Exhibit A: Metro Model Information

Introduction to Metro Model Set

The following description of the Metro model is provided to assist respondents with determining the extent, if any, to which it may use the Metro models as a starting point in developing its investment-grade modeling set. Metro's travel demand model is an enhanced four-step, trip-based model consisting of trip generation, destination choice, mode choice, and assignment. Metro's trip generation, destination choice, and mode choice models are programmed and maintained by Metro in the R scripting language. Metro uses Emme as its primary traffic assignment model and has the ability to convert Emme output into a VISUM format. Metro is currently developing several dynamic traffic assignment (DTA) models using both DynusT and Dynameq. This modeling component is anticipated to be operational by the time the Consultant is selected under this RFP.

Metro's vehicle assignments incorporate output from a freight traffic model based upon a commodity-flows database maintained by the Port of Portland. Metro currently assigns vehicles classified by mode (single-occupant vehicles (SOV), high-occupant vehicles (2+), heavy trucks (4 or more axles), medium trucks (2 and 3 axles), and transit. However, Metro has the ability to expand theses classifications by trip-purpose and/or other socio-economic factors.

Metro's destination choice, mode choice, and assignment models incorporate toll factors based on values-of-travel time from the 2009 stated preference survey prepared for the CRC Project. The models employ the value-of-travel time for work trips as a proxy for all peak-period trips and the value-of-travel time for non-work trips as a proxy for off-peak period trips.

Previous modeling work for the CRC Project focused on three time-of-day segments: 4-hour AM-Peak, 4-hour PM-Peak, and 1-hour Mid-Day. However, Metro has the capability to run its models in any desired aggregation of hourly segmentations.

Current Updating of the Metro Modeling Set

In 2011 Metro completed a regional travel survey to update its modeling coefficients and algorithms. Metro is currently in the process of recalibrating its models based on this data. The updated model set is anticipated to be fully functional, validated, and available to the Consultant by October 2012. The base year for the model will be 2010; all costs and values of time relationships will be expressed in 2010 dollars.

Metro is also currently involved in updating its population and employment forecasts for the region. Metro has completed an allocation of 2010 population and employment to the traffic zone level based on 2010 census and other data; this data is available for base year purposes. Metro has completed a preliminary forecast of 2035 population and employment on a traffic analysis zone level (referred to as the "Beta" forecast) which will require several more months of review and refinement by local planning officials and Metro before being finalized. The approved forecast (referred to as the "Gamma" forecast) is anticipated to be available to the Consultant by October 2012.

Attachments

Metro Travel Forecasting 2008 Trip-Based Demand Model Methodology Report (Mach 2008)

Addendum to the Metro Travel Forecasting March 2008 Trip-Based Demand Model Methodology Report (updated September 2010)

Metro Travel Forecasting
2008 Trip-Based Demand Model
Methodology Report

March 2008

METRO

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The preparation of this report has been financed in part by funds from the U.S. Department of Transportation, Federal Highway Administration, and by funds from the U.S. Department of Transportation, Federal Transit Administration.

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2008 Trip-Based Demand Model

This document summarizes the technical specifications for the travel demand model used in the Portland-Vancouver metropolitan area. It includes descriptions of the model structure, model application, the variables employed in model equations and their coefficients.

This model uses the person trip as the unit of analysis. This report does not address the tour-based Activity and TRANSIMS models, two federal Travel Model Improvement Program (TMIP) studies that are being conducted using Portland data.

On a regular basis, the region's trip-based model is modified to incorporate new data and research findings. Since the last report in 1998, many model enhancements have been implemented, affecting all trip purposes except Home-Based School. The current model offers the following methodological advances:

- The model includes trips by children younger than five years old.
- The cost assumptions have been updated to 1994 dollars.
- The worker model was re-estimated using new income categories.
- The auto ownership model was simplified with the introduction of a dwelling type variable.
- The trip generation models have been completely overhauled:
  - Home-Based Work (HBW) trips are now generated solely based on number of workers.
  - The home-based other trip purpose has been split into Home-Based Shop (HBshop), Home-Based Recreation (HBrec), and Home-Based Other (HBoth).
  - The non-home based trip purposes (NHBW and NHBNW) employ pre-production rates based on household characteristics to determine the total number of trips from each zone. These are then parceled out among zones based on the number of households and employees (by industry) in each zone.
  - Trip attraction rates are no longer computed, though for HBW and HBcoll attractions are calculated then scaled to productions.
- The destination choice models were also completely overhauled:
  - Multimodal accessibility functions from the mode choice model substitute for auto times.
  - K-factors have been replaced by river-crossing flags.
  - HBW, HBshop, HBrec, and HBoth trips are distributed separately by income group.
  - Many discrete categories of employment are used to distribute trips.
  - HBrec trips use park acres as an input.
- The mode choice models were updated in three key ways:
  - Peak and off-peak skims are used in all trip purposes.
  - Distributed trips are allocated among three auto modes (Drive alone, Drive with passenger, and Passenger), four transit modes (Bus and LRT by walk access, Bus by walk access, LRT by walk access, and Park & Ride), and two non-motorized modes (Bike and Walk).
  - The HBW, HBshop, HBrec, and HBoth trip purposes employ household demographic variables and income-specific cost coefficients.

Features of former models that have been rendered unnecessary by these enhancements include:

- Destination choice K-factors
- Pre-mode choice models for pedestrian and bicycle trips
- "LRT factors" to adjust for light rail transit service
- Auto occupancy factors

An outline of the document structure is provided below. Most of the document describes the modeling of internal person trips. The flow chart shown in Appendix A gives a visual description of the logic contained in sections B through H. Sections I through K describe models that are independent of the main model structure, although their output is integrated with the main model prior to trip assignment.

- Section A describes the base input data used in all stages of model specification.
- Section B describes pre-generation—the development of household characteristics by TAZ.
- Section C describes the trip generation models for internal person trips by trip purpose.
- Section D describes the multimodal accessibility functions used in the mode choice model.
- Section E describes the destination choice model for internal person trips.
- Section F describes the mode choice model.
- Section G describes the time of day (peaking) factors.
- Section H describes the trip assignment process.
- Section I describes the model for external trips.
- Section J describes the Metro Interim Truck model, used to develop a truck trip table.
- Section K describes the Portland International Airport Model.

A Input Data

Metro's model requires a variety of input data.

A.1 Land Use and Access Measurement Data

A.1.a Socioeconomic and Land Use Data

The socioeconomic and land use data used in Metro's modeling process are listed below:

- H.I.A. – Sixty-four categories of households are formed when the following characteristics are cross-classified:
  - Household size by four groups (1, 2, 3, 4+)
  - Income class by four groups (< $15K, $15-25K, $25-50K, > $50K), 1994 dollars
  - Age of household head by four groups (0-25, -55, -65, >65)
- Employment by two-digit SIC category
  - Agriculture, forestry (SIC 01-09)
  - Mining (SIC 10-14)
  - Construction (SIC 15-17)
  - Manufacturing (SIC 20-39)
  - Transportation, communications, public utilities (SIC 40-49)
  - Wholesale trade (SIC 50-51)
  - Retail trade (SIC 52-59)
  - Financial, insurance, real estate (SIC 60-67)
  - Service (SIC 70-89)
  - Government
- Number of local intersections

A.1.b Accessibility Measure Calculation

The following base accessibility variables are computed for use in the model:

- Number of employees within 30 minutes of transit travel time (includes walk and wait time)
- Households within ½ mile of each zone
- Retail employment within ½ mile of each zone
- Total employment within ½ mile of each zone
- Number of local intersections within ½ mile of each zone

Composite accessibility measures (commonly referred to as "mix" variables) are then developed to account for both the relative magnitudes of and the interactions between three urban design variables known to affect travel behavior. This has an added benefit of eliminating the collinearity problem associated with using these variables individually:

- Household density
- Employment density
- Intersection density (a measure of street connectivity)

Two accessibility variables are computed: one uses retail employment density (MixRet) and the other uses total employment density (MixTot). The household and employment values are normalized to intersection units using geometric means. The natural log is used to transform the variables' units for compatibility with other variables in the auto ownership, multimodal accessibility, and mode choice models. Here is the equation form:

Mix = Ln ((int*(emp*(int.mean / emp.mean)) * (hh*(int.mean / hh.mean))) /
(int + (emp*(int.mean / emp.mean)) + (hh*(int.mean / hh.mean))))

where:

- int = Number of local intersections within ½ mile of each zone
- emp = Retail OR Total employment within ½ mile of each zone
- hh = Households within ½ mile of each zone
- int.mean = Mean int value across all zones
- emp.mean = Mean emp value across all zones
- hh.mean = Mean hh value across all zones

A.1.c Special Trip Generators

Major shopping centers and universities receive special treatment in the generation and distribution models. Due to the unique trip generation characteristics of these locations, the following data are required for each site:

- Shopping center square footage
- College students and staff

A.2 Travel Time Data

Travel time is an important variable in the destination choice and mode choice models.

Door-to-door travel time is used for the model estimation, and zone-to-zone travel time is used for the calibration. Travel time data in this section refer to zone-to-zone travel time.

For all modes but bike and walk, two sets of weekday travel time matrices are developed:

- Peak: A.M. 2-hour peak (07:00-08:59)
- Off-Peak: Mid-day 1-hour (14:00-14:59)

Household survey data are used to estimate the percentage of peak vs. off-peak travel for each trip purpose (except school). These factors determine which proportion of trips experience peak vs. off-peak travel times in the multimodal accessibility functions and mode choice models:

TABLE 1. Peak Factors Applied to Skims in Mode Choice Models

Trip Purpose		Peak Skims	Off-Peak Skims
HBW	Home-Based Work	0.606	0.394
HBshop	Home-Based Shopping	0.300	0.700
HBrec	Home-Based Recreation	0.309	0.691
HBoth	Home-Based Other	0.377	0.623
NHBW	Non-Home-Based Work	0.382	0.618
NHBNW	Non-Home-Based Non-Work	0.331	0.669
HBcoll	Home-Based College	0.407	0.593

A.2.a Auto Skims

Auto skims are prepared using the results of previous EMME/2 assignments.

A.2.b Transit Skims

The peak and off-peak transit skims account for differences in levels of transit service and network congestion. Five transit impedance matrices are developed for each time period:

- In-vehicle time
- Walk time
- First wait time
- Transfer wait time
- Number of Boardings

A boarding penalty is used to affect path choice, but it is not included in the actual impedance time. Each boarding incurs an additional boarding penalty, which varies by location:

- 10 minutes – CBD location, LRT stations, and transit centers
- 20 minutes – other bus stop locations

For model application, wait times are modeled at 50% of headway, on the assumption that transit riders are generally aware of schedules. Note that timed transfer locations receive no special consideration.

Total walk time, initial wait time, and total accumulated transfer wait time each have a maximum value of 30 minutes. This means that no zone pair with transit access (see Section F) has more than 30 minutes walk time, 30 minutes initial wait time, and 30 minutes transfer wait time.

Due to the limitations of the EMME/2 software, the walk, wait, and boarding weights applied to pathbuilding (skim) runs differ from those used in the demand model.

- Transit skim wait time factor: 0.5
- Transit skim wait time weight: 0.5
- Transit skim auxiliary transit (walk) time weight: 1.0
- Transit skim boarding time weight: 1.0

For each zone pair, skims are prepared for the following walk-access transit modes:

- Bus only
- LRT only
- Combo (LRT and Bus)

Only one set of transit times is used for each zone pair. If a zone pair has a travel time by more than one transit mode, the mode with the most optimal time is chosen for input to the model. The optimal time is determined using the Multimodal Accessibility logsum calculation described in Section D.

A.2.c Park & Ride Skims

Park & ride skims are calculated from auto and transit skims, as follows:

- In-vehicle time: sum of:
  - auto in-vehicle time from the production (home) zone to a logically defined lot location
  - transit in-vehicle time from the park & ride lot to the work location
- Walk time: transit skims from the park & ride lot to the work location
- Total wait time: transit skims from the park & ride lot to the work location
- Total trip distance

A.2.d Bike and Walk Time

Bike and walk travel times are calculated based on assumed speeds. The bike distances are the same as auto distances, while the walk distances for intrazonal trips are capped at 0.5 miles so as not to over-penalize the walk mode in large zones. These times do not vary by time period.

- Bike time = Trip distance / 10 mph * 60 mins
- Walk time = Walk distance / 3 mph * 60 mins

A.3 Trip Cost Data

Travel cost is an input to the mode choice model. All cost values are in 1994 dollars:

- Drive Alone = ($0.091 / mile*distance) + (½ of parking charge in attraction zone)
- Shared Ride = [($0.091 / mile*distance) + (½ of parking charge in attraction zone)] / 2
  –
- Park & Ride = ($0.091 / mile*distance / 4) + transit fare

Transit fares are based on the average fares charged by the region's transit providers in 2005 (converted to 1994 dollars):

- TriMet
  - Travel within CBD-Lloyd fareless area : $0.000
  - For 1 zone travel: $0.831
  - For 2 zone travel: $0.852
  - For 3 zone travel: $0.919
- C-Tran
  - For intra-Clark County service : $0.761
  - For Portland-Clark County service: $1.370
- Sandy Area Metro (SAM)
  - For intra-Rhododendron service: $0.385
  - For Sandy-Rhododendron service: $0.963
- South Clackamas Transportation District (SCTD)
  - For Molalla-Clackamas Community College service: $0.770

The parking charge used as an input to auto cost varies by trip purpose:

- Home-based work (HBW) and home-based college (HBcoll) use long-term parking cost.
- Other trip purposes use half of the long-term parking cost.

A.4 Transportation Service Inputs

Various transportation service inputs are applied at different stages in the model:

- Average weekday volumes at external station locations.
- Household transit coverage factor by TAZ for both the peak and off-peak periods, i.e. percent of the households within a zone that are 1/5 mile or less from a bus line, or 1/2 mile or less from a major transit station, including all LRT stations.
- Employment transit coverage factor by TAZ for both the peak and off-peak periods, i.e. percent of the households within a zone that are 1/5 mile or less from a bus line, or 1/2 mile or less from a major transit station, including all LRT stations.
- Park and ride lot location assigned to each TAZ outside the central city. A shadow cost is assigned to some lots; this has the effect of lowering the utility of the Park & Ride mode choice where the assigned lot's capacity is constrained.

B Pre-Generation

Several models must be run before starting the travel demand process. This stage is called pre-generation and includes the worker model, the auto ownership model, and the children model.

