2018 Kate v2.0 Trip-Based Travel Demand Model

Methodology Report

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Metro

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List of Supporting Documentation

1. **Kate_Estimation_Data_Prep_Report_August2017.docx**
   Report outlining methodology for preparing data for use in Kate model estimation
2. **Kate_Model_Input_Data_Report_ August2017.docx**
   Report outlining methodology for preparing input data for use in Kate model simulations
3. **Kate_Validation_Report_ August2017.docx**
   Report for year 2015 validation of Kate v1.0 travel demand model
4. **Kate_Peak_Spreading_Methodology_FAQ_ August2017.docx**
   Report detailing peak spreading methodology and answers to frequently asked questions
5. **Portland Airport Departure Model.doc**
   Report detailing Portland Airport Passenger Demand Model (APDM)

2017 Kate v1.0 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 and, as such, does not address the tour-based activity model under development.

On a regular basis, the region's trip-based model is modified to incorporate new data and research findings. Since the last report in 2015, a number of model enhancements have been implemented. The current model offers the following methodological advances:

- All major model components have been re-estimated using data collected in the 2011 Oregon Household Activity Survey (OHAS), Portland and Vancouver area samples.
- The auto and transit access network has been substantially revised. Centroid connector distances are a function of TAZ size, which both improves representation of vehicle-miles driven on local streets and results in median transit walk distances that are consistent with those observed in OHAS. Intra-zonal distances are also a function of zone size and connector lengths rather than the older "nearest neighbor" method.
- TAZ transit coverage factors have been eliminated, and walk access to transit has been added to all non-freeway links. Where previous transit access + egress distances were limited by connector lengths (typically a total of 0.26 miles), walk access + egress is now capped at 1.0 mile, and a new transit mode choice variable discourages trips where out-of-vehicle time exceeds in-vehicle time.
- Walk distance (Wdist) is calculated using the transit access network, which includes pedestrian-only facilities.
- Destination choice logsums now include both travel time and travel cost variables, as well as alternative-specific constants for the available modes to each destination zone.

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

- The share of trips by transit from a given TAZ was restricted by transit coverage factors
- Each transit boarding node required a centroid connector. Most transit trips boarded the nearest route, even if walking a few blocks to a more direct route would eliminate a transfer or result in less travel time.

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

(For a more complete description**, s**ee *Metro Model Estimation and Application 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 (< $25K, $25-$50K, $50-$100K, > $100K), 2010 dollars
  - Age of household head by four groups (25<, 25-54,55-64, >65)
- Employment categories
  - Agriculture, Mining, and Forestry
  - Arts, Entertainment, and Recreation
  - Construction
  - Education
  - Food Services and Drinking Places
  - Government
  - Health and Social Services
  - Manufacturing (except high-tech)
  - Manufacturing – High Tech
  - Other Services
  - Professional and Business Services
  - Retail and Consumer Services
  - Transportation, Warehousing, and Utilities
  - Wholesale Trade
- 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 (12:00-12:59)

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	0.6346	0.3654
HBshop	Home-Based Shopping	0.3390	0.6610
HBrec	Home-Based Recreation	0.3650	0.6350
HBoth	Home-Based Other	0.3853	0.6147
NHBW	Non-Home-Based Work	0.4623	0.5377
NHBNW	Non-Home-Based Non-Work	0.3495	0.6505
HBcoll	Home-Based College	0.4126	0.5874

A.2.a Auto Skims

Auto skims are prepared using the results of previous Emme assignments.

A.2.b Transit Skims

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

- In-vehicle time by transit sub-mode
- Walk time
- First wait time
- Transfer wait time
- Number of total boardings
- Number of transfer boardings

Boarding time is calculated as the time equivalent of the coefficient on the number of transfers, with the resulting value of 7.5 minutes applied universally.

For model application, wait times are modeled at 50% of headway. Timed transfer locations receive no special consideration.

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 initial wait time or 30 minutes transfer wait time.

Transit is not available for trips between zone pairs where more than 20 minutes' total access and egree walking time is required.

The walk and wait time weights used in the demand model are identical to those applied in pathfinding:

- Transit skim wait time weight: 1.6
- Transit skim auxiliary transit (walk) time weight: 2.76

For each zone pair, in-vehicle time skims are prepared by transit mode; in the case of multimodal journeys and/or path sets, these values represent the individual mode's constituent portion of total in-vehicle time.

A.3 Trip Cost Data

Travel cost is an input to the mode choice model. All cost values are in 2010 dollars.

A.3.a Auto Operating Cost

Auto operating cost varies by mode:

- Drive Alone = ($0.2138 / mile*distance) + (½ of parking charge in attraction zone)
- Shared Ride Driver = [($0.2138 / mile*distance) + (½ of parking charge in attraction zone)] * .667
- Shared Ride Passenger = [($0.2138 / mile*distance) + (½ of parking charge in attraction zone)] * .333
- Park and Ride = $0.2139 / mile*distance (between production zone and lot)

A.3.b Parking Charges

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 charge.
- Other trip purposes use short-term parking charge (½ of long-term parking charge).

A.3.c Transit Fare

Transit fares are based on the average fares charged by the region's transit providers in May 2010. Average fares for all transit providers providing a transit pass option were estimated at 73% of the cash fare price, which is the 2010 ratio for TriMet.

- TriMet
  - Travel within CBD-Lloyd District Free Rail Zone : $0
  - All other travel: $1.678
- C-Tran
  - For intra-Clark County service : $1.095
  - For Clark County-North/Northeast Portland: $1.716
  - For Clark County-Portland premium service: $2.190
    - 2010-2017: to Portland CBD, Lloyd District, Marquam Hill
    - 2018 and beyond: to Marquam Hill only
- Sandy Area Metro (SAM)
  - For Sandy-Rhododendron service: $1.460
- SMART
  - For Wilsonville-Portland service: $2.591
- South Clackamas Transportation District (SCTD)
  - For Molalla-Portland service: $2.678
  - For Molalla-Clackamas Community College service: $1.000

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: percent of the households within a zone that are within 0.2 miles of a bus stop or 0.5 miles of a rail station (straight line distances)
- Employment transit coverage factor by TAZ for both the peak and off-peak periods: percent of the jobs within a zone that are within 0.2 miles of a bus stop or 0.5 miles of a rail station (straight line distances)
- Park-and-ride lot locations, capacities, and types

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:

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

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 2010 household income < $25,000
Income2	=	1 if 2010 household income >= $25,000 and < $50,000
Income3	=	1 if 2010 household income >= $50,000 and < $100,000
Income4	=	1 if 2010 household income >= $100,000
Agecat1	=	1 if age of household head 18-24
Agecat2	=	1 if age of household head 25-54
Agecat3	=	1 if age of household head 55-64
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 (**8.1802 – 2.1436*HHsize + 6.1394*Income1 + 3.0767*Income2 + 0.9966*Income3 – 6.4436*Agecat1 – 3.7234*Agecat2 – 3.4183*Agecat3 **)**

1 worker households

U = **exp (** 7.2623– 1.8731*HHsize + 3.7194*Income1 + 2.2650*Income2 + 0.7563*Income3 –2.9635*Agecat1 – 0.4402*Agecat2 – 1.3386*Agecat3 **)**

2 worker households

U = **exp (** 5.3724 – 1.2747*HHsize + 1.2257*Income1 + 0.7633*Income2 + 0.2345*Income3 - 0.7721*Agecat1+ 0.6739* Agecat2 – 0.4320*Agecat3 **)**

3+ worker households

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

B.1.c Estimated Variable Coefficients

TABLE 2. Worker Model

Variable	**0 worker**		**1 worker**		**2 worker**	
	Coefficient	Z-Statistic	Coefficient	Z-Statistic	Coefficient	Z-Statistic
Calib Constant	*7.9*		*6.99*		*5.315*	
Constant	8.1802	43.3	7.2623	40.1	5.3724	29.6
HHsize	-2.1436	-50.8	-1.8731	-48.1	-1.2747	-34.1
Income1	6.1394	30.4	3.7194	19.1	1.2257	6.2
Income2	3.0767	28.8	2.2650	24.3	0.7633	8.3
Income3	0.9966	12.9	0.7563	13.3	0.2345	4.4
Agecat1	-6.4436	-32.1	-2.9365	-16.1	-0.7721	-4.1
Agecat2	-3.7234	-27.7	-0.4402	-3.4	0.6739	5.1
Agecat3	-3.4183	--24.3	-1.3386	-9.7	-0.4320	-3.1

The worker model was estimated from 2012_5yr PUMS for the 4-county region. The 3+ worker choice utility is held constant at zero. Income4 and Agecat4 are the reference categories for Income and Agecat

B.2 Auto Ownership Model

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

The model estimation dataset includes all (OHAS) 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
Income	=	1 if 2010 household income < $25,000
	=	2 if 2010 household income >= $25,000 and < $50,000
	=	3 if 2010 household income >= $50,000 and < $100,500
	=	4 if 2010 household income >= $100,000
SFPC	=	Percentage of TAZ dwellings that are single-family detached units
logMIXTHM	=	LN (Total employment accessibility within ½ mile + 1) (see Section A.1.b)
Tot30Tk	=	(Total employment within 20 minutes by mid-day transit) /1000

B.2.b Calibrated Choice Utilities

0 car households

U = **exp** (-3.0278 + 4.9228*h1w0 + 3.8632*h1w1 + 1.6074*h2w0 +0.9721*h2w1 +0.7961*h2w2 +2.6325*h3w0 +0.75*h3w1 +0.4637*h3w2 +h4w0 + 0.5*h4w1 +0.25*h4w2 - 1.6745 * income - 2.0721*sfpc + 0.0169*Tot30Tk + 0.4233*logMIXTHM)

1 car households

U = **exp** (-1.4954 + 6.3568*h1w0 + 5.9245*h1w1 + 4.0594*h2w0 + 3.4905*h2w1 + 2.9585*h2w2 + 3.4712*h3w0 + 3.5113*h3w1 + 2.6011*h3w2 + 2.6011*h3w3 + 2.8079*h4w0 + 3.2346*h4w1 + 2.8861*h4w2 - 0.8833*income -1.5633*sfpc + 0.0102*TOT30Tk + 0.2223*logMIXTHM)

2 car households

U = **exp**(-1.8268 + 2.7548*h1w0 + 2.3944*h1w1 + 2.5439*h2w0 + 2.0346*h2w1 + 1.8537*h2w2 + 2.0169*h3w0 + 1.7867*h3w1 + 1.5335*h3w2 + 0.7326*h3w3 + 1.2802*h4w0 + 2.2461*h4w1 + 2.0506*h4w2 - 0.1749*income + 0.0038*TOT30Tk + 0.1544*logMIXTHM)

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	*-3.0278*		*-1.4954*		*-1.8268*	
Constant	-1.3028	-1.63	-1.4954	-1.82	-1.8268	-3.87
HHsize1:Wkr0	4.9228	9.00	6.3568	8.36	2.7548	6.95
HHsize1:Wkr1	3.8632	7.17	5.9245	7.96	2.3944	6.94
HHsize2:Wkr0	1.6074	2.85	4.0594	5.58	2.5439	8.65
HHsize2:Wkr1	0.9721	1.75	3.4905	4.82	2.0346	7.25
HHsize2:Wkr2	0.7961	1.28	2.9585	4.08	1.8537	6.80
HHsize3:Wkr0	2.6325	3.58	3.4712	4.35	2.0169	4.84
HHsize3:Wkr1	0.7500	fixed	3.5113	4.49	1.7867	5.28
HHsize3:Wkr2	0.4637	0.96	2.6011	3.48	1.5335	5.38
HHsize3:Wkr3	--	na	2.6011	3.48	0.7326	1.93
HHsize4:Wkr0	1.0000	fixed	2.8079	3.30	1.2802	2.16
HHsize4:Wkr1	0.5000	fixed	3.2346	4.34	2.2461	7.33
HHsize4:Wkr2	0.2500	fixed	2.8861	3.90	2.0506	7.39
Income	-1.6745	-12.72	-0.8833	-10.36	-0.1749	-2.50
SFPC	-2.0721	-5.23	-1.5633	-6.06	--	na
Tot30Tk	0.0169	7.24	0.0102	5.52	0.0038	2.39
logMIXTHM	0.4233	5.13	0.2223	5.34	0.1544	4.64

The 3+ car choice utility is held constant at zero. HHSize4:Wkr3 is the reference category for Size x Wkr

While the Worker and Children models use only HIA demographic inuts, Auto Ownership is influenced by changes in land use and transit LOS.

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
Age4 = 1 if age of household head 18-24
= 2 if age of household head 25-54
= 3 if age of household head 55-64
= 4 if age of household head >=65

B.3.b Calibrated Choice Utilities

This model was not changed in calibration.

0 child households

U = **exp (**-4.069012*HHsize + 6.922379*Age4 **)**

1 child households

U = **exp** (-2.425297*HHsize +4.598579 *Age4 **)**

2 child households

U = **exp** (-0.6128247*HHsize + 1.639239*Age4 **)**

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	-4.069012	-24.3	-2.425297	-15.5	-0.6128247	-4.0
Agecat4	6.922379	22.8	4.598579	15.5	1.639239	5.5

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 the non-home TAZs where they actually occur. NHBW trip productions are allocated to workplace TAZ's, while NHBNW trip productons are allocated to place of trip origin. 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	1.386047
2	2.462282
3+	3.578358

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 1.36) 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	0.5889655	0.3597194		
2	1.02852	0.7578216	0.6313181	
3	1.371429	1.121711	0.9657534	0.8703704
4+	1.847826	1.260241	0.9130435	1.14375

The resulting trips are multiplied by a calibration factor of 1.025.

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	0.1783567	0.2772414
2	0.4122894	0.5582865
3	0.5462963	0.7933884
4+		1.43126

The resulting trips are multiplied by a calibration factor of 1.025.

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	0.6723447	1.187586
2	1.421209	2.076545
3	1.916667	2.613932
4+		4.027823

The resulting trips are multiplied by a calibration factor of 1.025.

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

Production of non-home-based trips in trip-based models takes place in two steps. First, household trip generation rates are used to determine how many trips are produced regionally. Then, those productions are spatially allocated to where they actually originate. A set of TAZ allocation weights were estimated using transposed destination choice (i.e., “origin choice”) models with TAZ size variables only.

C.5.a Production Totals

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

- Input Variable: Number of workers
- Output: Person trips (all modes), regional control totals

TABLE 9. NHBW Household Production Rates

Workers	Rate
0	0.107864
1	0.835659
2	1.723404
3+	2.33209

The resulting trips are multiplied by a calibration factor of 1.025.

C.5.b Production Spatial Allocation

NHBW Productions are allocated to TAZ’s using the following production allocation weights shown in Table 10. Total regional productions are scaled to control totals obtained from household productions above. See Section (xxxx) for a description of employment sectors used here and in the Destination Choice models.

