80	-0.1	100
Truck	2.2	-0.5	100

The volumes and volume/capacity ratios for links or streets were plotted for comparison with the future year alternatives. These colors range light green through dark green, orange, red, and dark red to show increasing amounts of congestion.

2008 Base Conditions

Finally, the "calibrated" model is verified against the base-year traffic counts. The verification process is a series of post-simulation run analyses that are designed to analyze the accuracy and degree of confidence presented in the calibrated results. Included in these analyses are verification of the trip distribution characteristics and comparisons of the traffic count data vs. modeled link volumes. These are typically analyzed with screenlines and scattergrams.

Screenlines

Nine (9) Screenlines were established showing major movements within the County. These were chosen at locations were counts were also available. The screenlines were summarized and analyzed for trends and acceptability. These are shown in Figure 5.

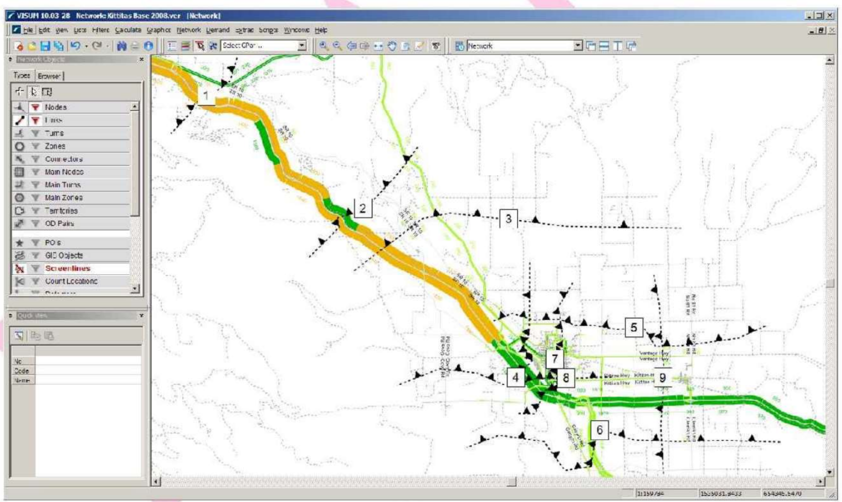


Figure 5
Kittitas County Screenline Locations

NCHRP 255 establishes standards for allowable deviation based upon traffic count volumes. Lower volume screenlines are allowed more deviation because of the increased amount of variation in count data and the lesser importance of lower volumes. The screenline results are summarized in Table 8. Locations with counts so low that they are less than the evaluation criteria are shown as "NA." All screenlines and the total of all screenlines are within acceptable standards. It should be noted that not all crossings of a screenline had count volumes. Therefore, there may be some variations that are not completely explained by this table. It is felt that all screenlines are within acceptable ranges.

Table 8					
Screenline Analysis					
No.	NAME	Tot Vol	Tot Count	% Deviation	% Allow
1	CleElum	128	76	68%	NA
2	West of Ellensburg	69	55	25%	NA
3	North of Ellensburg	116	84	38%	NA
4	West Ellensburg	3207	2388	34%	47%
5	North Ellensburg	474	442	7%	70%
6	South of Ellensburg	488	451	8%	69%
7	Central Ellensburg	5041	5522	-9%	33%
8	EW Central Ellensburg	3184	2841	12%	43%
9	East of Ellensburg	577	629	-8%	67%
	Total	13284	12488	6%	23%

Scattergram Analysis

Several analyses of scattergram plots showing the correlation between traffic count observations and model volumes were conducted. Figures 6 and 7 show comparisons for ALL traffic counts and counts on just Freeways, Ramps, and Principal and Minor Arterials, respectively. Typical standards are usually compared on roads classified as Principal Arterial and higher classifications. More deviation is expected when analyzing lower classification facilities such as collectors and local roads due to the variation in traffic count data and the lower volumes. Both figures show link ground counts on the X axis and assigned volumes on the Y axis. On the green 'goal' line the assignment volume is equal to the ground count. The red linear 'regression' line shows the best straight line estimate of the assignment volume for any count. The blue 'allowable' curves show the maximum allowable errors according to the graph discussed from NCHRP 255. In both graphs there is one significant outlier. This is the westbound I-90 on-ramp at Cascade/University Way. This is an older count and may not have an actual deviation of this magnitude. This comparison also affects screenline number 4.