These models were estimated using a multinomial logit procedure. The listed utilities are converted into probabilities to determine the number of workers, cars, and children in each TAZ. The following example probability is used for zero-worker households:

$$Prob_{0\text{-worker HH}} = U_{0\text{-workerHH}} \,/\, \left(U_{0\text{-workerHH}} + U_{1\text{-workerHH}} + U_{2\text{-workerHH}} + U_{3\text{-workerHH}} \right)$$

B.1 Worker Model

The worker model estimates the number of households with 0, 1, 2, and 3 or more workers.

B.1.a Variable Definitions

HHsize = 1 person, 2 person, 3 person, 4+ person
Workercl = 0 worker, 1 worker, 2 worker, 3+ worker
Income1 = 1 if 1994 household income < $15,000
Income2 = 1 if 1994 household income >= $15,000 and < $25,000
Income3 = 1 if 1994 household income >= $25,000 and < $50,000
Income4 = 1 if 1994 household income >= $50,000
Agecat1 = 1 if age of household head 18-24
Agecat2 = 1 if age of household head 25-55
Agecat3 = 1 if age of household head 56-65
Agecat4 = 1 if age of household head > 65

B.1.b Calibrated Choice Utilities

Constants may differ from the original estimation due to the calibration process. These coefficients are the same as in the calibration code.

0 worker households

U = **exp (** 7.034 – 1.406*HHsize + 2.823*Income1 + 2.024*Income2 + 0.5145*Income3 – 4.396*Agecat1 – 5.054*Agecat2 – 2.8*Agecat3 **)**

1 worker households

U = **exp (** 5.101 – 1.125*HHsize + 1.64*Income1 + 1.909*Income2 + 0.9023*Income3 – 1.605*Agecat1 – 1.478*Agecat2 – 1.095*Agecat3 **)**

2 worker households

U = **exp (** 3.4 – 0.571*Hhsize - 0.4828*Income1 + 0.502*Income2 + 0.235*Income3 **)**

3+ worker households

U = **exp (** 0 **)**

B.1.c Estimated Variable Coefficients

TABLE 2. Worker Model

Variable	**0 worker**		**1 worker**		**2 worker**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	*7.034*		*5.101*		*3.4*	
Constant	8.011	25.1	6.083	20.2	3.73	17.6
HHsize	-1.406	-16.5	-1.125	-19.1	-0.571	-10.9
Income1	2.823	5.9	1.64	3.6	-0.4828	-1.0
Income2	2.024	5.3	1.909	5.4	0.502	1.4
Income3	0.5145	2.6	0.9023	5.3	0.235	1.4
Agecat1	-4.936	-13.9				
Agecat2	-5.054	-22.5	-1.478	-6.7		
Agecat3	-2.8	-11.9	-1.095	-4.6		

The 3+ worker choice utility is held constant at zero.

B.2 Auto Ownership Model

Auto ownership is an important input to the mode choice models.

The model estimation dataset includes all surveyed households that reported income and whose locations could be geocoded.

B.2.a Variable Definitions

Hhsize1	=	1 person
Hhsize2	=	2 person
Hhsize3	=	3 person
Hhsize4	=	4 person
Worker0	=	0 worker
Worker1	=	1 worker
Worker2	=	2 worker
Worker3	=	3 worker
Income1	=	1 if 1994 household income < $15,000
Income2	=	1 if 1994 household income >= $15,000 and < $25,000
Income3	=	1 if 1994 household income >= $25,000 and < $50,000
Income4	=	1 if 1994 household income >= $50,000
Sfdwell	=	1 if single family house, 0 if other dwelling type
MixTot	=	Total employment accessibility within ½ mile (see Section A.1.b)
Tot20t	=	(Total employment within 20 minutes by mid-day transit) /1000

B.2.b Calibrated Choice Utilities

0 car households

U = **exp (** -7.152 + 2.81*Hhsize1 + 0.562*Hhsize2 + 2.822*Worker0 + 1.965*Worker1 + 2.587*Income1 + 1.344*Income2 – 1.056*Sfdwell + 0.2737*MixTot + 0.01495*Tot20t **)**

1 car households

U = **exp (** -3.678 + 2.829*Hhsize1 + 0.9735*Hhsize2 + 0.3272*Hhsize3 + 1.493*Worker0 + 1.326*Worker1 + 1.335*Income1 + 1.212*Income2 + 0.2684*Income3 – 0.4071*Sfdwell + 0.2251*MixTot + 0.007245*Tot20t **)**

2 car households

U = **exp (** -2.342+ 0.3485*Hhsize2 – 0.2177*Hhsize3 + 2.299*Worker1 + 2.355*Worker2 + 1.908*Worker3 + 0.5937*Income2 + 0.3964*Income3 + 0.4813*Income4 + 0.09206*MixTot + 0.002282*Tot20t **)**

3+ car households

U = **exp (** 0 **)**

B.2.c Estimated Variable Coefficients

TABLE 3. Auto Ownership Model

Variable	0 car		1 car		2 car	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	*-7.152*		*-3.678*		*-2.342*	
Constant	-7.145	-11.9	-3.501	-12.3	-2.211	-8.9
Hhsize1	2.81	9.7	2.829	18.8		
Hhsize2	0.562	1.9	0.9735	6.4	0.3485	3.4
Hhsize3			0.3272	1.9	-0.2177	-1.9
Hhsize4						
Worker0	2.822	7.7	1.493	9.1		
Worker1	1.965	5.6	1.326	1019	2.299	10.6
Worker2					2.355	12.5
Worker3					1.908	10.8
Income1	2.587	12.0	1.335	7.6		
Income2	1.344	6.3	1.212	7.7	0.5937	3.9
Income3			0.2684	2.5	0.3964	3.9
Income4					0.4813	4.5
Sfdwell	-1.056	-6.5	-0.4071	-4.8		
MixTot	0.2737	4.1	0.2251	6.1	0.09206	3.6
Tot20t	0.01495	8.7	0.007245	6.2	0.002282	2.3

The 3+ car choice utility is held constant at zero.

The land use variables (along with the binary dwelling type variable) are the sole model inputs that can be modified for future scenario testing.

B.3 Children Model

The school trip purpose requires the calculation of the number of households with 0, 1, 2, or 3+ children.

B.3.a Variable Definitions

HHsize = 1 person, 2 person, 3 person, 4+ person
Agecat4 = 1 if age of household head > 65

B.3.b Calibrated Choice Utilities

This model was not changed in calibration.

0 child households

U = **exp (** -3.239336*HHsize + 5.537674*Agecat4 **)**

1 child households

U = **exp (** -1.81999*HHsize + 3.458333*Agecat4 **)**

2 child households

U = **exp (** 0.0118144*HHsize + 0.3199485*Agecat4 **)**

3+ child households

U = **exp (** 0 **)**

B.3.c Estimated Variable Coefficients

TABLE 4. Children Model

Variable	**0 child**		**1 child**		**2 child**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
HHsize	-3.239336	-26.9	-1.81999	-16.5	0.0118144	0.1
Agecat4	5.537674	26.2	3.458333	16.9	0.3199485	1.5

The 3+ child choice utility is held constant at zero.

C Trip Generation

Average weekday person trips are generated for eight trip purposes:

- HBW – Home-Based Work
- HBshop – Home-Based Shopping
- HBrec – Home-Based Recreation
- HBoth – Home-Based Other (excludes school and college)
- NHBW – Non-Home-Based Work
- NHBNW – Non-Home-Based Non-Work
- HBcoll – Home-Based College
- HBsch – Home-Based School

For each zone, the number of households in each demographic category is multiplied by a production rate. The number of trips is then factored up to match regional control totals by applying a calibration factor which varies by purpose. The demographic categories, production rates, and calibration factors are described by purpose in the following subsections.

Most home-based trips are generated by production zone in the two steps described above, then they are attached to an attraction zone within the destination choice models. Non-home-based trips add an extra step within generation: the allocation of trip productions to zones according to their total households and employment. Finally, school and college generation models incorporate trip attraction, whereas the other purposes address attraction through the destination choice models.

C.1 HBW (Home-Based Work)

C.1.a Productions

HBW trips are produced solely by the number of workers in a household:

- Input Variable: Number of workers
- Output: Person trips (all modes), by zone of production (home)

TABLE 5. HBW Production Rates

Workers	Rate
1	1.38325222
2	2.39110122
3+	3.88667372

C.1.b Attractions

HBW trip attractions are estimated by the following procedure:

- A regional average trip rate per employee is generated by dividing the sum of HBW productions by total employees.
- Trip attractions are generated by multiplying the average trip rate by the total employment in each TAZ.

C.1.c Scaling

Final HBW trips are generated by the following procedure:

- Total employment (multiplied by a calibration factor of 1.48) is divided by total productions to produce a production factor.
- Final HBW trips are calculated by multiplying the number of productions in each TAZ by the production factor.

C.2 HBshop (Home-Based Shopping)

HBshop productions are generated by a cross-classification model:

- Input Variables: Household size, Number of workers
- Output: Person trips (all modes), by zone of production (home)

TABLE 6. HBshop Production Rates

	Workers			
HHsize	**0**	**1**	**2**	**3+**
1	0.65370595	0.36543758		
2	1.4747858	0.96459839	0.66841305	
3	1.4397819	1.1695282	0.93650663	1.0063395
4+	1.7925876	1.8066825	1.5106965	1.2347277

The resulting trips are multiplied by a calibration factor of 1.2.

C.3 HBrec (Home-Based Recreation)

HBrec productions are generated by a cross-classification model:

- Input Variable: Household size by worker status
- Output: Person trips (all modes), by zone of production (home)

TABLE 7. HBrec Production Rates

HHsize	all household members work	some household members do not work
1	0.50317472	0.47897259
2	0.57970395	0.8811184
3	1.1656474	1.2137337
4+	.	2.2400753

The resulting trips are multiplied by a calibration factor of 1.2.

C.4 HBoth (Home-Based Other)

HBoth productions are generated by a cross-classification model:

- Input Variable: Household size by worker status
- Output: Person trips (all modes), by zone of production (home)

TABLE 8. HBoth Production Rates

HHsize	all household members work	some household members do not work
1	0.54391065	0.89368165
2	1.2416304	1.628105
3	1.4489857	2.2256102
4+		3.4876336

The resulting trips are multiplied by a calibration factor of 1.2.

C.5 NHBW (Non-Home-Based Work)

Production of non-home-based travel in trip-based models requires some measure of attraction.

C.5.a Pre-Production

Total NHBW productions are initially generated solely by number of workers:

- Input Variable: Number of workers
- Output: Person trips (all modes), by zone of production (work)

TABLE 9. NHBW Pre-Production Rates

Workers	Rate
0	0.02585558
1	0.72965676
2	1.5252267
3+	1.9130584

C.5.b Scaling

NHBW productions are scaled to total employment by the following procedure:

- Total employment (multiplied by a calibration factor of 0.803) is divided by total productions to produce a production factor.
- Adjusted NHBW productions are calculated by multiplying the number of productions in each TAZ by the production factor.

Resulting trips are summed to develop a control total of NHBW trips produced by all zones.

C.5.c Variable Definitions

Hhold = Number of households in production (work) zone
Employment in production (work) zone by two-digit SIC codes…
- RetEmp = retail trade (SIC 52-59)
- SvcEmp = service (SIC 70-89)
- GvtEmp = government
- NonRetSvcGvt = all employment other than retail, service and government

C.5.d Choice Utility

U = **exp (ln (** 0.1427*Hhold + 2.3955*SvcEmp + 1.7828*GvtEmp + 1.2263NonRetSvcGov + RetEmp **))**

C.5.e Estimated Variable Coefficients

TABLE 10. NHBW Production Utility

Variable	NHBW	
	Coefficient	T-Statistic
Hhold	0.1427	12.4
SvcEmp	2.3955	7.3
GvtEmp	1.7828	4.8
NonRetSvcGvt	1.2263	1.8
Retail	1	0

For each production zone, the control total (described in Section C.5.b) is multiplied by the ratio of the zone's production utility (calculated by the utility equation in Section C.5.d) to the sum of all zones' production utilities. In this manner total NHBW trip productions are allocated according to proportion of production by zone.

C.6 NHBNW (Non-Home-Based Non-Work)

C.6.a Pre-Production

NHBNW productions are initially estimated by a cross-classification model:

- Input Variables: Household size by worker status
- Output: Person trips (all modes), by zone of production

TABLE 11. NHBNW Pre-Production Rates

HHsize	all household members work	some household members do not work
1	0.55627805	0.98518294
2	0.94975883	1.2483164
3	1.2344123	1.802035
4+	.	2.8792371

Resulting trips are multiplied by a calibration factor of 1.2 then summed to develop a control total of NHBNW trips.

C.6.b Variable Definitions

Employment in production zone by two-digit SIC codes…
RetEmp = retail trade (SIC 52-59)
SvcEmp = service (SIC 70-89)
GvtEmp = government
NonRetSvcGvt = all employment other than retail, service, and government

C.6.c Choice Utility

U = **exp (ln (**RetEmp + 0.5086*SvcEmp + 0.388*GvtEmp + 0.05239*NonRetSvcGvt **))**

C.6.d Estimated Variable Coefficients

TABLE 12. NHBNW Production Utility

Variable	NHBW	
	Coefficient	T-Statistic
RetEmp	1	0
SvcEmp	0.5086	14.3
GvtEmp	0.388	16.9
NonRetSvcGvt	0.05239	25.5

For each production zone, the control total (detailed in Section C.6.a) is multiplied by the ratio of the zone's production utility (calculated by the utility equation in Section C.6.c) to the sum of all zones' production utility. In this manner total NHBNW trip productions are allocated according to proportion of production by zone.

C.7 HBcoll (Home-Based College)

C.7.a Productions

HBcoll productions are generated by a cross-classification model:

- Input Variables: Household size, Age group (age of household head)
- Output: Person trips (all modes), by zone of production (home)

TABLE 13. HBcoll Production Rates

	Age Group			
Hhsize	**<25**	**25-54**	**55-64**	**>65**
1	0.52380952	0.05958549	0.02985075	0.01823708
2	0.48387097	0.17915691	0.03581267	0.03353057
3	1.0	0.23421927	0.33980583	0.06557377
4+	0.45833333	0.38158996	0.58510638	0

Productions are adjusted upward by a calibration factor of 1.074.

C.7.b Attractions

College vehicle trips are used as the HBcoll attraction factor. The vehicle computation is derived from ITE rates (modified to avoid double counting):

- 4 year college vehicle trips = students*2.5 or staff*9.8
- 2 year college vehicle trips = students*1.5 or staff*28.2

Each college is assigned vehicle trips according to whichever formula (student or staff) generates the fewest number of trips.

Attractions are scaled to productions by multiplying the vehicles in each zone by the ratio of total productions to total vehicles.