TABLE 10. NHBW Production Allocation Weights

TAZ Variable	Coefficient	T-Statistic
AMF,FDS,RCS	1	*(fixed)*
CON,EDU,OSV	4.2631	*9.24*
TWU,PBS	3.2544	*7.70*
WT,MFG,MHT	2.5396	*6.28*
AER,HSS,GOV	1.9232	*4.46*
households	0.3362	*-5.51*

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), regional control totals

TABLE 10. NHBNW Production Rates

HHsize	all household members work	some household members do not work
1	0.511022	1.165517
2	0.9187314	1.651685
3	1.425926	1.956316
4+		3.161211

The resulting trips are multiplied by a calibration factor of 1.025.

C.6.b Production Spatial Allocation

NHBNW Productions are allocated to TAZ's using the following production allocation weights shown in Table 12. Total regional productions are scaled to control totals obtained from household productions above. See Section (xxxx) for a description of employment sectors used here and in the Destination Choice models.

TABLE 12. NHBNW Production Allocation Weights

TAZ Variable	Coefficient	T-Statistic
Othser	1.0000	*fixed*
FoodSv	0.4253	*-12.89*
Retcns	0.3263	*-20.00*
Agrfrm	0.2060	*-7.56*
Educat	0.1901	*-25.32*
Areart	0.1604	*-9.05*
Constr	0.1249	*-13.62*
Health	0.0429	*-28.40*
Govmnt	0.0255	*-22.47*
Tranwu	0.0185	*-8.28*
Probns	0.0106	*-11.96*
Wholes	0.0085	*-8.79*
MHitec	0.0005	*-3.71*
Mfacrt	0.0005	*-3.71*

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 11. HBcoll Production Rates

	Age Group			
Hhsize	**<25**	**25-54**	**55-64**	**>65**
1	0.5384615	0.0473684	0.0059761	0.007837
2	0.375	0.1138107	0.0289079	0.0183357
3	0.6666667	0.1226576	0.1610487	0.1413043
4+	0.8333333	0.1359852	0.468254	0.2758621

The resulting trips are multiplied by a calibration factor of 1.5

Note that HBColl productions apply to households only, since group quarters (e.g., dormitories, fraternities) were not surveyed.

C.8 HBsch (Home-Based School)

HBsch productions are generated by a cross-classification model using the combined Portland-Vancouver-Salem-Eugene samples of the 2011 OHAS. HBSchool person-trips include both students and adult escorts for the home-to-school and school-to-home trip.

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

TABLE 12. HBsch Production Rates

	Children			
HHsize	**0**	**1**	**2**	**3+**
1	--	--	--	--
2	--	1.978448	--	--
3	--	1.84793	3.326389	--
4+	--	2.248879	3.441193	5.103783

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 seven 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
Transit by walk access – only available if both trip ends are within either 0.2 miles of a bus stop or 0.5 miles of a rail station
Transit by park-and-ride access – only available if destination trip end is within 0.2 miles of a bus stop or 0.5 miles of a rail station; only available for home-based non-school trips; utilities and lot usage for formal park-and-ride lots and informal park-and-ride locations are calculated by a nested park-and-ride lot choice model
Bike – utilities and distances are produced by a stand-alone tool based on a dedicated bicycle network
Walk – only available for trips with a distance less than five miles

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):

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

D.1 Variables Used in Multimodal Accessibility Functions

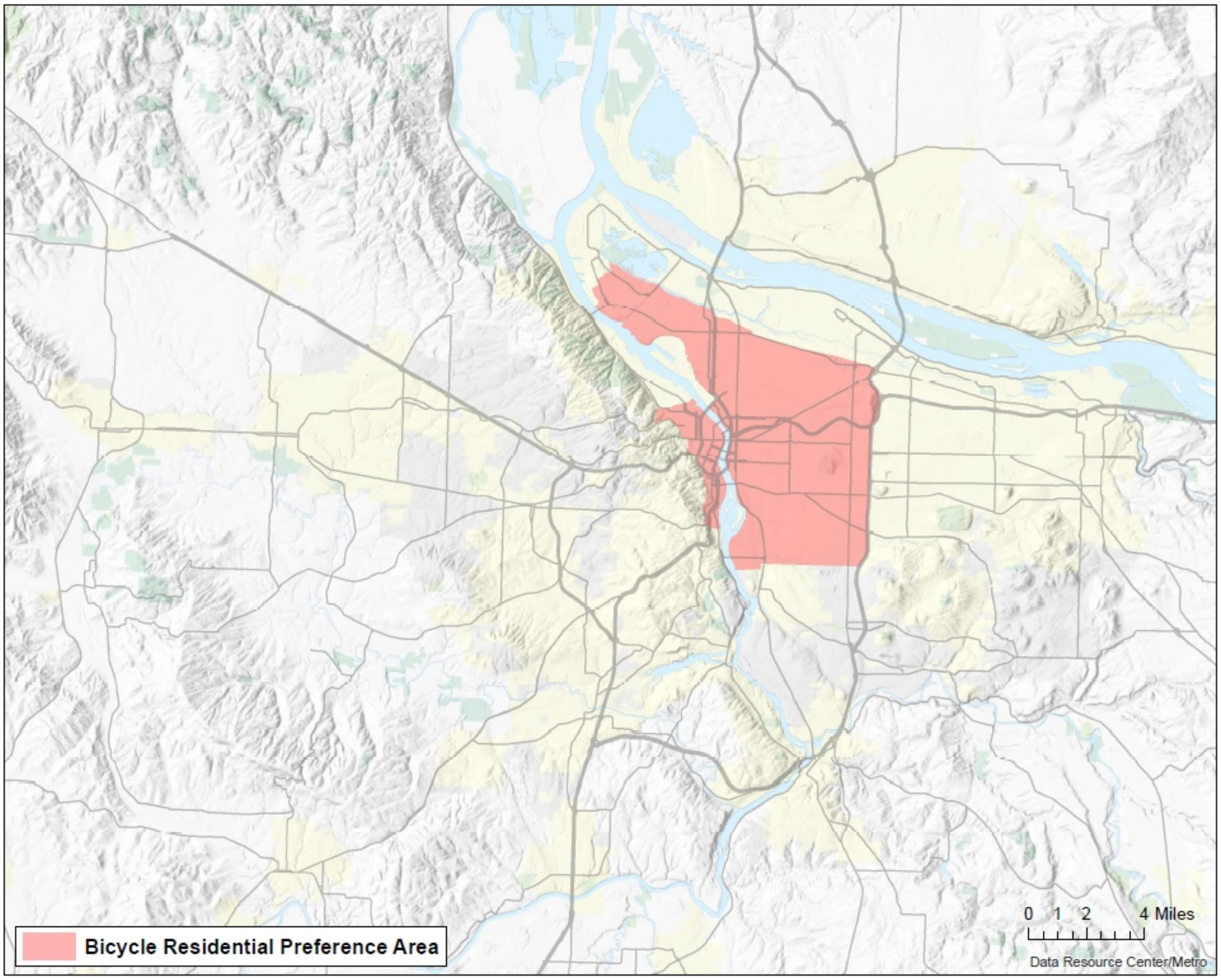
D.1.a Variable Definitions

IvTime = In-vehicle travel time (minutes, varies by mode)
WalkTime = Walk time (minutes), 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
- Walk: zone-to-zone time via key walk-accessible links at 3 mph (for trips < 5 miles)

TranWait1 = Transit initial wait time (minutes)
TranWait2 = Transit transfer wait time (minutes)
TranModc = Transit mode constant (varies by transit path)
TranStypc = Transit stop type constant (varies by transit path)
TranXfrs = Transit # of transfers
TrOVIV = ratio of total out-of-vehicle time to in-vehicle time
Formal = 1 if considering formal park-and-ride lots
Informal = 1 if considering informal park-and-ride locations
Shadow = Park-and-ride lot shadow cost (calculated by lot choice model)
BikeDist = Bicycle trip distance (miles)
Cbutil = Bicycle commute route attractiveness
Nbutil = Bicycle non-commute route attractiveness
BikeResPref = 1 if production zone in bicycle user residential preference area (see Figure 1)
LowInc = 1 if household income <$25K (2010$)
MidInc = 1 if household income $25-100K (2010$)
HighInc = 1 if household income $100K+ (2010$)
OpCost = Out-of-pocket cost, by mode:
- Drive Alone: 100% of $0.211 / mile (2010$)
- Drive with Passenger: 66.7% of $0.211 / mile (2010$)
- Auto Passenger: 33.3% of $0.211 / mile (2010$)
- Walk-access Transit: transit fare (2010$)
- Park-and-ride: $0.211 / mile for auto leg, transit fare for transit leg

PkgCost = Parking cost, by mode:
- Drive Alone: 100% of long-term parking charge in attraction zone
- Drive with Passenger: 66.7% of long-term parking charge in attraction zone
- Auto Passenger: 33.3% of long-term parking charge in attraction zone

FIGURE 1. Bicycle User Residential Preference Area



D.2 HBW (Home-Based Work)

D.2.a Peak / Off-Peak Weights

HBW: 63.46% peak skims, 36.54% off-peak skims

D.2.b Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0414*IvTime – 0.1*WalkTime – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost – 0.509*LowInc*PkgCost – 0.509*MidInc*PkgCost – 0.461*HighInc*PkgCost**)**

Drive with Passenger

U = **exp (-**3.21 – 0.0414*IvTime – 0.1*WalkTime – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost – 0.509*LowInc*PkgCost – 0.509*MidInc*PkgCost – 0.461*HighInc*PkgCost**)**

Auto Passenger

U = **exp (-**3.49 – 0.0414*IvTime – 0.1*WalkTime – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost – 0.509*LowInc*PkgCost – 0.509*MidInc*PkgCost – 0.461*HighInc*PkgCost**)**

Transit by Walk Access

U = **exp (**0.00258 + TranModc + TranStypc – 0.0414*IvTime – 0.0543*TranWait1 – 0.061*TranWait2 – 0.1*WalkTime – 0.16*TranXfrs – 0.4*TrIVOV – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost**)**

Park and Ride

Park and Ride uses older model specifications; only the mode-specific constant and informal constant were recalibrated in 2017. The coefficient on auto in-vehicle time is doubled in order to maintain a balance between auto and transit time that is comparable to the observed relationship; otherwise, too many trips include unreasonably high auto times as travelers choose to drive to the periphery of the CBD before boarding transit.

U = **exp (**1.85 + 0.75***ln**(**exp**(Formal*0.5***ln**($\sum_{1\rightarrow N}$ [**exp**(($U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) + **exp**(Informal*0.5***ln**($\sum_{1\rightarrow N}$ [**exp**((-4.5 + $U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) **)**

where

$U_{AutoLeg}$ = -0.03608*2*IvTime – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost

and

$U_{TransitLeg}$ = -0.03608*($IvTime_{Bus}$ + 0.88*$IvTime_{LRT}$ + $IvTime_{SC}$ + 0.88*$IvTime_{Rail}$) – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*TranXfrs – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost

and

N = number of formal park-and-ride lots or informal par-and-ride locations under consideration

Bike

U = **exp (**-1.81 – 0.25*BikeDist + 0.0636*Cbutil + 1.35*BikeResPref **)**

Walk

U = **exp (**-0.0511 **–** 0.1*WalkTime**)**

D.2.c Estimated Variable Coefficients

TABLE 13. HBW Multimodal Accessibility Functions – Auto Modes

Variable	Drive Alone		Drive with Passenger		Auto Passenger	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			-3.21			
Constant			-3.27		-3.49	
IvTime	-0.0414	*-4.74*	-0.0414	*-4.74*	-0.0414	*-4.74*
Calib WalkTime	*-0.1*		*-0.1*		*-0.1*	
WalkTime	-0.0791	-14.01	-0.0791	-14.01	-0.0791	-14.01
LowIncOpCost	-0.309	-2.83	-0.309	-2.83	-0.309	-2.83
MidIncOpCost	-0.252	-6.34	-0.252	-6.34	-0.252	-6.34
HighIncOpCost	-0.252	-6.34	-0.252	-6.34	-0.252	-6.34
LowIncPkgCost	-0.509	-13.53	-0.509	-13.53	-0.509	-13.53
MidIncPkgCost	-0.509	-13.53	-0.509	-13.53	-0.509	-13.53
HighIncPkgCost	-0.461	-11.65	-0.461	-11.65	-0.461	-11.65

TABLE 14. HBW Multimodal Accessibility Functions – Transit Modes

Variable	Walk Access		Park and Ride	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	0.00258		*1.85*	
Constant	-0.195		-6.504	-7.3
Ivtime	-0.0414	*-4.74*	-0.03608	-6.3
Wait1	-0.0543	-3.69	-0.0576	-5.8
Wait2	-0.061	-4.66	-0.04002	-5.2
Calib WalkTime	*-0.1*			
WalkTime	-0.0791	-14.01	-0.09956	-9.7
Transfers	-0.16	*fixed*	-0.3	*fixed*
Calib TrIVOV	*-0.4*			
TrIVOV	-0.0519	-2.65		
LowIncOpCost	-0.309	-2.83	-0.6587	-9.5
MidIncOpCost	-0.252	-6.34	-0.6097	-12.1
HighIncOpCost	-0.252	-6.34	-0.4029	-7.1
Nested Park & Ride Lot Choice Model				
Informal Constant			-5.0	
Park & Ride Nest			0.75	
Formal Nest			0.5	
Informal Nest			0.5	

TABLE 15. HBW Multimodal Accessibility Functions – Nonmotorized Modes

Variable	Bike		Walk	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-1.81		-0.0511	
Constant	-1.71		-0.157	
Calib BikeDist	-0.25			
BikeDist	-0.215	-6.19		
Cbutil	-0.0636	2.92		
Calib BikeResPref	1.35			
BikeResPref	0.5	*fixed*		
Calib WalkTime			-0.1	
WalkTime			-0.0791	-14.01

D.3 HBshop, HBrec, HBoth (Other Home-Based)

D.3.a Peak / Off-Peak Weights

HBshop: 33.9% peak skims, 66.1% off-peak skims
HBrec: 36.5% peak skims, 63.5% off-peak skims
HBoth: 38.53% peak skims, 61.47% off-peak skims

D.3.b Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0315*IvTime – 0.125*WalkTime – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost – 0.731*LowInc*PkgCost – 0.393*MidInc*PkgCost – 0.393*HighInc*PkgCost**)**

Drive with Passenger

U = **exp (**-1.06*Shop – 0.703*Rec – 0.517*Oth -0.0315*IvTime – 0.125*WalkTime – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost – 0.731*LowInc*PkgCost – 0.393*MidInc*PkgCost – 0.393*HighInc*PkgCost**)**

Auto Passenger

U = **exp (**-1.65*Shop – 1.54*Rec – 1.5*Oth -0.0315*IvTime – 0.125*WalkTime – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost – 0.731*LowInc*PkgCost – 0.393*MidInc*PkgCost – 0.393*HighInc*PkgCost**)**

Transit by Walk Access

U = **exp (**1.32*Shop + 0.775*Rec + 0.844*Oth + TranModc + TranStypc – 0.0315*IvTime – 0.05*TranWait1 – 0.05*TranWait2 – 0.125*WalkTime – 0.16*TranXfrs – 1*TrIVOV – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost**)**

Park and Ride

Park and Ride uses older model specifications; only the mode-specific constant and informal constant were recalibrated in 2017. The coefficient on auto in-vehicle time is doubled in order to maintain a balance between auto and transit time that is comparable to the observed relationship; otherwise, too many trips include unreasonably high auto times as travelers choose to drive to the periphery of the CBD before boarding transit.