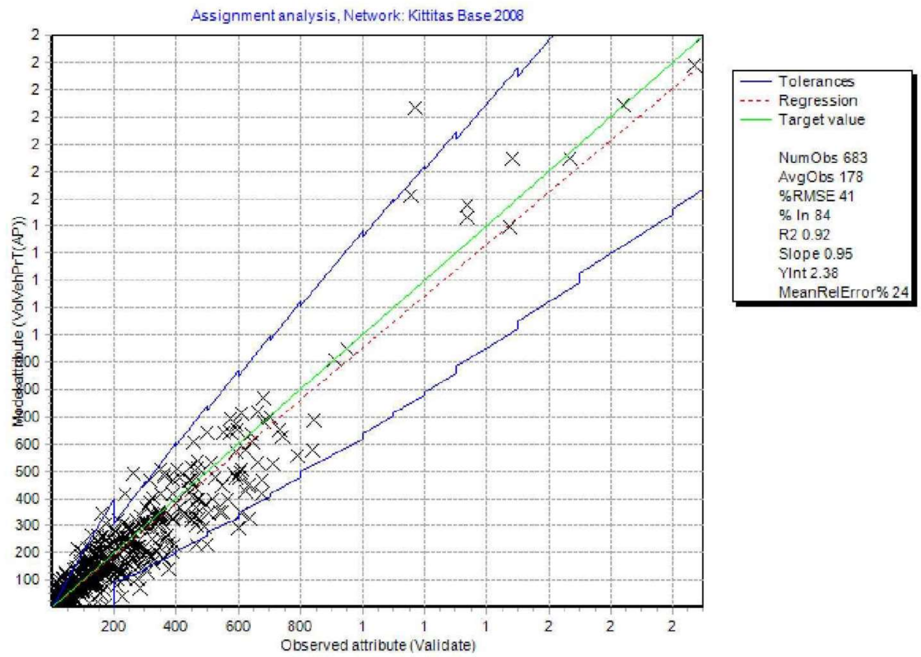


Figure 6
Kittitas County Scattergram for ALL Links

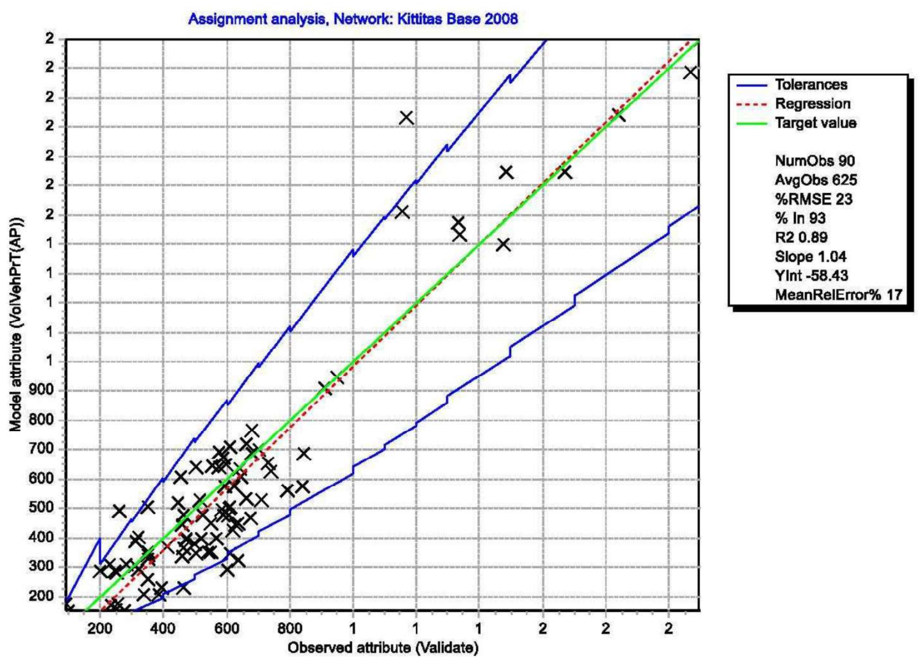


Figure 7
Kittitas County Scattergram for Freeway, All Arterials, and Ramps

As can be seen, the majority of the deviations fall between the curves. Other statistics calculated are:

AvgObs is the average assignment volume for all analyzed links.

%RMSE, the percent root mean square error, a summary statistic representing the average assignment error, disregarding sign, in percent.

$$\% \text{ RMSE} = 100 \times \frac{\sqrt{\dfrac{\sum(\text{Assignment Errors})^2}{\text{Number of Links}}}}{\text{Average Count}}$$

%In shows the percent of assigned volumes within allowable errors specifications.

R^2, the coefficient of determination or 'goodness of fit' statistic, shows how well the regression line represents the assignment data.

There are no national standards for R^2 or RMSE. However, there are guidelines that have been established by Caltrans for data used in air quality analysis. The guidelines recommend an R^2 of 0.88, a maximum RMSE of 35%, and a minimum %In of 75% for links classified as Principal Arterials and above.

Analysis of all links shows an R^2 of 0.92 and of Arterials and above shows an R^2 of 0.89, which are both better than the guideline of 0.88. Typically we see higher values of R^2 when there is a broader range of counts. If analyzing just higher volume facilities, the counts are more clustered and thus it is more difficult to plot these in a straight line.

The model also shows a %RMSE of 41% for all links and a %RMSE of only 23% for Arterials and above. The guideline of 35% or less is only applicable for Principal Arterials and above, so the 23% looks very good.

Analyzing all link classes shows the 84% of the count locations within acceptable bounds. The analysis of Arterials and above shows 93% of the count locations are within bounds. This is much better than the recommended standard of 75% for only links classified as Principal Arterial or above.