C.8 HBsch (Home-Based School)

HBsch productions are generated by a cross-classification model, which is based on Metro's 1985 household travel survey.

- Input Variables: Household size, Number of children
- Output: Person trips (all modes), by zone of production (home)

TABLE 14. HBsch Production Rates

	Children			
Hhsize	**0**	**1**	**2**	**3+**
1	0	1.0	0.8	.
2	0	1.3933333	2.5	.
3	0	1.313253	2.9808102	4.875
4+	0	1.0	0.8	.

HBsch attractions are set equal to productions because school employment is difficult to obtain at any degree of zonal accuracy and because most schools are located close to students' homes.

Unadjusted HBsch attractions (schat):	equal to total productions by zone
HH Growth rate "1985 to current" (hhgrow):	households / 501,701 (1985 HH)
School Target (schtar – scalar):	hhgrow*392,005 (1985 sch prod)
Total Raw Productions (totsch – scalar):	schat
Adjusted Productions (schat):	(schat/totsch)*schtar

D Multimodal Accessibility Functions

Modal accessibility functions were estimated for use in the destination choice model. For each trip purpose, they measure the utility of choosing one of nine discrete modes:

Drive alone – only available to households with at least one car
Drive with passenger – only available to households with at least one car
Auto passenger
Bus Only by walk access
LRT Only by walk access
Bus/LRT by walk access
Transit by park & ride access – only available if one trip end is within ½ mile of a transit stop
Bike – only available for trips with a distance less than ten miles
Walk – only available for trips with a distance less than five miles

Note: Per the discussion in Section A.2.b, no more than one walk-access transit mode is used for each zone pair.

The logsum of all modal utilities is a key input to the destination choice model (Section E). It is generated as follows for each trip purpose (and for some purposes, by income group):

$$\mathbf{Ln\ (}\ U_{\text{Drive Alone}} + U_{\text{Drive with Passenger}} + U_{\text{Auto Passenger}} + U_{\text{Walk to Bus}} + U_{\text{Walk to BusLRT}} + U_{\text{Walk to LRT}} + U_{\text{Park\&Ride}} + U_{\text{Bike}} + U_{\text{Walk}}\ \mathbf{)}$$

D.1 HBW (Home-Based Work)

D.1.a Variable Definitions

IvTime = In-vehicle travel time (varies by mode)
WalkTime = Walk time, by mode:
Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere)
Shared Ride: Drive Alone walk time plus 5 minutes
Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1 = Transit initial wait time
TranWait2 = Transit transfer wait time
TranBrds = Transit # of transfers
Tdist = Total Trip Distance
Wdist = Total Walk Distance

D.1.b Calibrated Choice Utilities

Drive Alone

U = **exp (** -0.03608*IvTime – 0.09956*WalkTime **)**

Drive with Passenger

U = **exp (** – 0.03608*IvTime – 0.09956*WalkTime **)**

Auto Passenger

U = **exp (** – 0.03608*IvTime – 0.09956*WalkTime **)**

Transit by Walk Access

U = **exp (** – 0.03608*IvTime – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*(TranBrds-1) **)**

Park & Ride

U = **exp (** – 0.03608*IvTime – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*(TranBrds-1) **)**

Bike

U = **exp (** -3.115***ln**(Tdist) **)**

Walk

U = **exp (** -4.307***ln**(Wdist) **)**

D.1.c Estimated Variable Coefficients

The generic multimodal accessibility functions use the same variable coefficients estimated for the mode choice model, which also includes extra variables relating to specific household characteristics. The estimated coefficients for the HBW accessibility functions are included in the tables in Section F.1.c.

D.2 HBshop, HBrec, HBoth (Other Home-Based)

Mode choice model variable coefficients do not vary between the HBshop, HBrec, and HBoth trip purposes. However, the model features different constants by purpose for some modes.

D.2.a Variable Definitions

IvTime = In-vehicle travel time (varies by mode)
WalkTime = Walk time, by mode:
Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere)
Shared Ride: Drive Alone walk time plus 5 minutes
Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1 = Transit initial wait time
TranWait2 = Transit transfer wait time
TranBrds = Transit # of Transfers
Tdist = Total Trip Distance
Wdist = Total Walk Distance

D.2.b Calibrated Choice Utilities

Drive Alone

U = **exp (** -0.0215*IvTime – 0.1033*WalkTime **)**

Drive with Passenger

U = **exp (** -0.0215*IvTime – 0.1033*WalkTime**)**

Auto Passenger

U = **exp (** -0.0215*IvTime – 0.1033*WalkTime **)**

Transit by Walk Access

U = **exp (** – 0.0215*IvTime – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*(TranBrds-1) **)**

Park & Ride

U = **exp (** – 0.0215*IvTime – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*(TranBrds-1) **)**

Bike

U = **exp (** -1.804 * **ln**(Tdist) **)**

Walk

U = **exp (**-2.466 * **ln**(Wdist)**)**

D.2.c Estimated Variable Coefficients

The generic multimodal accessibility functions use the same variable coefficients estimated for the mode choice model, which also includes extra variables relating to specific household characteristics. The estimated coefficients for the HBshop, HBrec, and HBoth accessibility functions are included in the tables in Section F.2.c.

D.3 NHBW & NHBNW (Non-Home-Based)

Cost coefficients do not vary by income group for non-home-based trips.

D.3.a Variable Definitions

IvTime	=	In-vehicle travel time (varies by mode)
WalkTime	=	Walk time, by mode: Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere) Shared Ride: Drive Alone walk time plus 5 minutes Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1	=	Transit initial wait time
TranWait2	=	Transit transfer wait time
TranBrds	=	Transit # of Transfers
Tdist	=	Total Trip Distance
Wdist	=	Total Walk Distance

D.3.b Calibrated Choice Utilities

Drive Alone

U = **exp (** -0.025*IvTime – 0.1493*WalkTime **)**

Drive with Passenger

U = **exp (** – 0.025*IvTime – 0.1493*WalkTime **)**

Auto Passenger

U = **exp (** – 0.025*IvTime – 0.1493*WalkTime **)**

Transit by Walk Access

U = **exp (**– 0.025*IvTime – 0.1337*TranWait1 – 0.07895*TranWait2 – 0.1493*WalkTime) – 0.3*(TranBrds-1) **)**

Bike

U = **exp (–** 0.8608***ln**(Tdist)**)**

Walk

U = **exp (** – 1.524***ln**(Wdist)**)**

D.3.c Estimated Variable Coefficients

The generic multimodal accessibility functions use the same variable coefficients estimated for the mode choice model. The estimated coefficients for the Non-Home Based accessibility functions are shown in the tables in Section F.3.b.

D.4 HBcoll (Home-Based College)

Cost coefficients do not vary by income group for college commute trips.

D.4.a Variable Definitions

IvTime = In-vehicle travel time (varies by mode)
WalkTime = Walk time, by mode:
    Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere)
    Shared Ride: Drive Alone walk time plus 5 minutes
    Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1 = Transit initial wait time
TranWait2 = Transit transfer wait time
TranBrds = Transit # of Transfers
Tdist = Total Trip Distance
Wdist = Total Walk Distance

D.4.b Calibrated Choice Utilities

Drive Alone

U = **exp (** -0.05319*IvTime – 0.2111*WalkTime**)**

Drive with Passenger

U = **exp (**– 0.05319*IvTime – 0.2111*WalkTime**)**

Auto Passenger

U = **exp (**– 0.05319*IvTime – 0.2111*WalkTime**)**

Transit by Walk Access

U = **exp (**– 0.05319*IvTime – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*(TranBrds-1) **)**

Park and Ride

U = **exp (**– 0.05319*IvTime – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*(TranBrds-1) **)**

Bike

U = **exp (–** 1.588***ln**(Tdist) **)**

Walk

U = **exp (** – 2.264***ln**(Wdist) **)**

D.4.c Estimated Variable Coefficients

The generic multimodal accessibility functions use the same variable coefficients estimated for the mode choice model. The estimated coefficients for the HBcoll accessibility functions are shown in the tables in Section F.4.c.

E Destination Choice

The destination choice models were developed using a multinomial logit estimation procedure. Estimation was based on the 1994-95 household activity survey. The models were calibrated to observed flows for 2005, at which point West Hills crossing dummy variables were added with half the value of the Willamette River crossing dummy variables.

E.1 HBW (Home-Based Work)

E.1.a Variable Definitions

Logsum of multimodal accessibility functions (all modes, by income)…
- LowLogSum = low income households (<$25K)
- MidLogSum = middle-income households ($25-50K)
- HighLogSum = high income households ($50K+)
- WashOr = 1 if trip crosses Columbia River from Washington to Oregon
- OrWash = 1 if trip crosses Columbia River from Oregon to Washington
- WillWE = 1 if trip crosses Willamette River from west to east
- HillWE = 1 if trip crosses West Hills from west to east

Employment in attraction zone by two-digit SIC codes…
- RetEmp = retail trade (SIC 52-59)
- FinEmp = financial, insurance, real estate (FIRE) (SIC 60-67)
- SvcEmp = service (SIC 70-89)

Other employment variables…
- TotEmp = total employment
- NonRet = all employment other than retail
- NonRetSvcFin = all employment other than retail, service, and FIRE

E.1.b Calibrated Choice Utilities

HBW – Low Income Households

U = **exp (** 2.235*LowLogSum – 0.4198*(LowLogSum$^{2)}$ + 0.0222*(LowLogSum^{3}) – 1.502*WashOr – 1.378*OrWash – 0.4949*WillWE – 0.4949/2*HillWE+ **ln (** TotEmp **))**

HBW – Middle Income Households

U = **exp (**2.097*MidLogSum – 0.3995*(MidLogSum$^{2)}$ + 0.02524*(MidLogSum^{3}) – 0.8209*WashOr – 1.635*OrWash – 0.3138*WillWE – 0.3138/2*HillWE + **ln (** RetEmp + 1.6005*NonRet **))**

HBW – High Income Households

U = **exp (**1.777*HighLogSum – 0.3908*(HighLogSum$^{2)}$ + 0.02555*(HighLogSum^{3}) – 1.139*WashOr – 1.429*OrWash – 0.4325*WillWE – 0.4325/2*HillWE + **ln (** RetEmp + 2.8605*SvcEmp + 5.6013*FinEmp + 2.4312*NonRetSvcFin **))**

E.1.c Estimated Variable Coefficients

TABLE 15. HBW Destination Choice Model

Variable	**Low Income <25K**		**Middle Income 25-50K**		**High Income 50K+**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib LogSum	*2.235*		*2.097*		*1.777*	
Calib LogSum^{2}	*-0.4198*		*-0.3995*		*-0.3908*	
Calib LogSum^{3}	*0.0222*		*0.02524*		*0.02555*	
LogSum	2.203	21.6	1.891	37.0	1.562	30.2
LogSum^{2}	-0.3701	-6.0	-0.3614	-11.1	-0.3164	-9.1
LogSum^{3}	0.01899	2.1	0.02154	4.5	0.02195	3.9
WashOr	-1.502	-8.6	-0.8209	-10.6	-1.139	-14.2
OrWash	-1.378	-5.1	-1.635	-9.7	-1.429	-9.2
WillWE	-0.4949	-3.0	-0.3138	-3.4	-0.4325	-5.6
HillWE	*-0.24745*		*-0.1569*		*-0.21625*	
TotEmp	1	0				
RetEmp			1	0	1	0
SvcEmp					2.8605	5.3
FinEmp					5.6013	7.9
NonRet			1.6005	4.1		
NonRetSvcFin					2.4312	5.0

E.2 HBshop, HBrec, HBoth (Other Home-Based)

E.2.a Variable Definitions

MsLogSum = Logsum of multimodal accessibility functions
WashOr = 1 if trip crosses Columbia River from Washington to Oregon
OrWash = 1 if trip crosses Columbia River from Oregon to Washington
WillWE = 1 if trip crosses Willamette River from west to east
WillEW = 1 if trip crosses Willamette River from east to west
HillWE = 1 if trip crosses West Hills from west to east
HillEW = 1 if trip crosses West Hills from east to west
Hhold = Number of households in attraction zone
ParkAcres = Park acres in attraction zone
Employment in attraction zone by two-digit SIC codes…
  RetEmp = retail trade (SIC 52-59)
  SvcEmp = service (SIC 70-89)
  GvtEmp = government
Other employment variables…
  NonRet = all employment other than retail
  NonRetSvcGvt = all employment other than retail, service, and government

E.2.b Calibrated Choice Utilities

HBShop

U = exp (7.595*((LowLogSum+MidLogSum+HighLogSum)/3) – 2.839*(((LowLogSum+MidLogSum+HighLogSum)/3)^2) + 0.3125*(((LowLogSum+MidLogSum+HighLogSum)/3)^3) – 0.698*WashOr – 1.873*OrWash – 0.4855*WillWE – 0.2656*WillEW – 0.4855/2*HillWE – 0.2656/2*HillEW + ln (RetEmp +.008396*NonRet + .022126*Hhold))

HBRec

U = exp (5.546*((LowLogSum+MidLogSum+HighLogSum)/3) – 1.801*(((LowLogSum+MidLogSum+HighLogSum)/3)^2) + 0.1907*(((LowLogSum+MidLogSum+HighLogSum)/3)^3) – 1.209*WashOr – 1.539*OrWash – 0.2962*WillWE – 0.1703*WillEW – 0.2962/2*HillWE – 0.1703/2*HillEW + ln (TotEmp + 1.278*Hhold + 4.6833*ParkAcres))

HBoth

U = exp (6.476*((LowLogSum+MidLogSum+HighLogSum)/3) – 2.284*(((LowLogSum+MidLogSum+HighLogSum)/3)^2) + 0.2505*(((LowLogSum+MidLogSum+HighLogSum)/3)^3) – 1.36*WashOr – 1.546*OrWash – 0.456*WillWE – 0.456/2*HillWE + ln (0.2393*Hhold + RetEmp + 0.6419*SvcEmp + 0.6109*GvtEmp + 0.06802*NonRetSvcGvt))