U = **exp (**-3.1*Shop – 2*Rec – 2.2*Oth + 0.75***ln**(**exp**(Formal*0.5***ln**($\sum_{1\rightarrow N}$ [**exp**(($U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) + **exp**(Informal*0.5***ln**($\sum_{1\rightarrow N}$ [**exp**((-4 + $U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) **)**

where

$U_{AutoLeg}$ = -0.0215*2*IvTime – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost

and

$U_{TransitLeg}$ = -0.0215*(IvTime$_{Bus}$ + 0.86*IvTime$_{LRT}$ + IvTime$_{SC}$ + 0.86*IvTime$_{Rail}$) – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*TranXfrs – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost

and

N = number of formal park-and-ride lots or informal par-and-ride locations under consideration

Bike

U = **exp (**-1.92*Shop – 1.61*Rec – 2.31*Oth – 0.223*BikeDist + 0.199*Nbutil + 1.03*BikeResPref**)**

Walk

U = **exp (**-0.197*Shop + 0*Rec + 0*Oth – 0.125*WalkTime**)**

D.3.c Estimated Variable Coefficients

TABLE 16. HBshop, HBrec, HBoth Multimodal Accessibility Functions – Auto Modes

Variable	**Drive Alone**		**Drive with Passenger**		**Auto Passenger**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Shop			-1.06		-1.65	
Calib Rec			-0.703		-1.54	
Calib Oth			-0.517		-1.5	
Shop			-1.24		-1.88	
Rec			-0.766		-1.29	
Oth			-0.628		-1.46	
IvTime	-0.0315	*-2.16*	-0.0315	*-2.16*	-0.0315	*-2.16*
Calib WalkTime	-0.125		-0.125		-0.125	
WalkTime	-0.0906	-27.55	-0.0906	-27.55	-0.0906	-27.55
LowIncOpCost	-0.255	*-7.47*	-0.255	*-7.47*	-0.255	*-7.47*
MidIncOpCost	-0.255	*-7.47*	-0.255	*-7.47*	-0.255	*-7.47*
HighIncOpCost	-0.174	*-3.99*	-0.174	*-3.99*	-0.174	*-3.99*
LowIncPkgCost	-0.731	*-3.1*	-0.731	*-3.1*	-0.731	*-3.1*
MidIncPkgCost	-0.393	*-5.2*	-0.393	*-5.2*	-0.393	*-5.2*
HighIncPkgCost	-0.393	*-5.2*	-0.393	*-5.2*	-0.393	*-5.2*

TABLE 17. HBshop, HBrec, HBoth Multimodal Accessibility Functions – Transit Modes

Variable	**Walk Access**		**Park and Ride**	
	Coefficient	T-Statistic	Coefficient	T-Statistic

Calib Shop	1.32		-3.1	
Calib Rec	0.775		-2	
Calib Oth	0.844		-2.2	
Shop	0.91		-7.023	-3.8
Rec	1.01		-7.023	-3.8
Oth	0.615		-7.023	-3.8
IvTime	-0.0315	*-2.16*	-0.0215	-3.2
Calib TranWait1	-0.05			
TranWait1	-0.0824	-4.7	-0.06847	-5.4
Calib TranWait2	-0.05			
TranWait2	-0.074	-4.42	-0.0524	-4.8
Calib WalkTime	-0.125			
WalkTime	-0.0906	-27.55	-0.1033	-8.3
TranXfrs	-0.16	*fixed*	-0.3	*fixed*
Calib TrIVOV	-1			
TrIVOV	-0.121	*-3.11*		
LowIncOpCost	-0.255	*-7.47*	-0.4724	-6.8
MidIncOpCost	-0.255	*-7.47*	-0.2457	-5.2
HighIncOpCost	-0.174	*-3.99*	-0.2457	-5.2
Nested Park & Ride Lot Choice Model				
Informal Constant			-4.5	
Park & Ride Nest			0.75	
Formal Nest			0.5	
Informal Nest			0.5	

TABLE 18. HBshop, HBrec, HBoth Multimodal Accessibility Functions – Nonmotorized Modes

Variable	**Bike**		**Walk**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Shop	-1.92		-0.197	
Calib Rec	-1.61		0	
Calib Oth	-2.31		0	
Shop	-2.09		-0.0767	
Rec	-1.18		1.02	
Oth	-2.18		0.208	
Calib BikeDist	-0.223			
BikeDist	-0.233	-5.38		
Nbutil	0.199	7.88		
Calib BikeResPref	1.03			
BikeResPref	0.5	*fixed*		
Calib WalkTime			-0.125	
WalkTime			-0.0906	-27.55

D.4 NHBW (Non-Home-Based Work)

D.4.a Peak / Off-Peak Weights

NHBW: 46.23% peak skims, 53.77% off-peak skims

D.4.b Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0452*IvTime – 0.157*WalkTime – 0.194*OpCost – 0.557*PkgCost**)**

Drive with Passenger

U = **exp (**-2.45 – 0.0452*IvTime – 0.157*WalkTime – 0.194*OpCost – 0.557*PkgCost**)**

Auto Passenger

U = **exp (**-3.03 – 0.0452*IvTime – 0.157*WalkTime – 0.194*OpCost – 0.557*PkgCost**)**

Transit by Walk Access

U = **exp (**0.759 + TranModc + TranStypc – 0.0452*IvTime – 0.118*TranWait1 – 0.118*TranWait2 – 0.157*WalkTime – 0.16*TranXfrs – 0.194*OpCost – 1*TrOVIV**)**

Bike

U = **exp (**-3.33 **–** 0.22*BikeDist + 0.0841*Nbutil + 1.13*BikeResPref **)**

Walk

U = **exp (**0 – 0.157*WalkTime**)**

D.4.c Estimated Variable Coefficients

TABLE 19. NHBW Multimodal Accessibility Functions – Auto Modes

Variable	**Drive Alone**		**Drive with Passenger**		**Auto Passenger**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			-2.45		-3.03	
Constant			-2.43		-2.99	
IvTime	-0.0452	-2.49	-0.0452	-2.49	-0.0452	-2.49
WalkTime	-0.157	-16.7	-0.157	-16.7	-0.157	-16.7
OpCost	-0.194	-3.33	-0.194	-3.33	-0.194	-3.33
PkgCost	-0.557	-5.41	-0.557	-5.41	-0.557	-5.41

TABLE 20. NHBW Multimodal Accessibility Functions – Transit Modes

Variable	**Walk Access**	
	Coefficient	T-Statistic
Calib Constant	0.759	
Constant	0.813	
IvTime	-0.0452	-2.49
TranWait1	-0.118	-5.07
TranWait2	-0.118	-5.07
WalkTime	-0.157	-16.7
TranXfrs	-0.16	*fixed*
OpCost	-0.192	-3.33
Calib TrIVOV	-1	
TrIVOV	0	*fixed*

TABLE 21. NHBW Multimodal Accessibility Functions – Nonmotorized Modes

Variable	**Bike**		**Walk**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-3.33		0	
Constant	-3.21		0.306	
BikeDist	-0.22	-4.06		
Nbutil	0.0841	1.98		
Calib BikeResPref	1.13			
BikeResPref	0.5	*fixed*		
WalkTime			-0.157	-16.7

D.5 NHBNW (Non-Home-Based Non-Work)

D.5.a Peak / Off-Peak Weights

NHBNW: 34.95% peak skims, 65.05% off-peak skims

D.5.b Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0278*IvTime – 0.125*WalkTime – 0.15*OpCost – 0.335*PkgCost**)**

Drive with Passenger

U = **exp (**-0.379 – 0.0278*IvTime – 0.125*WalkTime – 0.15*OpCost – 0.335*PkgCost**)**

Auto Passenger

U = **exp (**-1.33 – 0.0278*IvTime – 0.125*WalkTime – 0.15*OpCost – 0.335*PkgCost**)**

Transit by Walk Access

U = **exp (**0.329 + TranModc + TranStypc – 0.0278*IvTime – 0.0781*TranWait1 – 0.0841*TranWait2 – 0.125*WalkTime – 0.16*TranXfrs – 1*TrIVOV – 0.15*OpCost**)**

Bike

U = **exp (**-2.76 **–** 0.453*BikeDist – 0.13*Nbutil + 1.13*BikeResPref**)**

Walk

U = **exp (**-0.438 – 0.125*WalkTime**)**

D.5.c Estimated Variable Coefficients

TABLE 22. NHBNW Multimodal Accessibility Functions – Auto Modes

Variable	**Drive Alone**		**Drive with Passenger**		**Auto Passenger**	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			-0.379		-1.33	
Constant			-0.492		-1.37	
IvTime	-0.0278	-1.63	-0.0278	-1.63	-0.0278	-1.63
Calib WalkTime	-0.125		-0.125		-0.125	
WalkTime	-0.0886	-14.68	-0.0886	-14.68	-0.0886	-14.68
OpCost	-0.15	-2.94	-0.15	-2.94	-0.15	-2.94
PkgCost	-0.335	-5.91	-0.335	-5.91	-0.335	-5.91

TABLE 23. NHBNW Multimodal Accessibility Functions – Transit Modes

Variable	**Walk Access**	
	Coefficient	T-Statistic
Calib Constant	0.329	
Constant	0.0253	
IvTime	-0.0278	-1.63
TranWait1	-0.0781	-2.85
TranWait2	-0.0841	-2.97
Calib WalkTime	-0.125	
WalkTime	-0.0886	-14.68
TranXfrs	-0.16	*fixed*
Calib TrIVOV	-1	
TrIVOV	-0.15	*fixed*
OpCost	-0.15	-2.94

TABLE 24. NHBNW Multimodal Accessibility Functions – Nonmotorized Modes

Variable	**Bike**		**Walk**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-2.76		-0.438	
Constant	-2.92		-0.592	
BikeDist	-0.453	-3.94		
Nbutil	0.13	2.83		
Calib BikeResPref	1.13			
BikeResPref	0.5	*fixed*		
Calib WalkTime			*-0.125*	
WalkTime			-0.0886	-14.68

D.6 HBcoll (Home-Based College)

D.6.a Peak / Off-Peak Weights

HBcoll: 41.26% peak skims, 58.74% off-peak skims

D.6.b Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0346*IvTime – 0.08*WalkTime – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost – 0.463*LowInc*PkgCost – 0.383*MidInc*PkgCost – 0.184*HighInc*PkgCost**)**

Drive with Passenger

U = **exp (**-3.24 – 0.0346*IvTime – 0.08*WalkTime – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost – 0.463*LowInc*PkgCost – 0.383*MidInc*PkgCost – 0.184*HighInc*PkgCost**)**

Auto Passenger

U = **exp (**-2.93 – 0.0346*IvTime – 0.08*WalkTime – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost – 0.463*LowInc*PkgCost – 0.383*MidInc*PkgCost – 0.184*HighInc*PkgCost**)**

Transit by Walk Access

U = **exp (**0.0169 + TranModc + TranStypc – 0.0346*IvTime – 0.055*TranWait1 – 0.055*TranWait2 – 0.08*WalkTime – 0.15*TranXfrs – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost**)**

Park and Ride

Park and Ride uses older model specifications; only the mode-specific constant and informal constant were recalibrated in 2017. The coefficient on auto in-vehicle time is doubled in order to maintain a balance between auto and transit time that is comparable to the observed relationship; otherwise, too many trips include unreasonably high auto times as travelers choose to drive to the periphery of the CBD before boarding transit.

U = **exp (**2.85 + 0.75***ln**(**exp**(Formal*0.5***ln**($\sum_{1\to N}$ [**exp**(($U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) + **exp**(Informal*0.5***ln**($\sum_{1\to N}$ [**exp**((-5.5 + $U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) **)**

where

$U_{AutoLeg}$ = -0.05319*2*IvTime – 0.1407*OpCost

and

$U_{TransitLeg}$ = -0.05319*(IvTime$_{Bus}$ + 0.86*IvTime$_{LRT}$ + IvTime$_{SC}$ + 0.86*IvTime$_{Rail}$) – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*TranXfrs – 0.1407*OpCost + 1.022***ln**(Tdist)

and

N = number of formal park-and-ride lots or informal par-and-ride locations under consideration

Bike

U = **exp (**-1.97 – 0.3*BikeDist + 0.05*Cbutil**)**

Walk

U = **exp (**0 – 0.08*WalkTime**)**

D.6.c Estimated Variable Coefficients

TABLE 25. HBcoll Multimodal Accessibility Functions – Auto Modes

Variable	Drive Alone		Drive with Passenger		Auto Passenger	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			-3.24		-2.93	
Constant			-2.92		-2.73	
IvTime	-0.0346	-1.48	-0.0346	-1.48	-0.0346	-1.48
Calib WalkTime	-0.08		-0.08		-0.08	
WalkTime	-0.0615	-4.25	-0.0615	-4.25	-0.0615	-4.25
LowIncOpCost	-0.463	-2.36	-0.463	-2.36	-0.463	-2.36
MidIncOpCost	-0.383	-3.58	-0.383	-3.58	-0.383	-3.58
HighIncOpCost	-0.184	-1.61	-0.184	-1.61	-0.184	-1.61
LowIncPkgCost	-0.463	-2.36	-0.463	-2.36	-0.463	-2.36
MidIncPkgCost	-0.383	-3.58	-0.383	-3.58	-0.383	-3.58
HighIncPkgCost	-0.184	-1.61	-0.184	-1.61	-0.184	-1.61

TABLE 26. HBcoll Multimodal Accessibility Functions – Transit Modes

Variable	Walk Access		Park and Ride	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	0.0169		2.85	
Constant	0.336		-1.175	-3.4
IvTime	-0.0346	-1.48	-0.05319	-2.9
Calib TranWait1	-0.055			
TranWait1	-0.0296	-1.15	-0.05302	-2.3
Calib TranWait2	-0.055			
TranWait2	-0.0296	-1.15	-0.05302	-2.3
Calib WalkTime	-0.08			
WalkTime	-0.0615	-4.25	-0.2111	-3.7
TranXfrs	-0.15	*fixed*	-0.3	*fixed*
Calib TrIVOV	0			
TrIVOV	-0.156	*fixed*		
LowIncOpCost	-0.463	-2.36	-0.1407	-1.2
MidIncOpCost	-0.383	-3.58	-0.1407	-1.2
HighIncOpCost	-0.184	-1.61	-0.1407	-1.2
Nested Park & Ride Lot Choice Model				
Informal Constant			-6.0	
Park & Ride Nest			0.75	
Formal Nest			0.5	
Informal Nest			0.5	

TABLE 27. HBcoll Multimodal Accessibility Functions – Nonmotorized Modes

Variable	**Bike**		**Walk**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-1.97		0	
Constant	-1.94		-0.0824	
Calib BikeDist	-0.3			
BikeDist	-0.153	-2.09		
Cbutil	0.05	*fixed*		
Calib WalkTime			-0.08	
WalkTime			-0.0615	-4.25

E Destination Choice

The destination choice models were developed using a multinomial logit estimation procedure. Only HBW has separate models by income group. For other home-based trip purposes, income-specific LogSums are weighted.