Slope of the line in both cases is very close to 1.0, with values ranging from 0.95 to 1.04. This is considered to be very good.

The 2008 Kittitas County model is well calibrated and can be used for forecasts.

Forecasts

Forecast Process

The traffic volume forecasts are based upon projected changes in land use, changes in interaction with the area outside of the model, changes in travel behavior, and changes in the transportation system. Typically, as the number of households and jobs increase, the traffic will increase as well. The calibration can be looked at as building and checking the "rules" for traffic generation, distribution, and assignment in the Kittitas County area. Then, as changes are made these same "rules" are used to project the change in traffic volumes and resulting changes in congestion, travel time, and emissions. The forecast process requires the projected number of housing units, projected number of employees by land use classification, number of acres of agricultural land, etc. It also requires a forecast of interaction with the area outside of the models. Information is needed to project the trips that enter and leave the model area. Finally, any planned transportation improvement projects should be included to properly assess the future operation of the transportation system. Each of these items is discussed.

Land Use Forecasts

Several sources were used to compile the forecast land use scenario. Previous work on forecast land use had been done by Studio Cascade, a land use planning consulting firm. Studio Cascade examined land use in Ellensburg during 2005 and compiled a forecast scenario for Ellensburg zones. Kittitas County also supplied PTV America, Inc. with a forecast scenario using growth factors with three ranges. It was decided to use a combination of these sources of forecast information to produce a detailed and more accurate land use forecast. The general methodology included using forecast data from Studio Cascade for all Ellensburg zones while using Kittitas County forecast data for all other zones with some exceptions.