E.2.c Estimated Variable Coefficients

TABLE 16. HBshop, HBrec, HBoth Destination Choice Model

Variable	HBshop		HBrec		HBoth	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib LogSum	*7.595*		*5.546*		*6.476*	
Calib LogSum^2	*-2.839*		*-1.801*		*-2.284*	
Calib LogSum^3	*0.3125*		*0.1907*		*0.2505*	
LogSum	7.765	46.1	5.616	45.7	6.586	64.6
LogSum^2	-2.801	-24.0	-1.793	-19.7	-2.274	-29.7
LogSum^3	0.3179	14.5	0.1907	10.9	0.2505	17.0
WashOr	-0.698	-8.0	-1.209	-15.5	-1.36	-21.0
OrWash	-1.873	-6.3	-1.539	-9.2	-1.546	-10.2
WillWE	-0.4855	-4.8	-0.2962	-4.0	-0.456	-7.1
WillEW	-0.2656	-2.7	-0.1703	-2.4		
HillWE	*-0.24275*		*-0.1481*		*-0.228*	
HillEW	*-0.1328*		*-0.08515*			
Hhold	0.22126	-41.5	1.2780	4.4	0.2393	-24.2
ParkAcres			4.6833	12.2		
TotEmp			1	0		
RetEmp	1	0			1	0
SvcEmp					0.6419	-5.9
GvtEmp					0.6109	-5.9
NonRet	0.008396	-22.5				
NonRetSvcGvt					0.06802	-14.2

E.3 NHBW & NHBNW (Non-Home-Based)

E.3.a Variable Definitions

MsLogSum = Logsum of multimodal accessibility functions
WashOr = 1 if trip crosses Columbia River from Washington to Oregon
OrWash = 1 if trip crosses Columbia River from Oregon to Washington
WillWE = 1 if trip crosses Willamette River from west to east
HillWE = 1 if trip crosses West Hills from west to east
Hhold = Number of households in attraction zone
Employment in attraction zone by two-digit SIC codes…
RetEmp = retail trade (SIC 52-59)
SvcEmp = service (SIC 70-89)
GvtEmp = government
Other employment variable…
NonRetSvcGvt = all employment other than retail, service, and government

E.3.b Calibrated Choice Utilities

NHBW

U = **exp (**2.874*MsLogSum – 0.3828*($MsLogSum^2$) + 0.003828*($MsLogSum^3$) – 1.927*WashOr + 0.2672*OrWash – 0.2039*WillWE – 0.2039/2*HillWE + **ln (** 0.2089*Hhold + RetEmp + 0.316*SvcEmp + 0.236*GvtEmp + 0.06911*NonRetSvcGvt **))**

NHBNW

U = **exp (**3.741*MsLogSum – 0.8652*($MsLogSum^2$) + 0.003402*($MsLogSum^3$) – 1.796*WashOr – 0.2155*OrWash – 0.208*WillWE – 0.208/2*HillWE + **ln (** 0.1722*Hhold + RetEmp + 0.1125*SvcEmp + 0.1877*GvtEmp + 0.01555*NonRetSvcGvt **))**

E.3.c Estimated Variable Coefficients

TABLE 17. Non-Home-Based Destination Choice Model

Variable	**NHBW**		**NHBNW**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib LogSum	*2.874*		*3.741*	
Calib $LogSum^2$	*-0.3828*		*-0.8652*	
Calib $LogSum^3$	*0.003828*		*0.003402*	
MsLogSum	2.886	46.9	3.841	65.4
$MsLogSum^2$	-0.3828	-10.5	-0.7402	-23.3
$MsLogSum^3$	N/A		N/A	
WashOr	-1.927	-17.6	-1.796	-19.7
OrWash	0.2672	3.6	-0.2155	-2.5
WillWE	-0.2039	-3.4	-0.208	-3.1
HillWE	*-0.10195*		*-0.104*	
Hhold	0.2089	-22.3	0.1722	-33.6
RetEmp	1	0	1	0
SvcEmp	0.316	-10.6	0.1125	-17.0
GvtEmp	0.236	-10.9	0.1877	-15.4
NonRetSvcGvt	0.06911	-14.6	0.01555	-13.2

E.4 HBcoll (Home-Based College)

HBcoll destination choice is a function of multimodal accessibility and college attractions. The multimodal accessibility value has a calibration coefficient. This simple model was not estimated by multinomial logit.

E.4.a Variable Definitions

MsLogSum	=	Logsum of multimodal accessibility function
Collat	=	HBcoll attractions

E.4.b Calibrated Choice Utility

$U = \mathbf{exp}\ (\ 2.50 * MsLogSum - 0.6 * (MsLogSum^2) + 0.004 * (MsLogSum^3) + \mathbf{Ln}\ (\ Collat\ )\ )$

E.5 HBsch (Home-Based School)

$U = \mathbf{exp}\ (\ \mathbf{ln}\ (\ ATTR_j\ ) - 0.6 * T_{ij} + 0.012 * T_{ij}^2\ )$

Where:

i = from zone
j = to zone
T = mid-day auto travel time

F Mode Choice Model

Modal accessibility functions were estimated as an input to the destination choice and mode choice models. For each trip purpose, they measure the utility of choosing one of nine discrete modes.

Drive alone – only available to households with at least one car
Drive with passenger – only available to households with at least one car
Auto passenger
Bus Only by walk access – only available if both trip ends are within 1/5 mile of a Bus stop
LRT Only by walk access – only available if both trip ends are within 1/5 mile of an LRT station
Bus/LRT by walk access – only available if both trip ends are within 1/5 mile of a Bus stop and 1/2 mile of an LRT station
Transit by park & ride access – only available if one trip end is within 1/5 mile of a transit stop and the other trip end is within a park-and-ride shed.
Bike – only available for trips with a distance less than ten miles
Walk – only available for trips with a distance less than five miles

Note: Per the discussion in Section A.2.b, no more than one walk-access transit mode is used for each zone pair.

Probabilities are applied to distributed trips to determine the number of trips by each mode. An example probability of choosing the Drive Alone mode follows:

$$Prob_{Drive\ Alone} = U_{Drive\ Alone} / (\ U_{Drive\ Alone} + U_{Drive\ with\ Passenger} + U_{Auto\ Passenger} + U_{Walk\ to\ Bus} + U_{Walk\ to\ LRT} + U_{Walk\ to\ Bus/LRT} + U_{Park\&Ride} + U_{Bike} + U_{Walk}\ )$$

F.1 HBW (Home-Based Work)

F.1.a Variable Definitions

IvTime = In-vehicle travel time (varies by mode)
WalkTime = Walk time, by mode:
    Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere)
    Shared Ride: Drive Alone walk time plus 5 minutes
    Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1 = Transit initial wait time
TranWait2 = Transit transfer wait time
TranBrds = Transit # of Transfers
Tdist = Total Trip Distance
Wdist = Total Walk Distance
LowInc = 1 if household income <$25K
MidInc = 1 if household income $25-50K
HighInc = 1 if household income $50K+
OpCost = Out-of-pocket cost, by mode:
    Drive Alone: $0.091 / mile
    Shared Ride: ½ of Drive Alone out-of-pocket cost
    Walk-access Transit: transit fare
    Park & Ride: transit fare + ($0.091 / mile * 0.25)
MixTotA = Total employment access within ½ mile of attraction zone (see Section A.1.b)
MixRetP = Retail employment access within ½ mile of production zone (see Section A.1.b)
Work1 = 1 if one (and only one) worker in household
Cval0 = 1 if no cars in household
Cval1 = 1 if fewer cars than workers in household (cars > 0)
Cval2 = 1 if same number of cars and workers (cars > 0)
LrgHH = 1 if large household (3+ persons)
Shadow = Park and ride lot shadow cost (see Section A.4)

F.1.b Calibrated Choice Utilities

Drive Alone

U = **exp (** -0.03608*IvTime – 0.09956*WalkTime – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost – 2.169*Cval1 – 0.02914*Cval2 – 1.887***ln**(Tdist)**)**

Drive with Passenger

U = **exp (** -3.362 – 0.03608*IvTime – 0.09956*WalkTime – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost – 0.8725*Cval1 + 0.5853*LrgHH – 1.887***ln**(Tdist)**)**

Auto Passenger

U = **exp (** -4.016– 0.03608*IvTime – 0.09956*WalkTime – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost + 0.07042*MixTotA – 1.887***ln**(Tdist)**)**

Transit by Walk Access - Bus

U = **exp (** -4.35 – 0.03608*IvTime – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*(TranBrds-1) –1.304***ln**(Tdist)– 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost + 0.1314*MixRetP + 0.09828***ln**(MixTotA) + 0.2842*Work1 + 1.268*Cval0**)**

Transit by Walk Access - LRT

U = **exp (** -3.809 – 0.03608*IvTime – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*(TranBrds-1) –1.304***ln**(Tdist)– 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost + 0.1314*MixRetP + 0.09828***ln**(MixTotA) + 0.2842*Work1 + 1.268*Cval0**)**

Transit by Walk Access – LRT/Bus

U = **exp (** -3.809– 0.03608*IvTime – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*(TranBrds-1) –1.304***ln**(Tdist)– 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost + 0.1314*MixRetP + 0.09828***ln**(MixTotA) + 0.2842*Work1 + 1.268*Cval0**)**

Park & Ride

U = **exp (** -6.504 – 0.03608*IvTime – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*(TranBrds-1) – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*Opcost + 0.5178*MixTotA – 1.498*Cval1 + Shadow**)**

Bike

U = **exp (** -5.445 – 3.115***ln**(Tdist)+ 0.1279***ln**(MixTotA)**)**

Walk

U = **exp (** -6.454 **–** 4.307***ln**(Wdist) + 0.3345***ln**(MixRetP)**)**

F.1.c Estimated Variable Coefficients

TABLE 18. HBW Mode Choice Model – Auto Modes

Variable	**Drive Alone**		**Drive with Passenger**		**Auto Passenger**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			*-3.362*		*-4.016*	
Constant			-3.262	-26.8	-3.044	-20.3
IvTime	-0.03608	-6.3	-0.03608	-6.3	-0.03608	-6.3
WalkTime	-0.09956	-9.7	-0.09956	-9.7	-0.09956	-9.7
LogTdist	-1.887	-6.4	-1.887	-6.4	-1.887	-6.4
LowIncOpCost	-0.6587	-9.5	-0.6587	-9.5	-0.6587	-9.5
MidIncOpCost	-0.6097	-12.1	-0.6097	-12.1	-0.6097	-12.1
HighIncOpCost	-0.4029	-7.1	-0.4029	-7.1	-0.4029	-7.1
MixTotA					0.07042	4.0
Cval1	-2.169	-20.7	-0.8725	-5.0		
Cval2	-0.02914	-0.4				
LrgHH			0.5853	5.0		

TABLE 19. HBW Mode Choice Model – Transit Modes

Variable	Walk Access Bus		Walk to LRT, LRT/Bus		Park & Ride	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	*-4.35*		*-3.809*		*-6.504*	
Constant	-4.678	-10.0	-4.678	-10.0	-6.504	-7.3
Ivtime	-0.03608	-6.3	-0.03608	-6.3	-0.03608	-6.3
Wait1	-0.0576	-5.8	-0.0576	-5.8	-0.0576	-5.8
Wait2	-0.04002	-5.2	-0.04002	-5.2	-0.04002	-5.2
WalkTime	-0.09956	-9.7	-0.09956	-9.7	-0.09956	-9.7
Transfers	-0.3	*	-0.3	*	-0.3	*
LogTdist	-1.304	-4.4	-1.304	-4.4	-1.304	-4.4
LowIncOpCost	-0.6587	-9.5	-0.6587	-9.5	-0.6587	-9.5
MidIncOpCost	-0.6097	-12.1	-0.6097	-12.1	-0.6097	-12.1
HighIncOpCost	-0.4029	-7.1	-0.4029	-7.1	-0.4029	-7.1
MixRetP	0.1314	3.9	0.1314	3.9		
MixTotA	0.09828	3.1	0.09828	3.1	0.05178	1.0
Work1	0.2842	2.5	0.2842	2.5		
Cval0	1.268	6.6	1.268	6.6		
Cval1					-1.498	-3.3

TABLE 20. HBW Mode Choice Model – Nonmotorized Modes

Variable	Bike		Walk	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	*-5.445*		*-6.454*	
Constant	-4.867	-13.6	-5.216	-13.7
LogTdist	-3.115	-9.9		
LogWdist			-4.307	-13.9
MixTotA	0.1279	3.0		
MixRetP			0.3345	7.7

F.2 HBshop, HBrec, HBoth (Other Home-Based)

F.2.a Variable Definitions

Shop	=	1 if HBshop trip
Rec	=	1 if HBrec trip
Oth	=	1 if HBoth trip
IvTime	=	In-vehicle travel time (varies by mode)
WalkTime	=	Walk time, by mode:
		Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere)
		Shared Ride: Drive Alone walk time plus 5 minutes
		Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1	=	Transit initial wait time
TranWait2	=	Transit transfer wait time
TranBrds	=	Transit # of Transfers
Tdist	=	Total Trip Distance
Wdist	=	Total Walk Distance
LowInc	=	1 if household income <$25K
MidInc	=	1 if household income $25-50K
HighInc	=	1 if household income $50K+
OpCost	=	Out-of-pocket cost, by mode:
		Drive Alone: $0.091 / mile
		Shared Ride: ½ of Drive Alone out-of-pocket cost
		Walk-access Transit: transit fare
		Park & Ride: transit fare + ($0.091 / mile * 0.25)
MixTotA	=	Total employment access within ½ mile of attraction zone (see Section A.1.b)
MixRetP	=	Retail employment access within ½ mile of production zone (see Section A.1.b)
Cval0	=	1 if no cars in household
Cval1	=	1 if fewer cars than workers in household (cars > 0)
Cval2	=	1 if same number of cars and workers (cars > 0)
SingHH	=	1 if 1-person household
LrgHH	=	1 if large household (3+ persons)
Shadow	=	Park and ride lot shadow cost (see Section A.4)

F.2.b Calibrated Choice Utilities

Drive Alone

U = **exp(** -0.0215*IvTime – 0.1033*WalkTime – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost – 0.747***ln**(Tdist)**)**

Drive with Passenger

U = **exp (**-0.6082*Shop – 0.6602*Rec + 0.0223*Oth – 0.0215*IvTime – 0.1033*WalkTime – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost –1.51*SingHH + 0.8491* LrgHH – 0.747***ln**(Tdist)**)**

Auto Passenger

U = **exp (** -0.6304*Shop –0.3492*Rec – 0.4104*Oth – 0.0215*IvTime – 0.1033*WalkTime – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost – 1.288*SingHH + 1.307*LrgHH – 0.747***ln**(Tdist)**)**

Transit by Walk Access - Bus

U = **exp (** -3.85*Shop – 3.85*Rec – 4.35*Oth – 0.0215*IvTime – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*(TranBrds–1) – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost + 0.1664*MixTotA + 1.971*Cval0 + 1.129*Cval1 + 0.2874*Cval2**)**

Transit by Walk Access - LRT

U = **exp (** -3.635*Shop – 3.635*Rec – 4.135*Oth – 0.0215*IvTime – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*(TranBrds–1) – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost + 0.1664*MixTotA + 1.971*Cval0 + 1.129*Cval1 + 0.2874*Cval2**)**