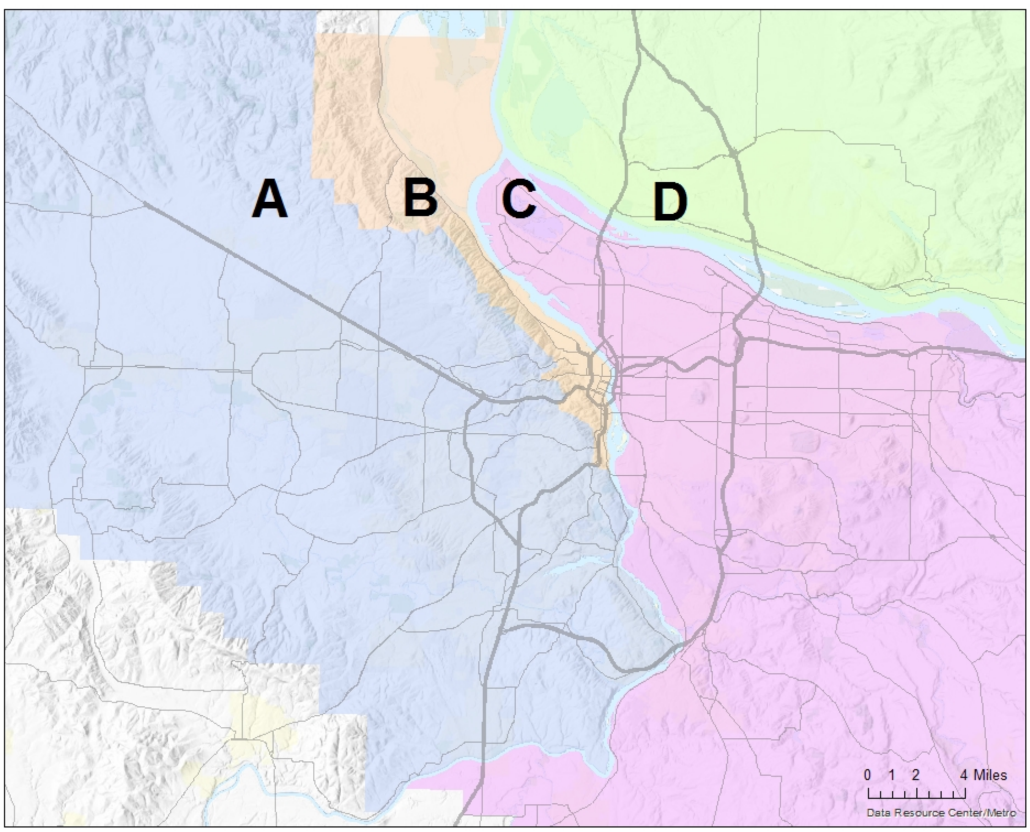
E.1 Variables Used in Destination Choice Models

E.1.a Accessibility Variable Definitions

The letter codes (A/B/C/D) in the hill and river crossing variables refer to Figure 2.

LogSum	=	Logsum of multimodal accessibility functions (all modes)
LogDist	=	Log of [distance (miles) + 1]
OR2WA	=	1 if trip is produced in Oregon (A/B/C) and attracted to Washington (D)
WA2OR	=	1 if trip is produced in Washington (D) and attracted to Oregon (A/B/C)
NoColXing	=	1 if trip does not cross Columbia River between Oregon and Washington
E2W_Hill	=	1 if trip is produced E of Tualatin Hills (B/C/D) and attracted to W of Tualatin Hills (A)
W2E_Hill	=	1 if trip is produced W of Tualatin Hills (A) and attracted to E of Tualatin Hills (B/C/D)
E2W_Riv	=	1 if trip is produced E of Willamette River (C/D) and attracted to W of Willamette River (A/B)
W2E_Riv	=	1 if trip is produced W of Willamette River (A/B) and attracted to E of Willamette River (C/D)

FIGURE 2. River and Hill Crossing Variables Used in Destination Choice



E.1.b Zonal Size Variable Definitions

Zonal size variables are applied at the attraction zone.

TABLE 28. Zonal Size Variables Used in Destination Choice Models

Name	Employment Sectors	NAICS
AerEmp	Arts, Entertainment, and Recreation	71
AmfEmp	Agriculture, Mining & Forestry	11,21
ConEmp	Construction	23
EduEmp	Education	61
FsdEmp	Food Services and Drinking Places	722
GovEmp	Government	All NAICS where owner=public, except 61 (edu), OHSU (hss) and Veterans Hosp (hss)
HssEmp	Health and Social Services	62
MfgEmp	Manufacturing (except high tech)	31-33 (except 334)
MhtEmp	Manufacturing - High tech	334
OsvEmp	Other Services (except Public Administration)	81
PbsEmp	Professional and Business Services	51-56
RcsEmp	Retail and Consumer Services	44,45,721
TwuEmp	Transportation, Warehousing and Utilities	22,48,49
WtEmp	Wholesale Trade	42
Households	Households	
OutAcres	Outdoor Activity Acres	
ParkAcres	Park Acres	
CollEnr	College Enrollment	

E.2 HBW (Home-Based Work)

E.2.a Calibrated Choice Utilities

HBW – Low Income Households

U = **exp (**0.2*LogSum – 1.9*LogDist*OR2WA – 1.8*LogDist*WA2OR – 1.8*LogDist*NoColXing + 0.05*LogDist*E2W_Hill + 0.1*LogDist*W2E_Hill + 0.1*LogDist*E2W_Riv + 0.05*LogDist*W2E_Riv + 0.1237*AerEmp + 1*AmfEmp + 0.5153*ConEmp + 0.5153*EduEmp + 1*FsdEmp + 0.1237*GovEmp + 0.1237*HssEmp + 0.1237*MfgEmp + 0.1237*MhtEmp + 0.5153*OsvEmp + 0.1237*PbsEmp + 0.1237*RcsEmp + 1*TwuEmp + 0.1237*WtEmp**)**

HBW – Middle Income Households

U = **exp (**0.2*LogSum – 1.95*LogDist*OR2WA – 1.78*LogDist*WA2OR – 1.4*LogDist*NoColXing + 0.05*LogDist*E2W_Hill + 0.1*LogDist*W2E_Hill + 0.2*LogDist*E2W_Riv + 0*LogDist*W2E_Riv + 0.2567*AerEmp + 0.4404*AmfEmp + 0.357*ConEmp + 0.3362*EduEmp + 0.0944*FsdEmp + 0.208*GovEmp + 0.1423*HssEmp + 0.1703*MfgEmp + 0.1212*MhtEmp + 1*OsvEmp + 0.2982*PbsEmp + 0.1313*RcsEmp + 0.4115*TwuEmp + 0.0846*WtEmp**)**

HBW – High Income Households

U = **exp (**0.2*LogSum – 1.5*LogDist*OR2WA – 1.78*LogDist*WA2OR – 1.4*LogDist*NoColXing + 0*LogDist*E2W_Hill + 0.1*LogDist*W2E_Hill + 0.2*LogDist*E2W_Riv + 0*LogDist*W2E_Riv +

0.3465*AerEmp + 0.075*AmfEmp + 0.6453*ConEmp + 1*EduEmp + 0.5051*FsdEmp + 0.5051*GovEmp + 0.5051*HssEmp + 0.5051*MfgEmp + 1*MhtEmp + 0.6453*OsvEmp + 1*PbsEmp + 0.075*RcsEmp + 0.5051*TwuEmp + 0.3465*WtEmp**)**

E.2.b Estimated Variable Coefficients

TABLE 29. HBW Destination Choice Model

Variable	Low Income <25K		Middle Income 25-100K		High Income 100K+	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
LogSum	0.2	*fixed*	0.2	fixed	0.2	fixed
Calib LogDist * OR2WA	-1.9		-1.95		-1.5	
LogDist * OR2WA	-2.09	-15.27	-2.05	-41.66	-1.66	-34.97
Calib LogDist * WA2OR	-1.8					
LogDist * WA2OR	-2.09	-24.48	-1.78	-74.26	-1.78	-53.52
Calib LogDist * NoColXing	-1.8		-1.4		-1..4	
LogDist * NoColXing	-1.81	-26.53	-1.56	-70.58	-1.53	-46.61
Calib LogDist * E2W_Hill	0.05		0.05			
LogDist * E2W_Hill	0	*fixed*	0	*fixed*	0	*fixed*
Calib LogDist * W2E_Hill	0.1		0.1		0.1	
LogDist * W2E_Hill	0	*fixed*	0	*fixed*	0	*fixed*
Calib LogDist * E2W_Riv	0.1		0.2		0.2	
LogDist * E2W_Riv	0	*fixed*	0	*fixed*	0	*fixed*
Calib LogDist * W2E_Riv	0.05					
LogDist * W2E_Riv	0	*fixed*	0	*fixed*	0	*fixed*
AerEmp	0.1237	-9.77	0.2567	-4.42	0.3465	-4.79
AmfEmp	1	fixed	0.4404	-3.74	0.075	-4.6
ConEmp	0.5153	-3.31	0.357	-6.27	0.6453	-2.95
EduEmp	0.5153	-3.31	0.3362	-10.23	1	fixed
FsdEmp	1	fixed	0.0944	-5.74	0.5051	-9.19
GovEmp	0.1237	-9.77	0.208	-15.08	0.5051	-9.19
HssEmp	0.1237	-9.77	0.1423	-17.04	0.5051	-9.19
MfgEmp	0.1237	-9.77	0.1703	-11.23	0.5051	-9.19
MhtEmp	0.1237	-9.77	0.1212	-7.59	1	fixed
OsvEmp	0.5153	-3.31	1	fixed	0.6453	-2.95
PbsEmp	0.1237	-9.77	0.2982	-12.38	1	fixed
RcsEmp	0.1237	-9.77	0.1313	-11.54	0.075	-4.6
TwuEmp	1	fixed	0.4115	-6.62	0.5051	-9.19
WtEmp	0.1237	-9.77	0.0846	-7.63	0.3465	-4.79

E.3 HBshop, HBrec, HBoth (Other Home-Based)

E.3.a LogSum Weights

TABLE 30. HBshop, HBrec, HBoth LogSum Weights

Income Group	HBShop LogSum Weight	HBRec LogSum Weight	HBoth LogSum Weight
Low Income < $25K	0.19	0.15	0.13
Middle Income $25-100K	0.60	0.58	0.61
High Income $100K+	0.21	0.27	0.26

E.3.b Calibrated Choice Utilities

HBShop

U = **exp (**1.37*LogSum – 2.25*LogDist*OR2WA – 3*LogDist*WA2OR – 1.75*LogDist*NoColXing + 0.1*LogDist*E2W_Hill + 0*LogDist*W2E_Hill + 0.1*LogDist*E2W_Riv + 0.05*LogDist*W2E_Riv + 0.172*FsdEmp + 0.1541*OsvEmp + 1*RcsEmp**)**

HBRec

U = **exp (**0.547*LogSum – 2.78*LogDist*OR2WA – 2.78*LogDist*WA2OR – 2.1*LogDist*NoColXing + 0*LogDist*E2W_Hill + 0*LogDist*W2E_Hill + 0*LogDist*E2W_Riv + 0*LogDist*W2E_Riv + 0.5117*AerEmp + 0.0276*EduEmp + 0.0963*FsdEmp + 0.0048*GovEmp + 0.0063*Households + 0.3499*OutAcres + 1*ParkAcres/10**)**

HBoth

U = **exp (**0.788*LogSum – 1.75*LogDist*OR2WA – 2.75*LogDist*WA2OR – 1.5*LogDist*NoColXing + 0*LogDist*E2W_Hill + 0.0523*LogDist*W2E_Hill + 0*LogDist*E2W_Riv + 0.172*LogDist*W2E_Riv + 0.1262*AerEmp + 0.3712*AmfEmp + 0.0048*ConEmp + 0.1437*EduEmp + 1*FsdEmp + 0.0916*GovEmp + 0.1588*HssEmp + 0.0048*MfgEmp + 0.0048*MhtEmp + 1*OsvEmp + 0.0665*PbsEmp + 0.206*RcsEmp + 0.162*TwuEmp + 0.0048*WtEmp + 0.1044*Households**)**

E.3.c Estimated Variable Coefficients

TABLE 31. HBshop, HBrec, HBoth Destination Choice Models

Variable	HBshop		HBrec		HBoth	
	Coeff	T-Stat	Coeff	T-Stat	Coeff	T-Stat
LogSum	1.37	13.26	0.547	5.92	0.788	15.97
Calib LogDist * OR2WA	-2.25		-2.78		-1.75	
LogDist * OR2WA	-3.05	-17.55	-2.74	-34.77	-2.67	-44.21
Calib LogDist * WA2OR	-3		-2.78		-2.75	
LogDist * WA2OR	-2.66	-33.23	-2.74	-34.77	-2.49	-62.25
Calib LogDist * NoColXing	-1.75		-2.1		-1.5	
LogDist * NoColXing	-2.4	-38.36	-2.25	-35.84	-2.17	-70.45
Calib LogDist * E2W_Hill	0.1		0		0	
LogDist * E2W_Hill	0.0767	1.09	-0.185	-2.63	0.0691	2.09
Calib LogDist * W2E_Hill					-0.0523	
LogDist * W2E_Hill	0	*fixed*	0	*fixed*	-0.0398	-1.3
Calib LogDist * E2W_Riv	0.1		0		0	
LogDist * E2W_Riv	-0.228	-3.84	-0.278	-5.68	-0.0839	-3.55
Calib LogDist * W2E_Riv	-0.05		0		-0.172	
LogDist * W2E_Riv	-0.193	-3.82	-0.374	-7.63	-0.174	-6.96
AerEmp			0.5117	-5.9	0.1262	-6.21
AmfEmp					0.3712	-5.06
ConEmp					0.0048	-14.04
EduEmp			0.0276	-15.81	0.1437	-16.96
FsdEmp	0.172	-10.66	0.0963	-21.41	1	*fixed*
GovEmp			0.0048	-16.25	0.0916	-21.67
HssEmp					0.1588	-25.79
MfgEmp					0.0048	-14.04
MhtEmp					0.0048	-14.04
OsvEmp	0.1541	-11.2			1	*fixed*
PbsEmp					0.0665	-20.3
RcsEmp	1	*fixed*			0.206	-13.38
TwuEmp					0.162	-10.94
WtEmp					0.0048	-14.04
Households			0.0063	-32.13	0.1044	-47.87
OutAcres			0.3499	-6.36		
ParkAcres / 10			1	*fixed*		

E.4 NHBW & NHBNW (Non-Home-Based)

E.4.a Calibrated Choice Utilities

NHBW

U = **exp (**1.01*LogSum – 1.15*LogDist*OR2WA – 1.4*LogDist*WA2OR – 1.49*LogDist*NoColXing + 0.1*LogDist*E2W_Hill + 0*LogDist*W2E_Hill + 0.1*LogDist*E2W_Riv + 0*LogDist*W2E_Riv + 0.1153*AerEmp + 0.4033*AmfEmp + 0.0561*ConEmp + 0.192*EduEmp + 1*FsdEmp + 0.0829*GovEmp + 0.0573*HssEmp + 0.0027*MfgEmp + 0.0027*MhtEmp + 0.6114*OsvEmp + 0.0686*PbsEmp + 0.3679*RcsEmp + 0.1013*TwuEmp + 0.0027*WtEmp + 0.0781*Households**)**