External growth was similarly adjusted. Typically external growth is based upon trends analysis. The area surrounding a model study area is usually not experiencing congestion or volume-to-capacity problems. It is usually sufficient to analyze historical trends based upon traffic counts and extrapolate these trends into the future. Caution should be used if any of the trend extrapolation pushes the traffic volume on any external close to its capacity. WSDOT ATR count data was used from 1997 to 2007 to establish trends. The growth rates were between 2.5% per year (for I-90) to less than

0.5% per year (for SR 97). Each external was factored with the appropriate rate and external-external trips were adjusted with the combined rates for both Car and Truck trips.

Trips were generated for the alternative scenario forecasts with the same rates as used for the calibrated 2008 model. Once the total productions and attractions were computed the totals were balanced for each trip purpose or demand strata. These were averaged before use in the gravity distribution model. The same procedure was used for distribution and assignment as in the base year calibration.

Transportation System Improvements

The forecast models were run for the future horizon year of 2030. The models were run with no-build and groups of assumed improvements to test the impacts of various improvements. The assumed network improvements included these 21 proposed corridors.

Alliance Rd to 6th Street
Bender Road to Dry Creek Road
Bowers Road to Look Road
Bowers Road to US 97
Exit 85 to Lower Peoh Point
Fowler Creek to Lund Lane
FS Rd 2600 to FS Rd 4930
Godawa Ln to Upper Peoh Point
Graham Road to Upper Peoh Point Road
Hidden Valley Road to US 97
Judge Ronald Road to Fields Road
Pasco Road to Westside Road
Pasco Road to Woods & Steele Road
Pays Rd to Godawa Ln
Pfenning Road to Kittitas Highway
Reecer Creek Rd to Tipton Rd
Silverton Road to Weaver Road
Smithson Road to Wilson Creek Road
Strande Road to Hanson Road
Winston Rd to Exit 78

Woods & Steele Road to Graham Road

No improvements are assumed for I-90 or other state facilities.

All network coding was checked for the revisions. Capacities were recomputed for the links and nodes. The Multi-Point Assignment (MPA) equivalencies were checked and revised as necessary. Turn penalties were checked and revised as necessary.

Growth Scenarios

The four growth scenarios were analyzed run for both the no-build and build conditions. PM Peak hour volumes were forecast and the links were plotted with colors depicting ranges of volume/capacity ratios for the roads. Similar to the previously displayed base year conditions, these colors range light green through dark green, orange, red, and dark red to show increasing amounts of congestion.

Also, relative amounts of delay are shown for nodes or intersections using red dot. The larger the red dot the more delay computed by the model. Intersections with large red dots indicate potential problem locations. Graphics of each of the scenarios are shown below with traffic volumes.

A comparison was made between alternatives to show the differences between land use scenarios and the Build/No-Build conditions. Vehicle Miles of Travel (VMT) and Vehicle Hours of Travel (VHT) were summarized for the Kittitas County. The average speed (VMT/VHT) was computed for each of the scenarios also to facilitate comparisons.

Summary Comparison of Alternatives

Scenario	VMT	VHT	VMT/VHT
No Build			
Full Corridor Development			
Medium Corridor Development			
Low Corridor			

Development			

Vehicle Miles of Travel (VMT) increased by approximately for Scenario XX for Scenario YY. Vehicle Hours of Travel (VHT) increased by approximately Scenario XX No-Build and for Scenario YY etc.

Conclusions

As with all models, these are tools to evaluate the impacts of future change. The results should be used with caution. A model is only as good as the data and assumptions that were used to develop the model and the forecasts of the future year inputs. Caution should especially be used when evaluating the future. Will the forecast land use really occur as projected? Will travel behavior stay essentially the same? Should adjustments be made to account for these changes?

These models should be considered working tools. They are now completed and ready for application and use. When they are used for specific studies, the results should be examined and analyzed. If conditions have changed in an area or the existing data is out of date, compensation or improvements should be made in the model and its result.