Transit by Walk Access – LRT/Bus

U = **exp (** -3.635*Shop – 3.635*Rec – 4.135*Oth – 0.0215*IvTime – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*(TranBrds–1) – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost + 0.1664*MixTotA + 1.971*Cval0 + 1.129*Cval1 + 0.2874*Cval2**)**

Park & Ride

U = **exp (** -6.742*Shop – 7.023*Rec – 6.723*Oth – 0.0215*IvTime – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*(TranBrds-1) – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost + 0.3073***ln**(MixTotA) + Shadow**)**

Bike

U = **exp (** – 4.105*Shop – 2.605*Rec – 4.194*Oth **–** 1.804***ln**(Tdist)**)**

Walk

U = **exp (** – 3.458*Shop – 2.461*Rec – 3.547*Oth – 2.466***ln**(Wdist)+ 0.1248***ln**(MixRetP) + 0.5997*LrgHH**)**

F.2.c Estimated Variable Coefficients

TABLE 21. HBshop, HBrec, HBoth Mode Choice Model – Auto Modes

Variable	Drive Alone		Drive with Passenger		Auto Passenger	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Shop			*-0.6082*		*-0.6304*	
Calib Rec			*-0.6602*		*-0.3492*	
Calib Oth			*0.0223*		*-0.4104*	
Shop			-0.4904	-6.3	-0.5719	-7.4
Rec			-0.585	-7.3	-0.2595	-3.3
Oth			0.153	2.1	-0.3144	-4.2
IvTime	-0.0215	-3.2	-0.0215	-3.2	-0.0215	-3.2
WalkTime	-0.1033	-8.3	-0.1033	-8.3	-0.1033	-8.3
LogTdist	-0.747	-7.8	-0.747	-7.8	-0.747	-7.8
LowIncOpCost	-0.4724	-6.8	-0.4724	-6.8	-0.4724	-6.8
MidIncOpCost	-0.2457	-5.2	-0.2457	-5.2	-0.2457	-5.2
HighIncOpCost	-0.2457	-5.2	-0.2457	-5.2	-0.2457	-5.2
Cval1	-0.3965	-5.4	-0.1503	-2.1		
SingHH			-1.51	-18.7	-1.288	-17.6
LrgHH			0.8491	21.1	1.307	32.8

TABLE 22. HBshop, HBrec, HBoth Mode Choice Model – Transit Modes

Variable	Walk Access Bus		Walk to LRT, LRT/Bus		Park & Ride	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Shop	*-3.85*		*-3.635*		*-6.472*	
Calib Rec	*-3.85*		*-3.635*		*-7.023*	
Calib Oth	*-4.35*		*-4.135*		*-6.723*	
Constant	-4.429	-11.3	-4.429	-11.3	-7.023	-3.8
IvTime	-0.0215	-3.2	-0.0215	-3.2	-0.0215	-3.2
TranWait1	-0.06847	-5.4	-0.06847	-5.4	-0.06847	-5.4
TranWait2	-0.0524	-4.8	-0.0524	-4.8	-0.0524	-4.8
WalkTime	-0.1033	-8.3	-0.1033	-8.3	-0.1033	-8.3
TranBrds	-0.3	*	-0.3	*	-0.3	*
LowIncOpCost	-0.4724	-6.8	-0.4724	-6.8	-0.4724	-6.8
MidIncOpCost	-0.2457	-5.2	-0.2457	-5.2	-0.2457	-5.2
HighIncOpCost	-0.2457	-5.2	-0.2457	-5.2	-0.2457	-5.2
MixTotA	0.1664	4.4	0.1664	4.4	0.3073	1.5
Cval0	1.971	11.3	1.971	11.3		
Cval1	1.129	5.5	1.129	5.5		
Cval2	0.2874	1.8	0.2874	1.8		

TABLE 23. HBshop, HBrec, HBoth Mode Choice Model – Nonmotorized Modes

Variable	**Bike**		**Walk**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Shop	*-4.105*		*-3.458*	
Calib Rec	*-2.605*		*-2.461*	
Calib Oth	*-4.194*		*-3.547*	
Constant	-3.734	-37.2	-2.622	-18.3
Rec	1.008	7.8		
LogTdist	-1.804	-14.1		
LogWdist			-2.466	-22.1
MixRetP			0.1248	7.6
LrgHH			0.5997	9.7

F.3 NHBW & NHBNW (Non-Home-Based)

Cost coefficients do not vary by income group for non-home-based trips.

F.3.a Variable Definitions

NHBW = 1 if NHBW trip
NHBNW = 1 if NHBNW trip
IvTime = In-vehicle travel time (varies by mode)
WalkTime = Walk time, by mode:
 Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere)
 Shared Ride: Drive Alone walk time plus 5 minutes
 Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1 = Transit initial wait time
TranWait2 = Transit transfer wait time
TranBrds = Transit # of Transfers
Tdist = Total Trip Distance
Wdist = Total Walk Distance
OpCost = Out-of-pocket cost, by mode:
 Drive Alone: $0.091 / mile
 Shared Ride: ½ of Drive Alone out-of-pocket cost
 Walk-access Transit: transit fare
MixRetP = Retail employment access within ½ mile of production zone (see Section A.1.b)

Calibrated Choice Utilities

Drive Alone

U = **exp (** -0.025*IvTime – 0.1493*WalkTime – 0.2916*OpCost**)**

Drive with Passenger

U = **exp (** -1.202*NHBW + 0.4297*NHBNW – 0.025*IvTime – 0.1493*WalkTime – 0.2916*OpCost**)**

Auto Passenger

U = **exp (** -1.745*NHBW + 0.757*NHBNW – 0.025*IvTime – 0.1493*WalkTime – 0.2916*OpCost – 0.06557***ln**(Tdist)**)**

Transit by Walk Access - Bus

U = **exp (** -1.863*NHBW – 1.434*NHBNW – 0.025*IvTime – 0.1337*TranWait1 – 0.07895*TranWait2 – 0.1493*WalkTime – 0.3*(TranBrds-1) – 0.2916*OpCost + 0.771*ln(Tdist)**)**

Transit by Walk Access - LRT

U = **exp (** -1.613*NHBW – 1.184*NHBNW – 0.025*IvTime – 0.1337*TranWait1 – 0.07895*TranWait2 – 0.1493*WalkTime – 0.3*(TranBrds-1) – 0.2916*OpCost + 0.771*ln(Tdist)**)**

Transit by Walk Access - LRT/Bus

U = **exp (** -1.613*NHBW – 1.184*NHBNW – 0.025*IvTime – 0.1337*TranWait1 – 0.07895*TranWait2 – 0.1493*WalkTime – 0.3*(TranBrds-1) – 0.2916*OpCost + 0.771*ln(Tdist)**)**

Bike

U = **exp (** -4.687*NHBW – 4.488*NHBNW **–** 0.8608***ln**(Tdist)**)**

Walk

U = **exp (** -4.289*NHBW – 4.054*NHBNW – 1.524***ln**(Wdist) + 0.2553***ln**(MixRetP)**)**

F.3.b Estimated Variable Coefficients

TABLE 24. Non-Home-Based Mode Choice Model – Auto Modes

Variable	**Drive Alone**		**Drive with Passenger**		**Auto Passenger**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib NHBW			*-1.202*		*-1.745*	
Calib NHBNW			*0.4297*		*0.757*	
NHBW			-1.393	-12.0	-1.476	-12.6
NHBNW			0.4992	4.7	0.7225	6.8
IvTime	-0.025	*	-0.025	*	-0.025	*
WalkTime	-0.1493	-7.6	-0.1493	-7.6	-0.1493	-7.6
LogTdist					-0.06557	-3.0
OpCost	-0.2916	-7.3	-0.2916	-7.3	-0.2916	-7.3

TABLE 25. Non-Home-Based Mode Choice Model – Transit Modes

Variable	**Walk Access Bus**		**Walk to LRT, LRT/Bus**	
	Coefficient	T-Statistic	T-Statistic	T-Statistic
Calib NHBW	*-1.863*		*-1.613*	
Calib NHBNW	*-1.434*		*-1.184*	
Constant	-2.384	-15.2	-2.384	-15.2
IvTime	-0.025	*	-0.025	*
TranWait1	-0.1337	-6.3	-0.1337	-6.3
TranWait2	-0.07895	-5.2	-0.07895	-5.2
WalkTime	-0.1493	-7.6	-0.1493	-7.6
TranBrds	-0.3	*	-0.3	*
LogTdist	0.771	8.6	0.771	8.6
OpCost	-0.2916	-7.3	-0.2916	-7.3

TABLE 26. Non-Home-Based Mode Choice Model – Nonmotorized Modes

Variable	**Bike**		**Walk**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib NHBW	*-4.687*		*-4.289*	
Calib NHBNW	*-4.488*		*-4.054*	
Constant	-4.367	-37.6	-3.924	-18.9
LogTdist	-0.8608	-8.0		
LogWdist			-1.524	-32.2
MixRetP			0.2553	10.6

F.4 HBcoll (Home-Based College)

Cost coefficients do not vary by income group for college commute trips.

F.4.a Variable Definitions

IvTime = In-vehicle travel time (varies by mode)
WalkTime = Walk time, by mode:
Drive Alone: vehicle egress at trip end (5 min in CBD, 2 min elsewhere)
Shared Ride: Drive Alone walk time plus 5 minutes
Transit Modes: access to first stop plus egress from last stop at 3 mph
TranWait1 = Transit initial wait time
TranWait2 = Transit transfer wait time
TranBrds = Transit # of Transfers
Tdist = Total Trip Distance
Wdist = Total Walk Distance
OpCost = Out-of-pocket cost, by mode:
Drive Alone: $0.091 / mile
Shared Ride: ½ of Drive Alone out-of-pocket cost
Walk-access Transit: transit fare
Park & Ride: transit fare + ($0.091 / mile * 0.25)
MixRetP = Retail employment access within ½ mile of production zone (see Section A.1.b)
MixTotA = Total employment access within ½ mile of attraction zone (see Section A.1.b)
Cval0 = 1 if no cars in household
Cval1 = 1 if fewer cars than workers in household (cars > 0)
LrgHH = 1 if large household (3+ persons)
Shadow = Park and ride lot shadow cost (see Section A.4)

F.4.b Calibrated Choice Utilities

Drive Alone

U = **exp (** -0.05319*IvTime – 0.2111*WalkTime – 0.1407*OpCost – 0.5914*Cval1**)**

Drive with Passenger

U = **exp (** -1.996 – 0.05319*IvTime – 0.2111*WalkTime – 0.1407*OpCost + 1.175*LrgHH**)**

Auto Passenger

U = **exp (** 1.152 – 0.05319*IvTime – 0.2111*WalkTime – 0.1407*OpCost + 1.128*Cval1 – 0.7154*ln(Tdist) – 0.1271***ln**(MixTotA)**)**

Transit by Walk Access - Bus

U = **exp (** -0.532 – 0.05319*IvTime – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*(TranBrds-1) – 0.1407*OpCost + 0.1941*Cval0 + 1.022***ln**(Tdist)**)**

Transit by Walk Access - LRT

U = **exp (** -0.05319*IvTime – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*(TranBrds-1) – 0.1407*OpCost + 0.1941*Cval0 + 1.022***ln**(Tdist)**)**

Transit by Walk Access – LRT/Bus

U = **exp (** -0.05319*IvTime – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*(TranBrds-1) – 0.1407*OpCost + 0.1941*Cval0 + 1.022***ln**(Tdist)**)**

Park and Ride

U = **exp (** -1.1 – 0.05319*IvTime – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*(TranBrds-1) – 0.1407*OpCost + Shadow**)**

Bike

U = **exp (** 0.086 – 1.588***ln**(Tdist) **+** 0.2431*MixTotA**)**

Walk

U = **exp (-**2.292 – 2.264***ln**(Wdist) + 0.386*MixRetP**)**

F.4.c Estimated Variable Coefficients

TABLE 27. HBcoll Mode Choice Model – Auto Modes

Variable	**Drive Alone**		**Drive with Passenger**		**Auto Passenger**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			*-1.996*		*1.152*	
Constant			1.839	-4.2	0.8889	2.2
IvTime	-0.05319	-2.9	-0.05319	-2.9	-0.05319	-2.9
WalkTime	-0.2111	-3.7	-0.2111	-3.7	-0.2111	-3.7
LogTdist	-0.8608	-8.0			-0.7154	-5.5
OpCost	-0.1407	-1.2	-0.1407	-1.2	-0.1407	-1.2
LrgHH			1.175	3.7		
Cval1	-0.5914	-1.9			1.128	3.4
MixTotA					-0.1271	-3.6

TABLE 28. HBcoll Mode Choice Model – Transit Modes

Variable	**Walk Access Bus**		**Walk to LRT, LRT/Bus**		**Park & Ride**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	*-0.532*		*0*		*-1.1*	
Constant	-1.175	-3.4	-1.175	-3.4	-1.175	-3.4
IvTime	-0.05319	-2.9	-0.05319	-2.9	-0.05319	-2.9
TranWait1	-0.0652	-2.7	-0.0652	-2.7	-0.0652	-2.7
TranWait2	-0.05302	-2.3	-0.05302	-2.3	-0.05302	-2.3
WalkTime	-0.2111	-3.7	-0.2111	-3.7	-0.2111	-3.7
TranBrds	-0.3	*	-0.3	*	-0.3	*
LogTdist	-0.8608	-8.0	1.022	3.5		
OpCost	-0.1407	-1.2	-0.1407	-1.2	-0.1407	-1.2
Cval0	0.1941	0.5	0.1941	0.5		

TABLE 29. HBcoll Mode Choice Model – Nonmotorized Modes

Variable	Bike		Walk	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	*0.086*		*-2.292*	
Constant	-4.211	-5.5	-4.271	-5.8
LogTdist	-1.588	-6.9		
LogWdist			-2.264	-11.2
MixRetP			0.3855	4.5
MixTotA	0.2431	2.8		

F.5 HBsch (Home-Based School)

The HBsch model is a simple cross-classification into mode by location of production (home). This accounts for varying levels of school bus service provision between school districts. District definitions refer to the 8-district boundaries shown in Appendix B.

TABLE 30. HBsch Mode Choice Model

Location	Dist	Auto Driver	Auto Passenger	City Transit	Walk or Bike	School Bus
City of Portland	1,5,7	0.0383	0.2487	0.1406	0.4068	0.1656
East Suburbs	4,6	0.062	0.2256	0.0143	0.2178	0.4803
West Suburbs	2,3	0.1015	0.1936	0.0148	0.1943	0.4958
Clark County	8	0.1184	0.2485	0.0065	0.2469	0.3797

G Time of Day Factors

Time of day travel is estimated separately for auto and transit, and the factors are direction-specific. Factors can be estimated for any hour by using start time data from the 1994-95 household activity survey. The most commonly used time of day factors are given in the following tables.