NHBNW

U = **exp (**1.13*LogSum – 1.8*LogDist*OR2WA – 2.4*LogDist*WA2OR – 1.8*LogDist*NoColXing + 0*LogDist*E2W_Hill – 0.153*LogDist*W2E_Hill – 0.1*LogDist*E2W_Riv – 0.167*LogDist*W2E_Riv + 0.1604*AerEmp + 0.206*AmfEmp + 0.1249*ConEmp + 0.1901*EduEmp + 0.4253*FsdEmp + 0.0255*GovEmp + 0.0429*HssEmp + 0.0005*MfgEmp + 0.0005*MhtEmp + 1*OsvEmp + 0.0106*PbsEmp + 0.3263*RcsEmp + 0.0185*TwuEmp + 0.0085*WtEmp**)**

E.4.b Estimated Variable Coefficients

TABLE 32. Non-Home-Based Destination Choice Models

Variable	NHBW		NHBNW	
	Coeff	T-Stat	Coeff	T-Stat
LogSum	1.01	15.38	1.13	23.57
Calib LogDist * OR2WA	-1.15		-1.8	
LogDist * OR2WA	-1.67	-31.31	-1.98	-46.26
Calib LogDist * WA2OR	-1.4		-2.4	
LogDist * WA2OR	-1.67	-31.31	-2.49	-52.86
Calib LogDist * NoColXing	-1.49		-1.8	
LogDist * NoColXing	-1.47	-30.39	-1.91	-67.01
Calib LogDist * E2W_Hill	0.1		0	
LogDist * E2W_Hill	0.168	4.05	0.214	6.08
Calib LogDist * W2E_Hill	0			
LogDist * W2E_Hill	-0.101	-2.02	-0.153	-3.93
Calib LogDist * E2W_Riv	0.1		-0.1	
LogDist * E2W_Riv	-0.148	-3.89	-0.203	-6.94
Calib LogDist * W2E_Riv	0			
LogDist * W2E_Riv	-0.101	-3.1	-0.167	-5.78
AerEmp	0.1153	-3.26	0.1604	-9.05
AmfEmp	0.4033	-2.78	0.206	-7.56
ConEmp	0.0561	-4.34	0.1249	-13.62
EduEmp	0.192	-11.02	0.1901	-25.32
FsdEmp	1	*fixed*	0.4253	-12.89
GovEmp	0.0829	-16.75	0.0255	-22.47
HssEmp	0.0573	-16.04	0.0429	-28.4
MfgEmp	0.0027	-7.51	0.0005	-3.71
MhtEmp	0.0027	-7.51	0.0005	-3.71
OsvEmp	0.6114	-2.72	1	*fixed*
PbsEmp	0.0686	-15.42	0.0106	-11.96
RcsEmp	0.3679	-6.75	0.3263	-20
TwuEmp	0.1013	-7.92	0.0185	-8.28
WtEmp	0.0027	-7.51	0.0085	-8.79
Households	0.0781	-26.35		

E.5 HBcoll (Home-Based College)

E.5.a LogSum Weights

TABLE 33. HBcoll LogSum Weights

Income Group	HBcoll LogSum Weight
Low Income < $25K	0.29
Middle Income $25-100K	0.57
High Income $100K+	0.14

E.5.b Calibrated Choice Utility

U = **exp (**0.2*LogSum – 2.01*LogDist*OR2WA – 2.99*LogDist*WA2OR – 1.35*LogDist*NoColXing + 0.55*LogDist*E2W_Hill – 0.0836*LogDist*W2E_Hill – 0*LogDist*E2W_Riv – 0.5*LogDist*W2E_Riv + 1*CollEnr**)**

E.5.c Estimated Variable Coefficients

Variable	**NHBW**	
	Coeff	T-Stat
LogSum	0.2	*fixed*
LogDist * OR2WA	-2.01	-8.13
LogDist * WA2OR	-2.99	-11.83
LogDist * NoColXing	-1.35	-8.99
LogDist * E2W_Hill	-0.55	-2.73
LogDist * W2E_Hill	-0.0836	-0.81
Calib LogDist * E2W_Riv	*0*	
LogDist * E2W_Riv	0.416	4.68
LogDist * W2E_Riv	-0.5	-4.22
CollEnr	1	*fixed*

E.6 HBsch (Home-Based School)

U = **exp (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 seven 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
Transit by walk access – only available if both trip ends are within 0.2 miles of a bus stop, 0.35 miles of a streetcar or BRT stop, or 0.5 miles of a rail station
Transit by park-and-ride access – only available if destination trip end is within 0.2 miles of a bus stop, 0.35 miles of a streetcar or BRT stop, or 0.5 miles of a rail station; only available for home-based non-school trips; utilities and lot usage for formal park-and-ride lots and informal park-and-ride locations are calculated by a nested park-and-ride lot choice model
Bike – utilities and distances are produced by a stand-alone tool based on a dedicated bicycle network
Walk – only available for trips with a distance less than five miles

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:

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

F.1 Variables Used in Mode Choice Models

F.1.a Variable Definitions

IvTime = In-vehicle travel time (minutes, varies by mode)
WalkTime = Walk time (minutes), 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
- Walk: zone-to-zone time via key walk-accessible links at 3 mph (for trips < 5 miles)

TranWait1 = Transit initial wait time (minutes)
TranWait2 = Transit transfer wait time (minutes)
TranModc = Transit mode constant (varies by transit path)
TranStypc = Transit stop type constant (varies by transit path)
TranXfrs = Transit # of transfers
TrOVIV = ratio of total out-of-vehicle time to in-vehicle time
Formal = 1 if considering formal park-and-ride lots
Informal = 1 if considering informal park-and-ride locations
Shadow = Park-and-ride lot shadow cost (calculated by lot choice model)
BikeDist = Bicycle trip distance (miles)
Cbutil = Bicycle commute route attractiveness
Nbutil = Bicycle non-commute route attractiveness
BikeResPref = 1 if production zone in bicycle user residential preference area (see Figure 1)
LowInc = 1 if household income <$25K (2010$)
MidInc = 1 if household income $25-100K (2010$)
HighInc = 1 if household income $100K+ (2010$)
OpCost = Out-of-pocket cost, by mode:
- Drive Alone: 100% of $0.211 / mile (2010$)
- Drive with Passenger: 66.7% of $0.211 / mile (2010$)
- Auto Passenger: 33.3% of $0.211 / mile (2010$)
- Walk-access Transit: transit fare (2010$)
- Park-and-ride: $0.211 / mile for auto leg, transit fare for transit leg

PkgCost = Parking cost, by mode:
- Drive Alone: 100% of long-term parking charge in attraction zone
- Drive with Passenger: 66.7% of long-term parking charge in attraction zone
- Auto Passenger: 33.3% of long-term parking charge in attraction zone

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)
HH1 = 1 if 1 person household
HH2 = 1 if 2 person household
HH34 = 1 if 3+ person household
Work1 = 1 if one (and only one) worker in household

F.2 HBW (Home-Based Work)

F.2.a Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0414*IvTime – 0.1*WalkTime – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost – 0.509*LowInc*PkgCost – 0.509*MidInc*PkgCost – 0.461*HighInc*PkgCost – 1.9*Cval1**)**

Drive with Passenger

U = **exp (-**3.62 – 0.0414*IvTime – 0.1*WalkTime – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost – 0.509*LowInc*PkgCost – 0.509*MidInc*PkgCost – 0.461*HighInc*PkgCost – 1.02*Cval1 - 1.4*HH1 + 0.729*HH34**)**

Auto Passenger

U = **exp (-**4.15 – 0.0414*IvTime – 0.1*WalkTime – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost – 0.509*LowInc*PkgCost – 0.509*MidInc*PkgCost – 0.461*HighInc*PkgCost + 0.299*HH2 + 0.0297*ln(MixRetP) + 0.0506*ln(MixTotA)**)**

Transit by Walk Access

U = **exp (**-1.15 + TranModc + TranStypc – 0.0414*IvTime – 0.0543*TranWait1 – 0.061*TranWait2 – 0.1*WalkTime – 0.16*TranXfrs – 0.4*TrIVOV – 0.309*LowInc*OpCost – 0.252*MidInc*OpCost – 0.252*HighInc*OpCost + 0.08*ln(MixTotA) + 1.34*Cval0 + 0.349*Cval1 + 0.784*Work1**)**

Park and Ride

Park and Ride uses older model specifications; only the mode-specific constant and informal constant were recalibrated in 2017. The coefficient on auto in-vehicle time is doubled in order to maintain a balance between auto and transit time that is comparable to the observed relationship; otherwise, too many trips include unreasonably high auto times as travelers choose to drive to the periphery of the CBD before boarding transit.

U = **exp (**1.85 + 0.75***ln**(**exp**(Formal*0.5***ln**($\sum_{1\to N}$ [**exp**(($U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow – 1.498*Cval1) / (0.5*0.75))])) + **exp**(Informal*0.5***ln**($\sum_{1\to N}$ [**exp**((-4.5 + $U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow – 1.498*Cval1) / (0.5*0.75))])) **)**

where

$U_{AutoLeg}$ = -0.03608*2*IvTime – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost

and

$U_{TransitLeg}$ = -0.03608*($IvTime_{Bus}$ + 0.88*$IvTime_{LRT}$ + $IvTime_{SC}$ + 0.88*$IvTime_{Rail}$) – 0.0576*TranWait1 – 0.04002*TranWait2 – 0.09956*WalkTime – 0.3*TranXfrs – 0.6587*LowInc*OpCost – 0.6097*MidInc*OpCost – 0.4029*HighInc*OpCost + 0.09828*ln(MixTotA)

and

N = number of formal park-and-ride lots or informal par-and-ride locations under consideration

Bike

U = **exp (**-2.1 – 0.25*BikeDist + 0.0636*Cbutil + 1.35*BikeResPref + 0.0517*ln(MixTotA)**)**

Walk

U = **exp (**-0.55 **–** 0.1*WalkTime + 0.107*ln(MixRetP)**)**

F.2.b Estimated Variable Coefficients

TABLE 34. 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			-3.62		-4.15	
Constant			-3.72	-31.72	-4.41	-19.18
IvTime	-0.0414	*-4.74*	-0.0414	*-4.74*	-0.0414	*-4.74*
Calib WalkTime	-0.1		-0.1		-0.1	
WalkTime	-0.0791	-14.01	-0.0791	-14.01	-0.0791	-14.01
LowIncOpCost	-0.309	-2.83	-0.309	-2.83	-0.309	-2.83
MidIncOpCost	-0.252	-6.34	-0.252	-6.34	-0.252	-6.34
HighIncOpCost	-0.252	-6.34	-0.252	-6.34	-0.252	-6.34
LowIncPkgCost	-0.509	-13.53	-0.509	-13.53	-0.509	-13.53
MidIncPkgCost	-0.509	-13.53	-0.509	-13.53	-0.509	-13.53
HighIncPkgCost	-0.461	-11.65	-0.461	-11.65	-0.461	-11.65
Ln(MixRetP)					0.0297	1.46
Ln(MixTotA)					0.0506	2.37
Cval1	-1.9	-18.06	-1.02	-5.07		
HH1			-1.4	-3.3		
HH2					0.299	2.69
HH34			0.729	5.45		

TABLE 35. HBW Mode Choice Model – Transit Modes

Variable	Walk Access		Park and Ride	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-1.15		1.85	
Constant	-2.34	-13.25	-6.504	-7.3
Ivtime	-0.0414	*-4.74*	-0.03608	-6.3
Wait1	-0.0543	-3.69	-0.0576	-5.8
Wait2	-0.061	-4.66	-0.04002	-5.2
Calib WalkTime	-0.1			
WalkTime	-0.0791	-14.01	-0.09956	-9.7
Transfers	-0.16	*fixed*	-0.3	*fixed*
Calib TrIVOV	-0.4			
TrIVOV	-0.0519	-2.65		
LowIncOpCost	-0.309	-2.83	-0.6587	-9.5
MidIncOpCost	-0.252	-6.34	-0.6097	-12.1
HighIncOpCost	-0.252	-6.34	-0.4029	-7.1
Ln(MixTotA)	0.08	*fixed*	0.05178	1.0
Work1	0.784	5.58		
Cval0	1.34	6.22		
Cval1	0.349	2.07	-1.498	-3.3
Nested Park & Ride Lot Choice Model				
Informal Constant			-4.5	
Park & Ride Nest			0.75	
Formal Nest			0.5	
Informal Nest			0.5	

TABLE 36. HBW Mode Choice Model – Nonmotorized Modes

Variable	Bike	Walk

	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-2.1		-0.55	
Constant	-2.51	-7.35	-1.82	-4.74
Calib BikeDist	-0.25			
BikeDist	-0.215	-6.19		
Cbutil	0.0636	2.92		
Calib BikeResPref	1.35			
BikeResPref	0.5	*fixed*		
Calib WalkTime			-0.1	
WalkTime			-0.0791	-14.01
Ln(MixTotA)	0.0517	2.18		
Ln(MixRetP)			0.107	2.54

F.3 HBshop, HBrec, HBoth (Other Home-Based)

F.3.a Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0315*IvTime – 0.125*WalkTime – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost – 0.731*LowInc*PkgCost – 0.393*MidInc*PkgCost – 0.393*HighInc*PkgCost – 0.704*Cval1**)**

Drive with Passenger

U = **exp (**-1.4*Shop – 1*Rec – 0.9*Oth -0.0315*IvTime – 0.125*WalkTime – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost – 0.731*LowInc*PkgCost – 0.393*MidInc*PkgCost – 0.393*HighInc*PkgCost – 0.436*Cval1 – 1.63*HH1 + 0.889* HH34**)**

Auto Passenger

U = **exp (**-0.85*Shop – 0.15*Rec – 0.6*Oth -0.0315*IvTime – 0.125*WalkTime – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost – 0.731*LowInc*PkgCost – 0.393*MidInc*PkgCost – 0.393*HighInc*PkgCost – 1.41*HH1 + 0.256*HH34**)**

Transit by Walk Access

U = **exp (**-2.84*Shop – 2.7*Rec – 3.45*Oth + TranModc + TranStypc – 0.0315*IvTime – 0.05*TranWait1 – 0.05*TranWait2 – 0.125*WalkTime – 0.16*TranXfrs – 1*TrIVOV – 0.255*LowInc*OpCost – 0.255*MidInc*OpCost – 0.174*HighInc*OpCost + 0.212* ln(MixTotA) + 1.96*Cval0 + 0.665*Cval1**)**

Park and Ride

Park and Ride uses older model specifications; only the mode-specific constant and informal constant were recalibrated in 2017. The coefficient on auto in-vehicle time is doubled in order to maintain a balance between auto and transit time that is comparable to the observed relationship; otherwise, too many trips include unreasonably high auto times as travelers choose to drive to the periphery of the CBD before boarding transit.