TABLE 31. Auto Peaking Factors

	AM2 0700-0859	AM4 0600-0959	MD1_12-1 1200-1259	MD1_2-3 1400-1459	PM2 1600-1759	PM4 1500-1859
HBW						
1-2 person HH Attractions	0.0062	0.0124	0.0193	0.0263	0.1853	0.2965
3-4 person HH Attractions	0.0066	0.0098	0.0193	0.0263	0.1932	0.3137
1-2 person HH Productions	0.2456	0.3695	0.0154	0.0150	0.0169	0.0284
3-4 person HH Productions	0.2342	0.3626	0.0154	0.0150	0.0173	0.0352
HBshop,rec,other						
0-1 worker HH Attractions	0.0264	0.0446	0.0281	0.0326	0.0888	0.1732
2-3 worker HH Attractions	0.0246	0.0403	0.0281	0.0326	0.1104	0.2142
0-1 worker HH Productions	0.0760	0.1340	0.0253	0.0310	0.0518	0.1303
2-3 worker HH Productions	0.0947	0.1397	0.0253	0.0310	0.0638	0.1477

<u>NHBW</u>						
Attractions	0.1250	0.1683	0.0437	0.0220	0.0121	0.0227
Productions	0.0262	0.0534	0.0839	0.0553	0.1897	0.2913
<u>NHBNW</u>						
Total - divide by 2 for P&A	0.0819	0.1365	0.0862	0.0943	0.1630	0.3061
<u>College</u>						
Attractions	0.0067	0.0137	0.0509	0.0489	0.0869	0.1411
Productions	0.2577	0.3228	0.0289	0.0048	0.0161	0.0821
<u>School</u>						
Attractions	0.0011	0.0119	0.0182	0.1623	0.0513	0.1524
Productions	0.5054	0.5275	0.0102	0.0045	0.0250	0.0140

Auto trips are adjusted to match counts during some peak periods.

TABLE 32. Adjustments to Auto Peaking Factors

	AM2 **0700-0859**	**AM4** **0600-0959**	**MD1_12-1** **1200-1259**	**MD1_2-3** **1400-1459**	**PM2** **1600-1759**	**PM4** **1500-1859**
<u>Columbia River Crossings</u>						
Oregon to Washington	1.0	1.6	0.8	1.0	0.7	0.78
Washington to Oregon	1.0	0.7	0.85	1.0	1.0	1.2
<u>Hayden Island – Washington</u>						
Hayden Island to Washington	1.0	1.0	2.0	1.0	1.0	2.0
Washington to Hayden Island	1.0	1.0	2.0	1.0	1.0	1.5
<u>West Hills Crossings</u>						
West to East	1.0	1.0	1.0	1.0	1.0	1.0
East to West	1.0	1.0	1.0	1.0	0.7	1.0
<u>Willamette River Crossings</u>						
West to East	1.0	1.0	1.0	1.0	0.75	1.0
East to West	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 33. Transit Peaking Factors

	Peak Portion of All Day	Off-Peak Portion of All Day		PM 1-Hour Peak	PM 2-Hour Peak
HBW			**HBW**		
Peak Direction	0.4806	0.5194	Attractions	0.1554	0.2380
Off-Peak Direction	0.0106	0.9894	Productions	0.0009	0.0046
HBshop,rec,other			**HBshop,rec,other**		
Peak Direction	0.2423	0.7577	Attractions	0.0627	0.1311
Off-Peak Direction	0.0607	0.9393	Productions	0.0208	0.0558
NHBW			**NHBW**		
Peak Direction	0.0353	0.9647	Attractions	0.0001	0.0094
Off-Peak Direction	0.3426	0.6574	Productions	0.1695	0.2404
NHBNW			**NHBNW**		
Peak Direction	0.10045	0.89955	Attractions	0.0209	0.04095
Off-Peak Direction	0.10045	0.89955	Productions	0.0209	0.04095
College			**College**		
Peak Direction	0.3421	0.6579	Attractions	0.0254	0.0543
Off-Peak Direction	0.0696	0.9304	Productions	0.0057	0.0696
School			**School**		
Peak Direction	0.4468	0.5532	Attractions	0.0390	0.0922
Off-Peak Direction	0.0088	0.9912	Productions	0.0088	0.0088

H Assignment

H.1 Auto Assignment

The model is developed in EMME/2 macro language and run with EMME/2 software. This package has a full capacity-restrained equilibrium path-finding algorithm. The number of lanes, lane capacity, initial speed, and distance are all link attributes. The link capacity, initial speed, and distance are attributes used in estimating the speed under two given flow rates. Autos and trucks are often assigned simultaneously using a multi-class assignment technique. Truck delays on the arterial system are higher than that for autos. Hence, truck flows tend to use higher order facilities in the path choice algorithm. Trucks are assigned as passenger car equivalents (PCEs) to account for the different space consuming characteristics.

H.2 Transit Assignment

Transit multipath assignment follows full auto assignment and 1) determines the shortest path using total impedance (weighting can be used), 2) identifies and collects all other alternative paths with in-vehicle impedance less than or equal to the total shortest path value, and 3) assigns trips to the subset of alternative paths based on the relative first wait impedance for each of them.

Transit speed is a function of the existing auto volumes on each network link, unless the transit vehicle is on its own right of way.

I External Model

The characteristics of external trips are different from the other purposes, so the procedure to calculate the trips is not the same as the others. The following steps are used to model external trip generation.

1. Calculate Average Weekday (AWD) target volume for each external location
2. Calculate Average Weekday (AWD) target volume for five trip components at each station by using percents from the 1987 external travel survey. The components follow:

- External-Internal Home-Based Work Trips
- External-Internal Non-Home-Based Work Trips
- Internal-External Recreational Trips
- Internal-External Non-Recreational Trips
- External-External Trips

TABLE 34. External Destination Choice Equations

Ext-Int HBW	**Estimation & Calibration**	U = exp ($\ln(ATTR_j) - 0.135*T_{ij}$)
Ext-Int NonHBW	**Estimation & Calibration**	U = exp ($\ln(ATTR_j) - 0.125*T_{ij}$)
Int-Ext Rec	**Estimation & Calibration**	U = exp ($0.0002448*AWD - 0.03474*T_{ij}$)
Int-Ext NonRec	**Estimation & Calibration**	U = exp ($0.0001106*AWD - 0.07041*T_{ij}$)
Ext-Ext	**Calibration**	using percents from 1987 cordon survey

Where:

i = from zone
j = to zone
T = travel time
AWD = average weekday traffic volume

Certain movements are restricted within the externals program; this is done to prevent illogical entry and exit combinations. External trips are added to the auto trip table at the end of the modeling process, but before trip assignment.

J Truck Model

Data from the strategic model database are the primary inputs to the tactical model. These data are reported in tons (also available in TEUs) and stratified by commodity group, primary mode, origin, destination, truck sub-mode (for some modes), containerized/non-containerized, and year (1996 to 2030).

J.1 Allocation of Flows to Truck Sub-modes

The total numbers of tons were summed by commodity, mode, and direction. These flows were then separated by primary mode. Where available, the flows were further stratified by truck sub-mode. The sea_truck, air_truck, and truck only groups directly or indirectly had truck sub-mode identified in the ICF database. Where truck sub-mode was not available, the Port provided some guidance to determine the factors.

Mode	Commodity	Private	LTL	TL
Rail_truck	All	50%	25%	25%
Sea_rail_dray	All	50%	25%	25%
Barge_truck	All	0%	0%	100%

J.2 Application of Weekday Factor

A simple 1/264 factor was used to reduce annual flows to daily. No seasonal adjustments were made.

J.3 Allocation of Flows with local Origins/Destinations to TAZs

Metro Data Resource Center was able to provide 1996 Employment data by 2-digit SIC. They were grouped as follows:

SIC Employment Group	SICs
Agriculture/Farming/Forestry (AGFF)	1-9
Mining (MIN)	10-14
Construction (CON)	15-17
Manufacturing (MAN)	20-39
Transportation/Communications/Public Utilities (TCPU)	40-49
Wholesale (WHLS)	50-51
Retail (RET)	52-59
Finance/Insurance/Real Estate (FIRE)	60-67
Service (SERV)	70-89
Government (GOV)	91-97

With CS guidance, the employment sectors that were likely to generate or attract freight were identified. Those SIC groups were the following:

- Agriculture/Farming/Forestry (AGFF)
- Mining (MIN)
- Construction (CON)
- Manufacturing (MAN)
- Transportation/Communications/Public Utilities (TCPU)
- Wholesale (WHLS)

The flows were allocated to regional TAZs using these SIC employment totals. Beginning with this step (2.1), all steps are performed in the EMME/2 software environment.

J.4 Allocation of Flows to Terminals and Other Regional "Gateways"

Those flows that entered or left the region at specific sites such as railyards, barge terminals, marine facilities, the airport, and external points were assigned one trip end at those places.

Based on discussions with the Port staff, percentages were determined to allocate flows to each of the specific rail, barge, ship, and air facilities.

Rail flows were allocated equally to the three main railyards in the region. All commodities were given the same percentage.

Railyard	Percent of Total Rail_Truck Flows
Albina	33%
Brooklyn	33%
Wilbridge	33%

Ship to truck flows were given commodity-specific distribution percentages for Portland vs. Vancouver, as per Port staff designations. These marine facilities included Portland and Vancouver locations along the Willamette and Columbia Rivers. Within Portland or Vancouver, the flows were allocated equally among the zones specified.

Railyards

Commodity	Import % Portland	Import % Vancouver	Export % Portland	Export % Vancouver	TAZs (1260-zone system)
Farm Products	80	20	70	30	6,846, 925,970,971
Metallic Minerals & Coal	40	60	40	60	25,925, 970,971
Non-metallic Minerals	100	0	70	30	25,925, 970,971
Chemicals	80	20	95	5	25,925, 970,971
Petroleum Products	95	5	70	30	25,26, 925,970,971
Stone, Clay, Concrete, Ceramic, or Glass	100	0	70	30	25,26, 950,852,912,925,970,971
Food, Fish, & Marine Products, Tobacco	80	20	99	1	925,970,971
Lumber or Wood Products, Furniture	80	20	80	20	25,26, 970,971
Pulp, Paper, & Printed Matter	N/A	N/A	N/A	N/A	N/A
Primary & Fabricated Metal Products	80	20	70	30	851,925,970,971
Machinery & Electrical Equipment	80	20	70	30	19,25,26,925,970,971
Transportation Equipment	80	20	70	30	925,926,971,971
Misc. Manufactures, Instruments, Ordnance	80	20	70	30	925,970,971
Textiles, Apparel, Leather, and Products	80	20	70	30	19,25,26,925,970,971
Waste by-Products	80	20	70	30	925
Courier Services (packages)	N/A	N/A	N/A	N/A	N/A

Barge flows were allocated in a similar fashion:

Commodity	Inbound % Portland	Inbound % Vancouver	Outbound % Portland	Outbound % Vancouver	TAZs (1260-zone system)
Farm Products	70	30	94	6	6,846, 925,970,971
Metallic Minerals & Coal	83	17	94	6	25,925, 970,971
Non-metallic Minerals	83	17	94	6	25,925, 970,971
Chemicals	83	17	94	6	25,925, 970,971
Petroleum Products	93	7	94	6	25,26, 925,970,971
Stone, Clay, Concrete, Ceramic, or Glass	83	17	94	6	25,26, 950,852,912,925,970,971
Food, Fish, & Marine Products, Tobacco	83	17	94	6	925,970,971
Lumber or Wood Products, Furniture	83	17	94	6	25,26, 970,971
Pulp, Paper, & Printed Matter	N/A	N/A	N/A	N/A	N/A
Primary & Fabricated Metal Products	83	17	94	6	851,925,970,971
Machinery & Electrical Equipment	83	17	94	6	19,25,26,925,970,971
Transportation Equipment	83	17	94	6	925,926,971,971
Misc. Manufactures, Instruments, Ordnance	83	17	94	6	925,970,971
Textiles, Apparel, Leather, and Products	83	17	94	6	19,25,26,925,970,971
Waste by-Products	83	17	94	6	925
Courier Services (packages)	N/A	N/A	N/A	N/A	N/A

External highway points are gateways for flows entering or leaving the region by truck. The ICF database identified three external directions (North, South, and other). The I-5 north external, in Clark County, was designated the gateway for all North flows; the I-84 east external for all Other flows; and the I-5 south external for all South flows. All other external points were assumed not to carry any significant truck traffic for external points, as defined by ICF.

J.5 Linking of flow Origins and Destinations

Proportions used to determine distribution of flows between origins and destinations were determined by the employment allocations.

J.6 Linkage of Commodity Flows to Reload Facilities or Terminals

As recommended in the CS document, all LTL flows from non-truck primary modes were allocated to reload facilities. The Port suggested designating all LTL flows for reload, so 100% of the truck-only LTL flows were also directed to reload and truck terminals. In addition, 3% of the TL/Private flows are routed through reload facilities. Port staff indicated that a small fraction of shipments transported by private trucks are reloaded. No unique factors were obtained for the separate commodity groups.

J.7 Allocation of LTL Flows to Reload Facilities

All LTL flows were routed through reload facilities, truck terminals, or distribution centers based on the proportion of expected total daily truck-ins and -outs. First, a list of reload facilities, truck terminals, and distribution centers was constructed to form the universe of all possible intermediate destinations for these flows. This list included the location (TAZ) of each site and number of employees. Other size variables, such as number of freight doors and square footage, that could have been used to estimate activity was included in the database, but not complete for all locations. Thus, the number of employees was used with the count data collected at select locations to estimate daily ins/outs at each facility in the database. Where available, actual count data was used. For all remaining sites, a factor of 1.75 truck ins/outs per employee was used to estimate activity. The daily ins/outs at each location were summed by TAZ. This data was then used to allocate the LTL flows to the possible intermediate destinations around the region. The same proportions were used to “back into” determining the allocation of the “second” leg of the flow from the reload facilities to the destination TAZ.

J.8 Modeling Pickup and Delivery Tours

Insufficient data were available to simulate pickup and delivery tours. This version of the model does not contain additional processing to replicate this type of trip. However, the zonal goods are picked up by fractions of trucks. The fraction being determined by the commodity load factor.