U = **exp (**-3.1*Shop – 2*Rec – 2.2*Oth + 0.75***ln**(**exp**(Formal*0.5***ln**($\sum_{1\rightarrow N}$ [**exp**(($U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) + **exp**(Informal*0.5***ln**($\sum_{1\rightarrow N}$ [**exp**((-4 + $U_{AutoLeg}$ + $U_{TransitLeg}$ + Shadow) / (0.5*0.75))])) **)**

where

$U_{AutoLeg}$ = -0.0215*2*IvTime – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost and

$U_{TransitLeg}$ = -0.0215*($IvTime_{Bus}$ + 0.86*$IvTime_{LRT}$ + $IvTime_{SC}$ + 0.86*$IvTime_{Rail}$) – 0.06847*TranWait1 – 0.0524*TranWait2 – 0.1033*WalkTime – 0.3*TranXfrs – 0.4724*LowInc*OpCost – 0.2457*MidInc*OpCost – 0.2457*HighInc*OpCost + 0.1664*ln(MixTotA)

and

N = number of formal park-and-ride lots or informal par-and-ride locations under consideration

Bike

U = **exp (**-2.65*Shop – 1.65*Rec – 2.75*Oth – 0.223*BikeDist + 0.199*Nbutil + 1.03*BikeResPref + 0.212*ln(MixTotA)**)**

Walk

U = **exp (**-0.8*Shop + 0.7*Rec + 0*Oth – 0.125*WalkTime + 0.188*ln(MixRetP)**)**

F.3.b Estimated Variable Coefficients

TABLE 37. 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			-1.4		-0.85	
Calib Rec			-1		-0.15	
Calib Oth			-0.9		-0.6	
Shop			-1.56	-32.21	-1.89	-34.42
Rec			-1.17	-20.87	-1.4	-22.98
Oth			-0.983	-28.87	-1.5	-38.77
IvTime	-0.0315	*-2.16*	-0.0315	*-2.16*	-0.0315	*-2.16*
Calib WalkTime	-0.125		-0.125		-0.125	
WalkTime	-0.0906	-27.55	-0.0906	-27.55	-0.0906	-27.55
LowIncOpCost	-0.255	*-7.47*	-0.255	*-7.47*	-0.255	*-7.47*
MidIncOpCost	-0.255	*-7.47*	-0.255	*-7.47*	-0.255	*-7.47*
HighIncOpCost	-0.174	*-3.99*	-0.174	*-3.99*	-0.174	*-3.99*
LowIncPkgCost	-0.731	*-3.1*	-0.731	*-3.1*	-0.731	*-3.1*
MidIncPkgCost	-0.393	*-5.2*	-0.393	*-5.2*	-0.393	*-5.2*
HighIncPkgCost	-0.393	*-5.2*	-0.393	*-5.2*	-0.393	*-5.2*
Cval1	-0.704	-9.07	-0.436	-5.25		
HH1			-1.63	-16.37	-1.41	-14.85
HH34			0.889	22.77	0.256	5.75

TABLE 38. HBshop, HBrec, HBoth Mode Choice Model – Transit Modes

Variable	Walk Access		Park and Ride	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Shop	-2.84		--3.1	
Calib Rec	-2.7		-2	
Calib Oth	-3.45		-2.2	
Shop	-4.95	-9.89	-7.023	-3.8
Rec	-4.4	-8.63	-7.023	-3.8
Oth	-5.03	-10	-7.023	-3.8
IvTime	-0.0315	*-2.16*	-0.0215	-3.2
Calib TranWait1	-0.05			
TranWait1	-0.0824	-4.7	-0.06847	-5.4
Calib TranWait2	-0.05			
TranWait2	-0.074	-4.42	-0.0524	-4.8
Calib WalkTime	-0.125			
WalkTime	-0.0906	-27.55	-0.1033	-8.3
TranXfrs	-0.16	*fixed*	-0.3	*fixed*
Calib TrIVOV	-1			
TrIVOV	-0.121	*-3.11*		
LowIncOpCost	-0.255	*-7.47*	-0.4724	-6.8
MidIncOpCost	-0.255	*-7.47*	-0.2457	-5.2
HighIncOpCost	-0.174	*-3.99*	-0.2457	-5.2
Ln(MixTotA)	0.212	6.18	0.3073	1.5
Ln(MixRetP)	0.203	5.2		
Cval0	1.96	12.4		
Cval1	0.665	3.93		
Nested Park & Ride Lot Choice Model				
Informal Constant			-4	
Park & Ride Nest			0.75	
Formal Nest			0.5	
Informal Nest			0.5	

TABLE 39. HBshop, HBrec, HBoth Mode Choice Model – Nonmotorized Modes

Variable	Bike		Walk	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Shop	-2.65		-0.8	
Calib Rec	-1.65		0.7	
Calib Oth	-2.75		0	
Shop	-3.74	-11.64	-2.6	-15.29
Rec	-2.73	-8.63	-1.41	-8.44
Oth	-3.73	-12.05	-2.15	-13.83
Calib BikeDist	-0.223			
BikeDist	-0.233	-5.38		
Nbutil	0.199	7.88		
Calib BikeResPref	1.03			
BikeResPref	0.5	*fixed*		
Calib WalkTime			-0.125	
WalkTime			-0.0906	-27.55
Ln(MixTotA)	0.212	7.29		
Calib Ln(MixRetP)			0.188	
Ln(MixRetP)			0.229	13.99

F.4 NHBW (Non-Home-Based Work)

F.4.a Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0452*IvTime – 0.157*WalkTime – 0.194*OpCost – 0.557*PkgCost**)**

Drive with Passenger

U = **exp (**-2.2 – 0.0452*IvTime – 0.157*WalkTime – 0.194*OpCost – 0.557*PkgCost**)**

Auto Passenger

U = **exp (**-2.6 – 0.0452*IvTime – 0.157*WalkTime – 0.194*OpCost – 0.557*PkgCost**)**

Transit by Walk Access

U = **exp (**0.95 + TranModc + TranStypc – 0.0452*IvTime – 0.118*TranWait1 – 0.118*TranWait2 – 0.157*WalkTime – 0.16*TranXfrs – 0.194*OpCost – 1*TrOVIV**)**

Bike

U = **exp (**-3.55 **–** 0.22*BikeDist + 0.0841*Nbutil + 1.13*BikeResPref + 0.1*Ln(MixTotA)**)**

Walk

U = **exp (**-1.15 – 0.157*WalkTime + 0.248*ln(MixRetP)**)**

F.4.b Estimated Variable Coefficients

TABLE 40. NHBW Mode Choice Model – Auto Modes

Variable	Drive Alone		Drive with Passenger		Auto Passenger	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			-2.2		-2.6	
Constant			-2.43	-46.75	-2.99	-48.6
IvTime	-0.0452	-2.49	-0.0452	-2.49	-0.0452	-2.49
WalkTime	-0.157	-16.7	-0.157	-16.7	-0.157	-16.7
OpCost	-0.194	-3.33	-0.194	-3.33	-0.194	-3.33
PkgCost	-0.557	-5.41	-0.557	-5.41	-0.557	-5.41

TABLE 41. NHBW Mode Choice Model – Transit Modes

Variable	Walk Access	
	Coefficient	T-Statistic
Calib Constant	0.95	
Constant	-1.76	-2.76
IvTime	-0.0452	-2.49
TranWait1	-0.118	-5.07
TranWait2	-0.118	-5.07
WalkTime	-0.157	-16.7
TranXfrs	-0.16	*fixed*
OpCost	-0.194	-3.33
Calib TrIVOV	-1	
TrIVOV	0	*fixed*
Calib Ln(MixTotA)	0	
Ln(MixTotA)	-0.161	-6.18

TABLE 42. NHBW Mode Choice Model – Nonmotorized Modes

Variable	Bike		Walk	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-3.55		-1.15	
Constant	-4.96	-52.56	-2.12	-5.52
BikeDist	-0.22	-4.06		
Nbutil	0.0841	1.98		
Calib BikeResPref	1.13			
BikeResPref	0.5	*fixed*		
WalkTime			-0.157	-16.7
Calib Ln(MixRetP)			0.248	
Ln(MixRetP)			0.2553	10.6
Ln(MixTotA)	0.1	*fixed*		

F.5 NHBNW (Non-Home-Based Non-Work)

F.5.a Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0278*IvTime – 0.125*WalkTime – 0.15*OpCost – 0.335*PkgCost**)**

Drive with Passenger

U = **exp (**-0.4 – 0.0278*IvTime – 0.125*WalkTime – 0.15*OpCost – 0.335*PkgCost**)**

Auto Passenger

U = **exp (**-0.3 – 0.0278*IvTime – 0.125*WalkTime – 0.15*OpCost – 0.335*PkgCost**)**

Transit by Walk Access

U = **exp (**0.9 + TranModc + TranStypc – 0.0278*IvTime – 0.0781*TranWait1 – 0.0841*TranWait2 – 0.125*WalkTime – 0.16*TranXfrs – 1*TrIVOV – 0.15*OpCost + 0.128*ln(MixTotA) + 0.135*ln(MixRetP)**)**

Bike

U = **exp (**-3.3 **–** 0.453*BikeDist – 0.13*Nbutil + 1.13*BikeResPref + 0.172*ln(MixTotA)**)**

Walk

U = **exp (**-2.25 – 0.125*WalkTime + 0.301*ln(MixRetP)**)**

F.5.b Estimated Variable Coefficients

TABLE 43. NHBNW Mode Choice Model – Auto Modes

Variable	Drive Alone		Drive with Passenger		Auto Passenger	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant			-0.4		-0.3	
Constant			-0.491	-18.74	-1.37	-41.17
IvTime	-0.0278	-1.63	-0.0278	-1.63	-0.0278	-1.63
Calib WalkTime	-0.125		-0.125		-0.125	
WalkTime	-0.0886	-14.68	-0.0886	-14.68	-0.0886	-14.68
OpCost	-0.15	-2.94	-0.15	-2.94	-0.15	-2.94
PkgCost	-0.335	-5.91	-0.335	-5.91	-0.335	-5.91

TABLE 44. NHBNW Mode Choice Model – Transit Modes

Variable	**Walk Access**	
	Coefficient	T-Statistic
Calib Constant	0.9	
Constant	-3.8	-4.82
IvTime	-0.0278	-1.63
TranWait1	-0.0781	-2.85
TranWait2	-0.0841	-2.97
Calib WalkTime	-0.125	
WalkTime	-0.0886	-14.68
TranXfrs	-0.16	*fixed*
Calib TrIVOV	-1	
TrIVOV	-0.15	*fixed*
OpCost	-0.15	-2.94
Calib Ln(MixRetP)	0	
Ln(MixRetP)	0.135	2.55
Calib Ln(MixTotA)	0	
Ln(MixTotA)	0.128	2.24

TABLE 45. NHBNW Mode Choice Model – Nonmotorized Modes

Variable	**Bike**		**Walk**	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-3.3		-2.25	
Constant	-4.26	-7.47	-3.73	-11.9
BikeDist	-0.453	-3.94		
Nbutil	0.13	2.83		
Calib BikeResPref	1.13			
BikeResPref	0.5	*fixed*		
Calib WalkTime			*-0.125*	
WalkTime			-0.0886	-14.68
Ln(MixRetP)			0.301	10.1
Ln(MixTotA)	0.172	3.3		

F.6 HBcoll (Home-Based College)

F.6.a Calibrated Choice Utilities

Drive Alone

U = **exp (**-0.0346*IvTime – 0.08*WalkTime – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost – 0.463*LowInc*PkgCost – 0.383*MidInc*PkgCost – 0.184*HighInc*PkgCost – 1.36*Cval1**)**

Drive with Passenger

U = **exp (**-3.1 – 0.0346*IvTime – 0.08*WalkTime – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost – 0.463*LowInc*PkgCost – 0.383*MidInc*PkgCost – 0.184*HighInc*PkgCost**)**

Auto Passenger

U = **exp (**-2.45 – 0.0346*IvTime – 0.08*WalkTime – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost – 0.463*LowInc*PkgCost – 0.383*MidInc*PkgCost – 0.184*HighInc*PkgCost**)**

Transit by Walk Access

U = **exp (**0.1 + TranModc + TranStypc – 0.0346*IvTime – 0.055*TranWait1 – 0.055*TranWait2 – 0.08*WalkTime – 0.15*TranXfrs – 0.463*LowInc*OpCost – 0.383*MidInc*OpCost – 0.184*HighInc*OpCost + 0.763*Cval0 + 0.528*Cval1 + 0.1*ln(LogMixTotA)**)**

Park and Ride

Park and Ride uses older model specifications; only the mode-specific constant and informal constant were recalibrated in 2017. The coefficient on auto in-vehicle time is doubled in order to maintain a balance between auto and transit time that is comparable to the observed relationship; otherwise, too many trips include unreasonably high auto times as travelers choose to drive to the periphery of the CBD before boarding transit.

$U = \mathbf{exp}\,(2.85 + 0.75 * \mathbf{ln}(\mathbf{exp}(\text{Formal} * 0.5 * \mathbf{ln}(\sum_{1\rightarrow N} [\mathbf{exp}((U_{AutoLeg} + U_{TransitLeg} + \text{Shadow}) / (0.5*0.75))])) + \mathbf{exp}(\text{Informal} * 0.5 * \mathbf{ln}(\sum_{1\rightarrow N} [\mathbf{exp}((-5.5 + U_{AutoLeg} + U_{TransitLeg} + \text{Shadow}) / (0.5*0.75))])))$

where

$U_{AutoLeg}$ = -0.05319*2*IvTime – 0.1407*OpCost

and

$U_{TransitLeg}$ = -0.05319*($IvTime_{Bus}$ + 0.86*$IvTime_{LRT}$ + $IvTime_{SC}$ + 0.86*$IvTime_{Rail}$) – 0.0652*TranWait1 – 0.05302*TranWait2 – 0.2111*WalkTime – 0.3*TranXfrs – 0.1407*OpCost + 1.022***ln**(Tdist)

and

N = number of formal park-and-ride lots or informal par-and-ride locations under consideration

Bike

U = **exp (**-1.9 – 0.3*BikeDist + 0.05*Cbutil **+** 0.1*Ln(MixTotA)**)**

Walk

U = **exp (**0.25 – 0.08*WalkTime + 0.119* ln(MixRetP)**)**

F.6.b Estimated Variable Coefficients

TABLE 46. 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			-3.1		-2.45	
Constant			-3.08	-12.85	-3.01	-16.8
IvTime	-0.0346	-1.48	-0.0346	-1.48	-0.0346	-1.48
Calib WalkTime	-0.08		-0.08		-0.08	
WalkTime	-0.0615	-4.25	-0.0615	-4.25	-0.0615	-4.25
LowIncOpCost	-0.463	-2.36	-0.463	-2.36	-0.463	-2.36
MidIncOpCost	-0.383	-3.58	-0.383	-3.58	-0.383	-3.58
HighIncOpCost	-0.184	-1.61	-0.184	-1.61	-0.184	-1.61
LowIncPkgCost	-0.463	-2.36	-0.463	-2.36	-0.463	-2.36
MidIncPkgCost	-0.383	-3.58	-0.383	-3.58	-0.383	-3.58
HighIncPkgCost	-0.184	-1.61	-0.184	-1.61	-0.184	-1.61
Cval1	-1.36	-3.5				
Calib HH34					*0*	
HH34					0.2	*fixed*