J.9 Apply Heavy Truck Flow Fractions to Remove Flows Made by Non-Heavy Trucks

Highway vehicle classification counts were used to develop average percentages of heavy versus non-heavy trucks on the system. This, combined with average weight carried by each truck type, produced split factors for flows carried by each truck type. The heavy and non-heavy truck count split was 70% and 30%, respectively. This translated to 92% of flows being carried by heavy trucks and the remaining 8% on medium trucks.

J.10 Apply Flow to Truck Trip Factors

Separate commodity class tons to truck trip factors were obtained for the heavy and medium trucks using data from the VIUS (Vehicle Inventory and Use Survey) which was provided to us by Cambridge staff.

Commodity Group	Heavy Trucks			Medium Trucks
Trips < 50 miles	Trips 50 to 500 miles	Trips < 50 miles		Trips 50 to 500 miles
Farm Products	19	22	6	11
Metallic Minerals & Coal	23	23	12	16
Non-metallic Minerals	23	23	12	16
Chemicals	18	21	6	12
Petroleum Products	21	24	5	10
Stone, Clay, Concrete, Ceramic, or Glass	23	23	12	16
Food, Fish, & Marine Products, Tobacco	18	20	4	7
Lumber or Wood Products, Furniture	16	19	3	8
Pulp, Paper, & Printed Matter	18	19	4	9
Primary & Fabricated Metal Products	18	20	4	7
Machinery & Electrical Equipment	17	19	3	5
Transportation Equipment	17	18	3	5
Misc. Manufactures, Instruments, Ordnance	13	17	2	5
Textiles, Apparel, Leather, and Products	17	19	3	7
Waste by-Products	11	16	5	5
Courier Services (packages)	17	19	7	10

These values were in-line with the Port’s estimate of average FEU weight overall of 21 tons/FEU. Based on discussions with Port staff, all TL/PVT flows were assigned to heavy trucks, except for those with origins/destinations in high density, central city areas. We assumed that flows with origins/destinations in the central city are transported primarily by medium trucks. All LTL and TL/PVT flows were put in medium trucks for those TAZs.

J.11 Estimate Additional Vehicle Trip Segment Trip Ends (Unbalanced)

Each matrix of commodity flows was reviewed to determine unbalanced trip origins and destinations. For any given zone, if the origins did not equal the destinations, the smaller of the two was increased to match the other. The purpose of this step is to partially account for empty truck moves.

J.12 Estimate Additional Vehicle Trip Segment Trip Ends (Balanced)

Certain movements such as repositioning and container maintenance require the addition of more truck trips to the trip table(s). However, at this point, there were limited data to estimate such trips. The only additional trips generated in this step were LTL trips to make up the difference between the reload and truck terminal counts (summed by TAZ) and the volumes produced by the tactical model.

J.13 Estimate Through Truck Trips

External-to-external flows which do not involve a mode change inside the region are not included in the strategic model database. Trip tables for medium and heavy external-to external moves were developed independently of the tactical model and then combined with the other trip tables just before assignment.

J.14 Estimate Truck Trip Table by Time of Day

Peaking factors were developed using regional highway count data and reload facility counts. A weighted average of all vehicle classification counts was used to develop the following factors:

A.M. 2-Hour: 12.6% of all day
Midday 1-Hour: 8% of all day, region wide; 5.6% at reload facilities
P.M. 2-Hour: 9.4% of all day

J.15 Assign AWD Truck Trips to Network

For initial review, a multi-class assignment was run using heavy trucks, medium trucks, and passenger cars as the three vehicle classes. All commodity groups were added together to form the two truck trip tables. If necessary, individual commodity class trip tables, could be assigned separately. However, software limitations prohibit all 16 commodity groups to be assigned at the same time without some aggregation.

Before assignment, the truck trip tables are converted to passenger car equivalents (PCEs). This is done to account for the extra space trucks take up on the road and the extra time they take to stop at intersections and accelerate on inclines.

The network also includes separate volume delay functions for the heavy trucks. That is, they are assigned an extra delay or cost when traveling on a non-freeway link in the system. This encourages the larger vehicles to use the freeway links, which more accurately reflects their true route choice.

Roadway counts were used for validation purposes. Model generated assigned trips are compared to observed counts. There are 80 counts locations included in the data set.

The freeway volumes matched fairly well with counts (most within 10%, a few over 20%) and the arterials were generally a little low compared with counts. We believe this is due to the under-representation of pickup and delivery tour intermediate stops.

K Portland International Airport Model

Trips to/from the zone containing the Portland International Airport (PDX) terminal are generated by a special model.

Home-Based Work trips to/from the PDX zone are retained from the household model. The sole change is an auto out-of-vehicle time of 5 minutes (equivalent to CBD zones) rather than 2 minutes (as in the rest of the region) to account for distance to the free employee parking.

Household model trips to/from the PDX zone for all other trip purposes are replaced by airport passenger trips as described in the following sections.

K.1 Enplanements as Inputs to the Model

Total number of enplanements (less transferring passengers) was used as the starting point. The Port of Portland supplied the average number of passengers that boarded their first flight or arrived on their last flight at PDX on a typical weekday in May 2005. The Airport Model assumes that on any given weekday, half of these passengers arrive at PDX and half depart PDX.

In 2005 the Port of Portland forecasted 2.8% annual growth in PDX passenger traffic over the period 2006-2010. This rate is applied to all future years to determine future enplanements/deplanements. For example, 34,617 passengers in 2005 grows to 69,043 in 2030. For 2030, 34,521.5 are treated as productions and 34,521.5 are treated as attractions.

K.2 Airport Mode Choice

While there is a diverse array of potential travel modes to/from PDX (including rental cars, taxis, limousines, vans, and shuttles), Metro lacks survey data on ground transportation choices of PDX passengers that date from the installation of LRT service to PDX in 2001. The PDX mode choice model thus splits arriving and departing passengers into Auto and LRT modes on the basis of the following data provided by the Port of Portland for FY 2006 (July 2005-June 2006):

- Business travelers represent 41% of passengers; 4% of them use LRT.
- Leisure travelers represent 59% of passengers; 7.1% of them use LRT.

For both productions and attractions, mode choice for passenger trips to/from PDX is determined as follows:

- Business Auto: Trips * 41% * 96% (in the case of 2030 productions, 13,587.7)
- Business LRT: Trips * 41% * 4% (in the case of 2030 productions, 566.2)
- Leisure Auto: Trips * 59% * 92.9% (in the case of 2030 productions, 18,921.6)
- Leisure LRT: Trips * 59% * 7.1% (in the case of 2030 productions, 1,446.1)

Auto occupancy of Airport auto trips is assumed to be 2.0. In the 2030 example, this generates 13,587.7 total Business vehicles trips and 18,921.6 total Leisure vehicle trips (productions + attractions / 2).

Neither parking cost nor transit fare play any role in this airport passenger mode choice model.

K.3 Airport Trip Distribution

Distribution of airport passenger trips takes place after mode choice. Airport passenger trips are apportioned among all zones (other than the airport zone) according to the following protocol:

- Business Vehicles: apportioned among all zones according to their share of the region's total employment
- Business LRT: apportioned among all zones with walk access to LRT according to their share of those zones' total employment
- Leisure Vehicles: apportioned among all zones according to their share of the region's total households
- Leisure LRT: apportioned among all zones with walk access to LRT according to their share of those zones' total households

Distance from PDX is not considered by this distribution model. Absent data on transfers of airport LRT trips to Bus or Park & Ride, all airport passenger LRT trips are LRT-only.

K.4 Airport Peaking

Airport peaks do not correspond to peaks in the rest of the region. Here are peaking factors applied to passenger trips to/from PDX, along with their basis:

TABLE 35. Peaking Factors for Trips to PDX
based on 2005 average weekday enplanements by hour

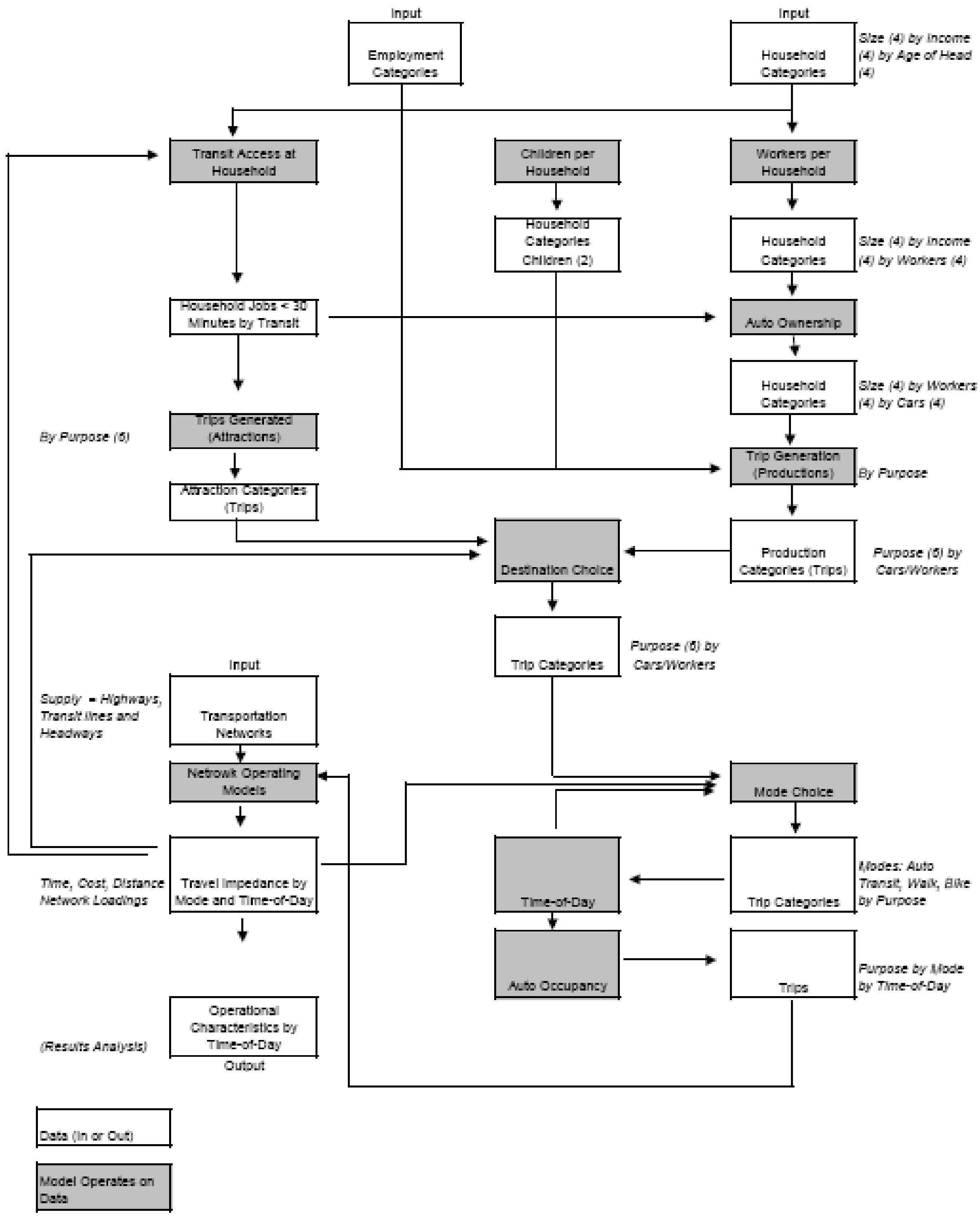
Enplane-ments	Peaking Factor	
6,152	0.322	AM4 Trips to PDX: Enplanements on Flights Departing 0600-0959
2,384	0.125	AM2 Trips to PDX: Enplanements on Flights Departing 0800-0959
1,110	0.058	MD1 (12-1) Trips to PDX: Enplanements on Flights Departing 1100-1159
1,759	0.092	MD1 (2-3) Trips to PDX: Enplanements on Flights Departing 1300-1359
3,407	0.178	PM4 Trips to PDX: Enplanements on Flights Departing 1600-1959
1,749	0.092	PM2 Trips to PDX: Enplanements on Flights Departing 1700-1859
640	0.034	PM1 Trips to PDX: Enplanements on Flights Departing 1800-1859
9,559	0.501	PKAD Trips to PDX: AM4 + PM4
9,530	0.499	OPAD Trips to PDX: AWD – PKAD
19,089		Total Average Weekday Enplanements

TABLE 36. Peaking Factors for Trips from PDX
based on 2005 average weekday deplanements by hour