TABLE 47. HBcoll Mode Choice Model – Transit Modes

Variable	Walk Access		Park and Ride	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	0.1		2.85	
Constant	-2.07	-1.99	-1.175	-3.4
IvTime	-0.0346	-1.48	-0.05319	-2.9
Calib TranWait1	-0.055			
TranWait1	-0.0296	-1.15	-0.05302	-2.3
Calib TranWait2	-0.055			
TranWait2	-0.0296	-1.15	-0.05302	-2.3
Calib WalkTime	-0.08			
WalkTime	-0.0615	-4.25	-0.2111	-3.7
TranXfrs	-0.15	*fixed*	-0.3	*fixed*
Calib TrIVOV	0			
TrIVOV	-0.156	*fixed*		
LowIncOpCost	-0.463	-2.36	-0.1407	-1.2
MidIncOpCost	-0.383	-3.58	-0.1407	-1.2
HighIncOpCost	-0.184	-1.61	-0.1407	-1.2
Calib Ln(MixTotA)	0			
Ln(MixTotA)	0.157	1.79		
Cval0	0.763	1.28		
Cval1	0.528	1.35		
Nested Park & Ride Lot Choice Model				
Informal Constant			-5.5	
Park & Ride Nest			0.75	
Formal Nest			0.5	
Informal Nest			0.5	

TABLE 48. HBcoll Mode Choice Model – Nonmotorized Modes

Variable	Bike		Walk	
	Coefficient	T-Statistic	Coefficient	T-Statistic
Calib Constant	-1.9		0.25	
Constant	-3.73	-7.49	-1.83	-1.29
Calib BikeDist	-0.3			
BikeDist	-0.153	-2.09		
Cbutil	0.05	*fixed*		
Calib WalkTime			-0.08	
WalkTime			-0.0615	-4.25
Ln(MixRetP)			0.119	0.81
Ln(MixTotA)	0.1	*fixed*		

F.7 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 49. HBsch Mode Choice Model

Location	Dist	Auto Driver	Auto Passenger	Transit	Walk	Bike	School Bus
City of Portland	1,5,7	0.2372	0.3601	0.0558	0.1953	0.0735	0.0781
East Suburbs	4,6	0.1875	0.3254	0.0123	0.131	0.0187	0.3251
West Suburbs	2,3	0.2256	0.3048	0.0027	0.1261	0.0086	0.3322
Clark County	8	0.2214	0.3139	0.0033	0.0682	0.0122	0.381

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 2010-11 household activity survey. Hourly peaking factors for both Production->Attraction and Attraction->Production trip ends for all trip purposes are provided in the tables on the following pages.

Once an hourly trip table has been calculated using the referenced peaking factors, a final daily adjustment factor is applied to the trip table based on a diurnal profile calculated from traffic counts on all Tier 1 cutlines. These adjustments are made to both SOV and HOV trip tables.

Metro utilizes a peak spreading algorithm as a post-demand model adjustment to all SOV and HOV trip tables. For further documentation on how this algorithm works, please refer to the supporting Kate Peak Spreading Methodology and FAQ document listed in the Table of Contents.

TABLE 50. Hourly peaking factors: HBW and HBO

Time Period	HBW Auto PA	HBW Auto AP	HBW Transit PA	HBW Transit AP	HBO Auto PA	HBO Auto AP	HBO Transit PA	HBO Transit AP
0:00 - 0:59	0.0007	0.0025	-	-	0.0001	0.0017	-	-
1:00 - 1:59	0.0002	0.0032	-	-	0.0001	0.0013	-	-
2:00 - 2:59	0.0000	0.0010	-	-	0.0002	0.0007	-	-
3:00 - 3:59	0.0037	0.0010	0.0017	-	0.0002	0.0001	-	-
4:00 - 4:59	0.0124	0.0012	0.0095	-	0.0021	0.0002	-	-
5:00 - 5:59	0.0395	0.0017	0.0677	-	0.0071	0.0016	0.0062	-
6:00 - 6:59	0.0905	0.0008	0.1249	0.0040	0.0204	0.0032	0.0184	-
7:00 - 7:59	0.1515	0.0036	0.1343	0.0026	0.0441	0.0084	0.0978	0.0029
8:00 - 8:59	0.0841	0.0043	0.0816	0.0000	0.0504	0.0157	0.0865	0.0139
9:00 - 9:59	0.0376	0.0039	0.0430	0.0038	0.0414	0.0172	0.0591	0.0237
10:00 - 10:59	0.0195	0.0077	0.0171	0.0043	0.0324	0.0198	0.0533	0.0186
11:00 - 11:59	0.0110	0.0118	0.0138	0.0034	0.0350	0.0267	0.0455	0.0276
12:00 - 12:59	0.0157	0.0180	0.0019	0.0038	0.0235	0.0253	0.0348	0.0406
13:00 - 13:59	0.0154	0.0173	0.0068	0.0054	0.0280	0.0259	0.0285	0.0398
14:00 - 14:59	0.0135	0.0292	0.0038	0.0175	0.0331	0.0336	0.0385	0.0506
15:00 - 15:59	0.0114	0.0544	0.0024	0.0550	0.0319	0.0465	0.0276	0.0337
16:00 - 16:59	0.0092	0.0809	0.0019	0.0913	0.0340	0.0498	0.0288	0.0208
17:00 - 17:59	0.0085	0.1069	0.0079	0.1757	0.0356	0.0575	0.0211	0.0580
18:00 - 18:59	0.0075	0.0487	0.0027	0.0443	0.0463	0.0446	0.0176	0.0400
19:00 - 19:59	0.0021	0.0209	0.0008	0.0222	0.0195	0.0372	0.0132	0.0141
20:00 - 20:59	0.0016	0.0144	0.0042	0.0175	0.0083	0.0432	0.0000	0.0298
21:00 - 21:59	0.0008	0.0153	0.0006	0.0094	0.0025	0.0259	0.0015	0.0076
22:00 - 22:59	0.0015	0.0065	-	0.0119	0.0019	0.0102	-	-
23:00 - 23:59	0.0004	0.0061	-	0.0013	0.0009	0.0050	-	-

TABLE 51. Hourly peaking factors: HBS and HBR

Time Period	HBS Auto PA	HBS Auto AP	HBS Transit PA	HBS Transit AP	HBR Auto PA	HBR Auto AP	HBR Transit PA	HBR Transit AP
0:00 - 0:59	-	-	-	-	-	0.0044	-	-
1:00 - 1:59	-	-	-	-	-	0.0014	-	-
2:00 - 2:59	-	-	-	-	-	0.0007	-	-
3:00 - 3:59	-	-	-	-	-	-	-	-
4:00 - 4:59	0.0007	-	-	-	0.0066	0.0021	-	-
5:00 - 5:59	0.0010	0.0002	-	-	0.0333	0.0027	0.0114	-
6:00 - 6:59	0.0054	0.0009	0.0110	-	0.0228	0.0140	0.0166	-
7:00 - 7:59	0.0104	0.0048	0.0362	-	0.0232	0.0109	0.0172	-
8:00 - 8:59	0.0187	0.0056	0.0236	0.0305	0.0321	0.0095	0.0257	-
9:00 - 9:59	0.0288	0.0145	0.0605	0.0061	0.0344	0.0224	0.1121	-
10:00 - 10:59	0.0335	0.0369	0.0194	0.0300	0.0326	0.0149	0.0567	0.0050
11:00 - 11:59	0.0349	0.0453	0.0607	0.0202	0.0213	0.0259	0.0173	0.1214
12:00 - 12:59	0.0237	0.0458	0.1112	0.0134	0.0224	0.0145	0.0131	0.0266
13:00 - 13:59	0.0334	0.0473	0.0201	0.0451	0.0118	0.0136	0.0893	0.0122
14:00 - 14:59	0.0327	0.0661	0.0134	0.0603	0.0203	0.0154	0.0313	0.0099
15:00 - 15:59	0.0320	0.0559	0.0400	0.0588	0.0260	0.0207	0.0440	0.0642
16:00 - 16:59	0.0264	0.0800	0.0354	0.0925	0.0484	0.0372	0.0066	0.0635
17:00 - 17:59	0.0249	0.0716	0.0248	0.0923	0.0586	0.0416	0.1061	0.0047
18:00 - 18:59	0.0232	0.0653	0.0061	0.0642	0.0672	0.0691	-	0.0424
19:00 - 19:59	0.0171	0.0372	0.0000	0.0068	0.0254	0.0663	-	0.0450
20:00 - 20:59	0.0079	0.0317	0.0044	0.0086	0.0076	0.0495	-	0.0375
21:00 - 21:59	0.0027	0.0252	-	-	0.0015	0.0405	-	0.0159
22:00 - 22:59	0.0007	0.0067	-	0.0044	0.0025	0.0175	-	0.0044
23:00 - 23:59	-	0.0009	-	-	-	0.0072	-	-

TABLE 52. Hourly peaking factors: College and School

Time Period	College Auto PA	College Auto AP	College Transit PA	College Transit AP	School Auto PA	School Auto AP	School Transit PA	School Transit AP
0:00 - 0:59	-	-	-	-	-	-	-	-
1:00 - 1:59	-	-	-	-	-	-	-	-
2:00 - 2:59	-	-	-	-	-	-	-	-
3:00 - 3:59	-	0.0014	-	-	-	-	-	-
4:00 - 4:59	-	-	-	-	-	-	-	-
5:00 - 5:59	-	-	-	-	0.0004	-	0.0108	-
6:00 - 6:59	0.0075	-	0.0732	-	0.0252	0.0049	0.1175	-
7:00 - 7:59	0.1082	-	0.1507	-	0.2034	0.0454	0.3613	-
8:00 - 8:59	0.0808	0.0013	0.0820	0.0086	0.1549	0.0809	0.0238	-
9:00 - 9:59	0.0630	0.0040	0.1622	0.0219	0.0174	0.0188	0.0098	-
10:00 - 10:59	0.0394	0.0084	0.0077	0.0000	0.0106	0.0057	-	-
11:00 - 11:59	0.0331	0.0089	0.0295	0.0000	0.0128	0.0108	-	-
12:00 - 12:59	0.0314	0.0496	0.0030	0.0219	0.0121	0.0150	-	-
13:00 - 13:59	0.0106	0.0271	0.0188	0.0306	0.0118	0.0070	-	0.0259
14:00 - 14:59	0.0129	0.0645	0.0038	0.0284	0.0667	0.0663	-	0.0395
15:00 - 15:59	0.0074	0.0400	0.0332	0.0717	0.0340	0.0649	-	0.2135
16:00 - 16:59	0.0361	0.0305	0.0066	0.0099	0.0172	0.0188	-	0.1422
17:00 - 17:59	0.0614	0.0445	0.0115	0.0263	0.0169	0.0321	-	0.0157
18:00 - 18:59	0.0300	0.0209	0.0244	0.0384	0.0086	0.0092	-	0.0400
19:00 - 19:59	0.0287	0.0544	-	0.0210	0.0059	0.0037	-	-
20:00 - 20:59	-	0.0485	-	0.0526	0.0026	0.0073	-	-
21:00 - 21:59	-	0.0416	-	0.0575	-	0.0040	-	-
22:00 - 22:59	-	0.0041	-	0.0048	0.0011	0.0014	-	-
23:00 - 23:59	-	-	-	-	-	0.0024	-	-

TABLE 53. Hourly peaking factors: Non-Home, Externals, and Trucks

Time Period	NHBW Auto PA	NHBW Auto AP	NHBW Transit PA	NHBW Transit AP	NHBNW Auto OD	NHBNW Transit OD	Externals	Heavy Trucks	Medium Trucks
0:00 - 0:59	0.0037	-	-	-	0.0004	0.0022	0.0132	0.0151	0.0055
1:00 - 1:59	0.0005	-	-	-	0.0008	-	0.0132	0.0161	0.0048
2:00 - 2:59	-	-	-	-	0.0003	-	0.0132	0.0142	0.0062
3:00 - 3:59	-	0.0002	-	-	0.0059	-	0.0132	0.0166	0.0068
4:00 - 4:59	0.0007	0.0021	-	-	0.0016	-	0.0132	0.0217	0.0140
5:00 - 5:59	0.0002	0.0040	-	-	0.0010	-	0.0132	0.0297	0.0200
6:00 - 6:59	0.0013	0.0171	-	0.0207	0.0053	-	0.0560	0.0445	0.0355
7:00 - 7:59	0.0073	0.0638	0.0088	0.0767	0.0261	0.0020	0.0628	0.0564	0.0540
8:00 - 8:59	0.0155	0.0606	0.0099	0.0537	0.0455	0.0572	0.0628	0.0609	0.0830
9:00 - 9:59	0.0223	0.0384	-	0.0054	0.0509	0.0189	0.0558	0.0721	0.0869
10:00 - 10:59	0.0297	0.0292	0.0050	0.0258	0.0756	0.0944	0.0558	0.0778	0.0847
11:00 - 11:59	0.0585	0.0351	0.0243	0.0106	0.0927	0.1108	0.0558	0.0750	0.0837
12:00 - 12:59	0.0578	0.0541	0.0358	0.0555	0.0845	0.2023	0.0558	0.0717	0.0821
13:00 - 13:59	0.0398	0.0425	0.0591	0.0195	0.1006	0.0798	0.0558	0.0691	0.0791
14:00 - 14:59	0.0483	0.0271	0.0861	0.0385	0.0944	0.0976	0.0596	0.0666	0.0801
15:00 - 15:59	0.0691	0.0228	0.0675	0.0219	0.0967	0.1591	0.0724	0.0573	0.0727
16:00 - 16:59	0.0858	0.0136	0.1887	0.0236	0.0891	0.0747	0.0724	0.0465	0.0551
17:00 - 17:59	0.0806	0.0052	0.0885	0.0226	0.0720	0.0477	0.0724	0.0364	0.0429
18:00 - 18:59	0.0293	0.0043	0.0261	-	0.0688	0.0236	0.0596	0.0352	0.0330
19:00 - 19:59	0.0074	0.0051	0.0106	0.0056	0.0396	0.0212	0.0326	0.0298	0.0227
20:00 - 20:59	0.0059	0.0014	-	-	0.0240	0.0085	0.0326	0.0259	0.0169
21:00 - 21:59	0.0042	0.0010	0.0027	0.0027	0.0187	-	0.0326	0.0228	0.0120
22:00 - 22:59	0.0022	0.0010	-	-	0.0045	-	0.0132	0.0200	0.0099
23:00 - 23:59	0.0014	-	-	0.0040	0.0011	-	0.0132	0.0186	0.0084