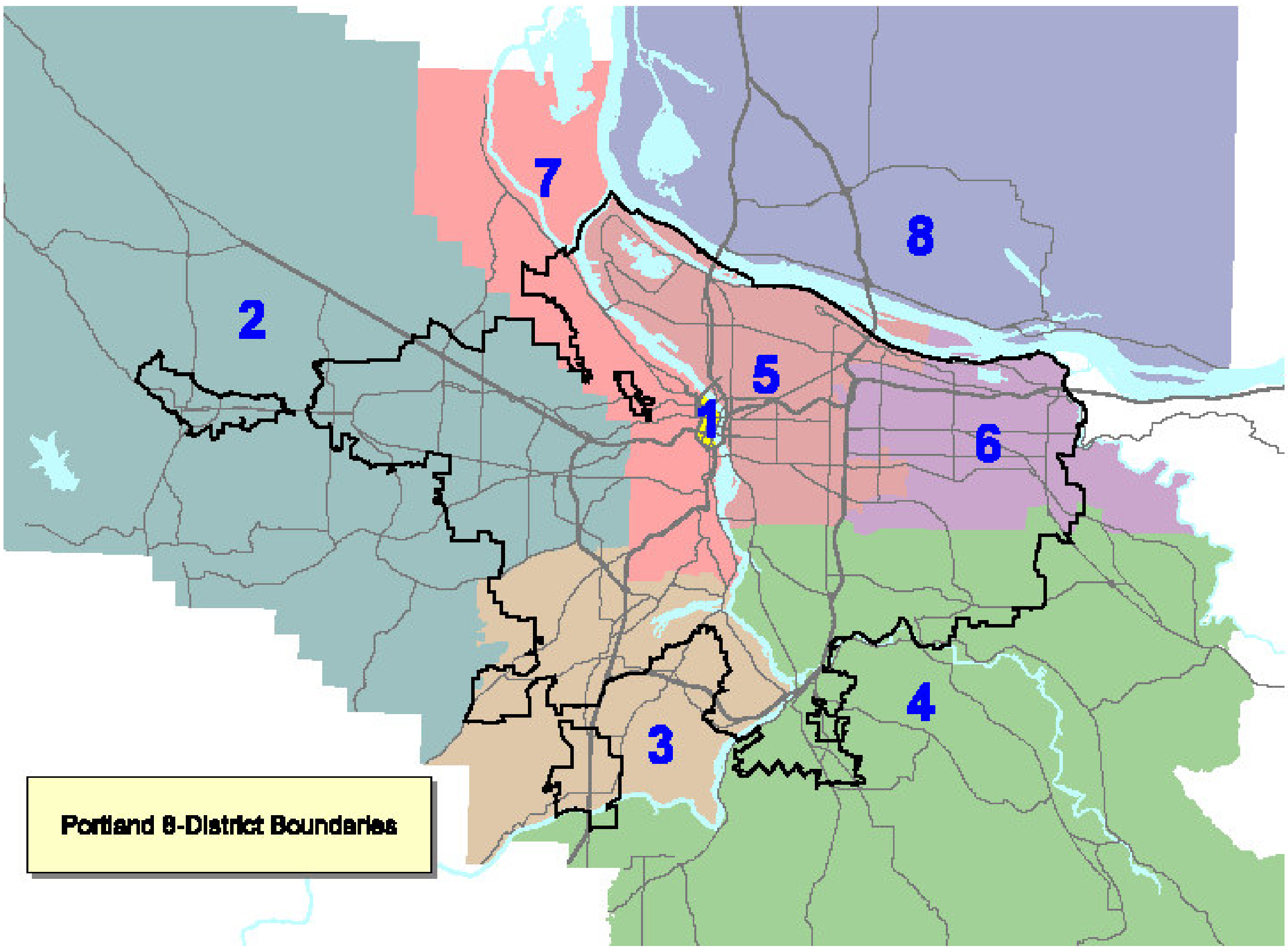
Deplane-ments	Peaking Factor	
1,771	0.092	AM4 Trips from PDX: Deplanements on Flights Arriving 0500-0859
864	0.045	AM2 Trips from PDX: Deplanements on Flights Arriving 0600-0759
870	0.045	MD1 (12-1) Trips from PDX: Deplanements on Flights Arriving 1300-1359
1,007	0.052	MD1 (2-3) Trips from PDX: Deplanements on Flights Arriving 1500-1559
3,743	0.194	PM4 Trips from PDX: Deplanements on Flights Arriving 1500-1859
1,846	0.096	PM2 Trips from PDX: Deplanements on Flights Arriving 1500-1659
839	0.044	PM1 Trips from PDX: Deplanements on Flights Arriving 1600-1659
5,514	0.287	PKAD Trips from PDX: AM4 + PM4
13,729	0.713	OPAD Trips from PDX: AWD – PKAD
19,242		Total Average Weekday Deplanements

In the absence of vehicle occupancy data for auto trips to/from PDX, half of the resulting vehicle trips are assigned as SOV, while the other half are assigned as HOV.

Appendix A – Metro Model Forecasting Model Structure



Appendix B – 8-District Boundaries



Addendum to the Metro Travel Forecasting
March 2008 Trip-Based Demand Model Methodology Report
(updated September 2010)

Transportation demand modeling as it relates to tolling in the Columbia River Crossing project

Introduction

The Metro model has been designed to provide the analyst many interfaces to connect tolling characteristics to the choices made by travelers. For example, three distinct income bins are included in the model to capture reactions due to economic factors. Special weights can be applied to the tolls to note their differing impact on destination, mode choice, and route choices.

However, challenges still are plentiful. The modeling of road pricing is nationally seen as one of the biggest challenges requiring research. A few reasons for this follow:

- Values-of-time typically found in models are not equivalent to those derived from economic studies. This is because many other factors beside cost and time influence travel choices within models.
- The relationship between time and cost is not a fixed value in one's daily life. It is an instantaneous effect. The value depends upon the urgency of the trip.
- The traveler response is likely influenced by his/her income profile. Typical models have two or three income ranges identified within the algorithms. In actuality, a much more continuous distribution range is required – not just several bins.
- It is not clear as to how a toll affects trip distribution choices versus mode choices versus path choices. The elasticity is likely not the same for all travel components.

Practical concerns and scientific shortcomings limit the ability of the analyst to specifically address each of the above points. For these reasons (and others), the introduction of a toll variable into a demand model is very dependent on the "philosophy" of the analyst. Consequently, a special working group was formed to define the modeling procedure for the Columbia River Crossing (CRC) project. Agency participants on the working group included Stantec Inc. (formerly Vollmer Associates), Regional Transportation Council (the metropolitan planning organization in Clark County, Washington), Metro (the metropolitan planning organization for the Portland, OR region), and other CRC contractors. This group is hereafter referred to as the CRC Tolling Team.

The following discusses the modeling methodology developed by the CRC Tolling Team that has been implemented in the CRC project. This approach is specific to this project, and does not represent a singular approach towards tolling adopted by Metro.

Toll rates and time penalties

Toll rates used in the FEIS and New Starts update of the CRC project are shown in Table 1. The Metro model uses assignments from a 2-hour PM peak period and 1-hour midday off-peak period as inputs into the demand model. The PM 2-hour period is 4:00 to 6:00 PM, while the midday is noon to 1:00 PM. The two toll rates of concern for modeling purposes are 3:00 to 7:00 PM and lowest off-peak rates (8:00 PM to Midnight)—both highlighted in Table 1. The CRC Tolling team determined that the floor rates in the off-peak scenario were more appropriate to use within the demand model than the higher 'noon' rates.

To convert the toll rates into time penalties for assignment purposes, several values of time are assumed: For autos, \$19.61/hr (2010\$) is used for peak periods and \$15.27 (2010\$) is used for off-peak periods; Trucks use \$39/hr (2010\$). These values are converted to 1994\$ for use in the model ($13.33/hr, $10.38/hr and $26.60/hr, respectively). Table 2 shows the assumed tolls in both dollars and converted penalty minutes.

Tolls vary by time of day, vehicle class, and use of automatic payment radio transponders. Work trips are assumed to have 100% transponder use. Therefore, all work trips see the 'lower' toll rates ($2.00 peak, $1.00 off-peak). All other trips are assumed to have a 75% / 25% split on transponder / non-transponder use. These trips have a toll rate of $2.25 peak, $1.25 off-peak. These inclusion of these transponder / non-transponder rates are discussed in further detail in later sections.

Table 1: Toll structure for CRC project
(Highlighted cells indicate tolls used in CRC model)

		Passenger Car		Trucks with Transponders		Trucks w/o Transponders	
Start	**End**	**w/ Transponder**	**No Transp.**	**Med Truck**	**Heavy Truck**	**Med Truck**	**Heavy Truck**
Midnight	5:00AM	$1.00	$2.00	$2.00	$4.00	$3.00	$5.00
5:00AM	6:00AM	$1.50	$2.50	$3.00	$6.00	$4.00	$7.00
6:00AM	10:00AM	$2.00	$3.00	$4.00	$8.00	$5.00	$9.00
10:00AM	3:00PM	$1.50	$2.50	$3.00	$6.00	$4.00	$7.00
3:00PM	7:00PM	$2.00	$3.00	$4.00	$8.00	$5.00	$9.00
7:00OM	8:00PM	$1.50	$2.50	$3.00	$6.00	$4.00	$7.00
8:00PM	Midnight	$1.00	$2.00	$2.00	$4.00	$3.00	$5.00

Toll influences in four-step model

The CRC Tolling team determined that the impact of the toll on choice depends upon the number of choices one has available. Many choices mean higher elasticity. If a decision maker is not facing immediate consequences from a decision point caused by a toll, it is less likely that the toll will influence the choice. This logic supports a hierarchy of perceived tolls for use in destination choice, mode choice, and route choice.

For example, since relocating to a new job or housing is difficult in the short term, one is much less likely to change destination—especially as home-based work trips are concerned—with the introduction of a toll (at least initially). . Mode choice, however, is a bit more sensitive to tolling, since users have more options of avoiding the full costs of the toll (both monetary and temporal) through transit or HOV use. Finally, route choice is most sensitive to tolling since drivers have the option of completely avoiding the toll by changing their route.

Based on the previous logic, the CRC Tolling Team determined that the effects on route choice should differ from the effects on destination and mode choice. As a result, the following approach was adopted in applying tolling effects within the four-step model:

- The actual toll rate will have the least amount of impact on destination choice. Therefore, only 25% of the toll is used in determining trip distribution.
- The toll rate will have more impact on mode choice. Therefore, commuters see 75% of the toll when determining which travel mode to use.
- The toll rate has the largest impact on route choice. Therefore, auto commuters see 100% of the toll when choosing a route for completing their trip.

Very little research currently exists on tolling—and, more specifically, the impact of tolls on the decisions of commuters in various stages of trip planning. Additionally, tolling is a new phenomenon to the Portland metro region, and so no prior examples exist by which to examine the impact of tolls upon commuters in this particular jurisdiction. Therefore, the above percentages are based on the professional judgment and reasoning of the CRC Tolling Team.

Table 2: Toll assumptions used in CRC model

Period		SOV & HOV (work trips)	SOV & HOV (non-work trips)	Medium Trucks	Heavy Trucks
Peak Period	*Toll cost (2005$)*	$2.00	$2.25	$4.25	$8.25
	Toll cost used in demand model (1994$)	$1.52	$1.71	$3.23	$6.27
	Additional toll time used in assignment (min)	6.84	----	7.28	14.14
Off-peak Period	*Toll cost (2005$)*	$1.00	$1.25	$3.25	$6.25
	Toll cost used in demand model (1994$)	$0.76	$0.93	$2.47	$4.75
	Additional toll time used in assignment (min)	4.39	----	5.57	10.71

Network assignment

Within the travel time skims building process and the final trip assignments, tolls are converted to time penalties, which are added to links representing the I-5 Bridge. These time penalties vary according to the time of day being modeled (PM 2-hr peak or MD 1-hr off-peak) and mode (private vehicle, medium truck, or heavy truck). Table 2 shows the appropriate time penalty assessed in each situation. Note that tolls are converted from dollars to minutes using a value of time of $19.61/hr (2010$) for peak period private vehicles, $15.27/hr (2010$) for off-peak period private vehicles, and $39/hr (2010$) for trucks ($13.33/hr, $10.38/hr and $26.60/hr in 1994$). These values were determined by the CRC Tolling Team to be appropriate for this particular project based on expert opinion, case studies, many rounds of sensitivity analysis, and through a stated preference survey of existing bridge users.

It should be noted that the 100% transponder usage time penalty is assumed for all private vehicles, since trip purpose cannot be assumed in the assignment process.

During skims building, three matrices are created for use in the demand model for both SOV and HOV trips. The first matrix is an O-D weighted toll time based on the percentage of trips between zones using the I-5 Bridge, which represents the ‘perceived’ toll cost for trips crossing the Columbia River. This matrix is passed on to the destination and mode choice models for use in calculating the monetary cost of the toll, which is seen as an additional operating cost (see below).

The second is an O-D tolled travel time matrix, which represents the travel time between zones PLUS the addition of the ‘perceived’ toll cost as calculated in the weighted toll time matrix. This matrix is representative of the path choices created by the introduction of the toll to the I-5 Bridge.

The final matrix is an O-D travel time skim that represents the ‘true’ travel time between zones without the additional toll cost. This matrix is calculated by subtracting the ‘perceived’ weighted toll time matrix from the tolled travel time matrix. The final travel time matrix is passed onto the destination and mode choice models for use in the auto logsum equations as the actual travel time impedance between zones.

Demand model – destination and mode choice

Within the destination and mode choice models, tolls are input as additional operating costs for the SOV and HOV modes. The O-D weighted toll time matrices calculated in the skim building assignment procedure are passed into the model, where they are converted into monetary values using a values of time of $19.61/hr (2010$) for peak period and $15.27/hr (2010$) for off-peak periods. The resulting matrices represent the O-D weighted toll costs for trips between zones that use the I-5 Bridge. Zone pairs in which 100% of all trips use the I-5 bridge would see 100% of the toll cost, zone pairs with 50% I-5 Bridge use for trips would see 50% of the toll cost, etc.

Since tolls vary by the use of automatic toll payment transponders by vehicles, it was determined by the CRC Tolling Team that the tolls should reflect a mix of transponders. For all work purposes (home based work and non-home based work), it is assumed that transponder use is 100% for all trips. The assumption is that commuters are likely to purchase transponders since their use of the I-5 Bridge would be often (daily) and predictable. All other trip purposes assume a 75% / 25% transponder / no-transponder mix. As a result, toll costs must be adjusted for these trip purposes since the original skim matrices produced in the skim building assignment process assume the lower, 100% transponder use toll values (trip purposes is not distinguished in the initial skim building network assignments).

Table 2 shows the toll costs by trip purpose. To adjust the tolls in the non-work based trip purposes, the costs of the tolls are adjusted up by 12.5% in the PM 2-hr peak period (the difference between $2.00 and $2.25) and 25% in the MD 1-hr off-peak period (the difference between $1.00 and $1.25).

In addition, these costs are then adjusted to reflect the assumed elasticity of tolls in different stages of the demand model. As discussed above, only 25% of the costs are used in the destination choice model. Seventy-five percent of the costs are used within the mode choice model. These adjusted toll costs are added to the vehicle operating costs for use in the logsum utility equations for the destination and mode choice models.

The result of this procedure is that while SOV and HOV trips with an option of using the I-5 Bridge will see an decrease in actual travel time with the introduction of a toll—due to trip diversion from this corridor established in the original skims building network assignment—the additional monetary costs of the toll can be captured in the demand model, often times out-weighting the travel time savings, and leading to changes in destination and mode choice through this corridor.

Final network assignment

Once the demand model is run, and the resulting trip tables are peaked, final SOV, HOV and transit trip tables are produced for the AM 4-hr (6am – 10am), MD 1-hr (12pm –1pm), PM 2-hr (4pm – 6pm), and PM 4-hr (3pm – 7pm) time periods. These tables are then assigned to the network using the full toll time penalties outlined in Table 2.

Assignment classes include SOV, HOV, medium trucks, heavy trucks and transit for each of the time periods mentioned above. Unlike the demand model, no differentiation is made to isolate the income classes or trip purpose of vehicles. This is due to several factors, which range from methodological (*False precision due to the presence of only three distinct income bins – not an income continuum*), to software and hardware constraints (*Each additional segmentation of modes—whether by income class or trip purpose—has a multiplicative effect on runtime and computer resource allocation*).

The MD 1-hr off-peak period has a slightly higher toll than that shown in Table 2, since the toll assumed for the off-peak in all previous steps of the model is based on the lowest toll range (8pm – 12am) highlighted in Table 1. The result is an assumed toll for SOV and HOV of $1.50 (2005$), or 6.59 minutes after conversion using previously discussed VOT assumptions.