FIGURE 3. Tier 1 traffic count cutlines

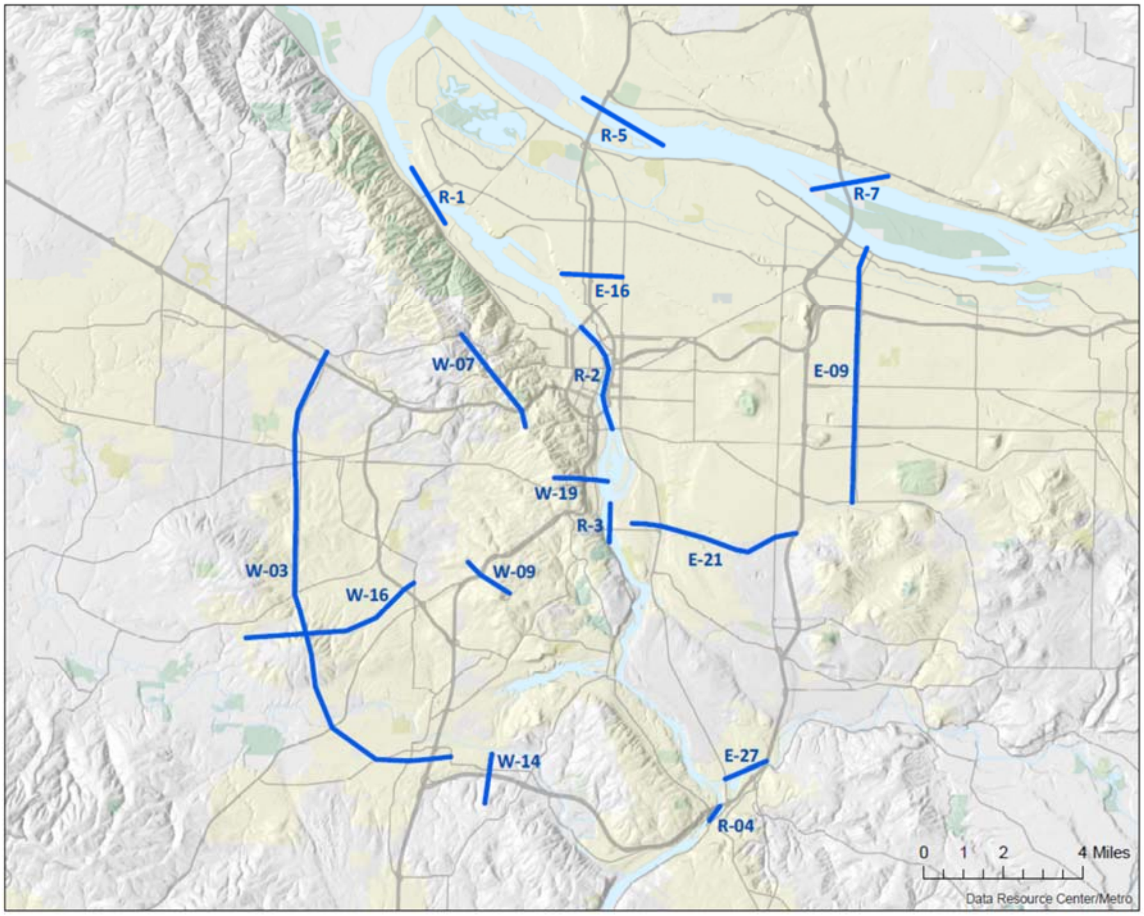


TABLE 54. Count-based adjustment factors

Time Period	Count-based Adjustment Factors	Time Period	Count-based Adjustment Factors
0:00 - 0:59	0.0064	12:00 - 12:59	0.0579
1:00 - 1:59	0.0045	13:00 - 13:59	0.0592
2:00 - 2:59	0.0042	14:00 - 14:59	0.0645
3:00 - 3:59	0.0053	15:00 - 15:59	0.0697
4:00 - 4:59	0.0110	16:00 - 16:59	0.0727
5:00 - 5:59	0.0288	17:00 - 17:59	0.0716
6:00 - 6:59	0.0527	18:00 - 18:59	0.0611
7:00 - 7:59	0.0669	19:00 - 19:59	0.0428
8:00 - 8:59	0.0643	20:00 - 20:59	0.0330
9:00 - 9:59	0.0559	21:00 - 21:59	0.0277
10:00 - 10:59	0.0531	22:00 - 22:59	0.0190
11:00 - 11:59	0.0557	23:00 - 23:59	0.0119

H Assignment

H.1 Auto Assignment

Auto assignment procedures are developed in Emme macro language and run with Emme 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 typically assigned simultaneously using a multi-class assignment technique. Additional truck delay is included on various links in the arterial system in order to account for factors such as slope that are known to affect truck path choice. 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

The multi-path transit assignment follows the auto assignment, with transit speed determined as a function of underlying auto speed except where transit vehicles operate on exclusive right-of-way. Transit time consists of auxiliary (walk) time, wait time (initial and transfer), boarding time, and in-vehicle time. Actual wait time at certain nodes and actual in-vehicle time on certain line segments are reduced by applying factors designed to account for perceptions of time that vary by stop and vehicle type. The transit assignment algorithm allocates trips among eligible paths by (1) distributing flow between multiple outgoing centroid connectors using an embedded logit model based on total transit time to the destination; and (2) distributing flow between multiple lines at a stop node by considering frequency and total transit time to destination.

I Portland International Airport Model

Trips to/from the zone containing the Portland International Airport (PDX) terminal are generated by the Airport Passenger Demand Model (APDM). This model is separate from the Kate travel demand model. Documentation for the APDM can be found in the supporting document referenced in the Table of Contents.

The output of the APDM is a set of hourly and daily zone-to-zone trip tables for SOV, HOV, and transit. These tables are added to the appropriate transit trip tables produced by the Kate model time of day programs, and then assigned to the mode-specific networks as applicable.

J 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 55. 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.

K Truck Model

The truck model forecasts the quantity, type, and distribution of truck trips generated by the flow of goods into, out from, and within the 4-county region. The model is based on a commodity flow (CF) database that forecasts annual tonnage flows of 44 commodity groups (2-digit SCTG) by primary mode, origin and destination regions and forecast year (2000 to 2035, in 5-year increments). The CF database was initially prepared for the Port of Portland using Freight Analysis Framework (1997 CFS) data. It was updated in 2005 using FAF2 (2002 CFS) data, then validated and augmented by the regional 2006 trade capacity study. It was most recently updated in December 2015, using a FAF3 (2007 CFS) database provided to the Port in April, 2015

The prepared CF data provides a commodity flow database that includes the FAF3 zone comprising Portland and surrounding Oregon counties, plus isolates freight flows to and from Clark County, WA from another FAF3 zone that includes all of Washington outside the Puget Sound area. Thus, the database includes flows to and from the whole Portland-Vancouver metropolitan region. In the April 2015 update, the contractor also post-processed FAF3 data to parse many of the multi-mode domestic flows into component legs by mode. .

Adjustments to Base Year (2010) Commodity Flows

The Port of Portland maintains annual statistics of freight tonnage entering and leaving Port facilities. Overall tonnage growth between 2005 and 2010 was generally consistent with forecasts flows in the CF database. However, ship-borne vehicle imports and all air freight shipments were reduced to 0.75 times 2005 levels to maintain consistency with Port data.

Adjustments to Future Year (2035) Commodity Flows

Forecasted regional employment growth has been significantly reduced since the time that the CF database was last validated. Accordingly, growth in internal flows of commodity groups associated with each employment sector has been scaled to maintain consistency with employment forecasts, while still allowing for marginal increases in productivity.

K.1 Allocation of Flows to Truck Sub-modes

Where truck is not the primary mode of travel, Port of Portland staff provided estimates of the proportion of each commodity flow that will utilize the truck sub-mode for part of the journey. It is assumed that 100% of air freight entering and leaving the region will utilize trucks to access and egress the airport. Similarly, 100% of rail-truck intermodal freight utilizes trucks. For other rail and for ship and barge, the proportion utilizing a truck submode varies by commodity. About one-fourth of total rail tonnage entering and leaving the region utilizes a truck sub-mode in 2005, increasing to one-third in 2035. About one-half of total water-borne tonnage is assumed to utilize a truck submode. It is assumed that no pipeline-borne commodities utilize a truck sub-mode en route to consumption or processing destinations.

The Port of Portland also provided estimates of the proportion of truck-borne flows in each commodity group that should be allocated to private carriers and truck load shipments with the balance allocated to less-than-truckload shipments.

K.2 Flows Modeled

TABLE 56. Truck flows modeled

FROM: \ TO:	Internal Zones	External	Port Facilities	Rail / Intermodal	PDX
Internal Zones	x	x	x	x	x
External	x	x	x	x	x
Port Facilities	x	x	na	na	na
Rail / Intermodal	x	x	na	na	na
PDX	x	x	na	na	na

K.3 Application of Weekday Factor

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

K.4 Allocation of Flows with local Origins/Destinations to TAZs

Metro Data Resource Center provided both base year and forecasted employment by industrial sector for each transportation analysis zone (TAZ). The sector groupings are as follows:

- Agriculture/Farming/Forestry (AGFF)
- Mining (MIN)
- Construction (CON)
- Manufacturing (MAN)
- Transportation/Communications/Public Utilities (TCPU)
- Wholesale (WHLS)
- Retail (RET)
- Finance/Insurance/Real Estate (FIRE)
- Service (SERV)
- Government (GOV)

With guidance from Cambridge Systematics, the SCTG2 commodities were consolidated into 16 commodity groups and allocated to employment sectors as follows:

TABLE 57. Commodity / employment sector associations

Commodity Group	Produced by	Attracted To
Farm	AFM	AFM, MFG
Metallic Minerals*	n/a	n/a
Non-metallic Minerals	CON	MFG
Chemicals	MFG	AFM, MFG
Petroleum	MFG	MFG, TPU
Stone	MIN, MFG	CON, MFG
Food	AFM, MFG	all
Wood	AFM, MFG	CON, MFG, RET
Paper	AFM, MFG	MFG, TPU, RET, FIRE, SERV, GOV
Metals	MFG	MFG
Machinery	MFG	MFG
Transportation Equipment	MFG	TPU
Manufactured Goods	MFG	MFG, RET
Textiles	MFG	RET
Waste Products	all	MFG
Courier	all	all

* no internal trip ends

K.5 Allocation of Flows to Terminals and Other Regional "Gateways"

Trucks carrying commodities that enter or leave the region at specific sites such as railyards, barge terminals, marine facilities, the airport, and external points are assigned one trip end at those places. Based on discussions with the Port staff, each of the specific rail, barge, ship, and air facilities was allocated a predetermined percentage of total flows to that facility type.

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

TABLE 58. Railyard allocations

Railyard	Percent of Total Rail-Truck Flows
Albina	33%
Brooklyn	33%
Wilbridge	34%

Ship and barge flows are allocated among port terminal facilities as follows:

TABLE 59. Commodity allocations by port facility

Commodity	Port Facility	TAZ #	Flow Portion
Farm Products	POP Terminal 6	128	12%
	POP Terminal 5	129	22%
	POP Terminal 4	162	22%
	Albina Docks	197	22%
	Albina Docks	201	22%
Metallic Minerals		(No Products to/from Port terminals)	
Non-Metalic Minerals	Rivergate	154	80%
	Ross Island	220	20%
Chemicals	Rivergate	154	100%
Petroleum	POP Terminal 2	34	25%
	Wilbridge - South	38	25%
	Wilbridge - North	48	25%
	POV Terminal 2	1508	25%
Stone	POP Terminal 2	34	14%
	Wilbridge - North	48	14%
	Pier 99	134	14%
	Albina Docks	197	14%
	Ross Island	220	15%
	POV Terminal 1	1506	15%
	POV Terminal 3/4/5	1531	14%
Food	POP Terminal 6	128	100%
Wood	POP Terminal 2	34	50%
	POV Terminal 2	1508	50%
Paper	POP Terminal 2	34	72%
	POP Terminal 6	128	25%
	POV Terminal 3/4/5	1531	3%
Metals	POP Terminal 2	34	33%
	POP Terminal 6	128	33%
	Rivergate	154	34%
Machinery	POP Terminal 2	34	100%
Transportation Equipment	POP Terminal 6	128	53%
	POP Terminal 4	162	34%
	POV Terminal 2	1508	13%
Manufactured Goods & Electronics		(No Products to/from Port terminals)	
Textiles	POP Terminal 6	128	100%
Waste Products	POV Terminal 1	1506	33%
	POV Terminal 3/4/5	1531	34%
	Columbia Way	1561	33%
Courier Services		(No Products to/from Port terminals)	

External highway cordon locations are gateways for flows entering or leaving the region by truck. The commodity flow origin-destination database identifies the distribution of each commodity entering or leaving the region by direction. For each direction, the flows are distributed among the various highways, based on available truck count data, as follows:

TABLE 60. External flow allocations

Direction	Facility	Cordon TAZ #	Distribution to/from TAZs and PDX	Distribution to/from Railyards and Port
North	I-5	2149	100%	100%
East	SR 14	2148	11%	0%
	US 26	2161	19%	0%
	I-84	2162	70%	100%
South	Bald Peak Rd.	2154	1%	0%
	OR 219	2155	2%	0%
	I-5	2157	84%	100%
	US 99E	2158	8%	0%
	OR211	2159	3%	0%
	OR 213	2160	2%	0%
West	US 30	2150	45%	55%
	US 26	2151	6%	0%
	OR 6	2152	12%	0%
	US 99W	2156	32%	45%
	OR 47	2153	5%	0%

All **Air Freight** is assumed to enter or leave the region via Portland International Airport (PDX), TAZ 139.

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

Reload facilities consist of truck terminals and major warehouse and distribution facilities. The model assumes that 60% of LTL shipments and about 6% of TL and PVT shipments are routed through a reload facility. The list of facilities in the region was compiled by the Data Resource Center using both employment security (ES202) data, ESRI Business Analyst data, and other available sources. Facilities were classified by type, and only those locations that are primarily engaged in trucking, warehousing, and distribution, and that have at least 50,000 square feet of floor space or 30 employees were retained. For example, the stores in a grocery chain are not included, but the chain's distribution center is. Actual base year employment, if available, was compiled. Otherwise, employment was estimated by business type and floor area. The employment, which serves as a proxy for level of freight activity at each facility, was summed for each TAZ.

Total LTL and TL/PVT tonnage for reload is calculated and routed from origin TAZs, in proportion to the total employment at reload facilities, and then on to destination TAZs. No unique factors were obtained for separate commodity groups.

K.7 Modeling Pickup and Delivery Tours

Insufficient data were available to simulate pickup and delivery tours, including deliveries of goods and services to houses and apartments. This version of the model does not contain additional processing to replicate this type of trip. However, shipments to and from zones having just a few businesses and employees are accounted for in fractional truck trips, the fraction being determined by the commodity load factor.

K.8 Determine Tonnage Allocation by Vehicle Type

Highway vehicle classification counts were used to develop average percentages of heavy vs. medium trucks on the system. This, combined with average weight carried by each vehicle type produced a vehicle split of 70% heavy truck and 30% medium truck. To obtain this split, about 92% of total commodity tonnage is allocated to heavy trucks and the remainder to medium trucks.

- Medium trucks are defined as FHWA Class 4-7, or single unit trucks
- Heavy trucks are defined as FHWA Class 8 and above, or trucks with one or more trailers

K.9 Determine Number of Trucks by Commodity Type

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. Separate payload factors were developed for internal and external truck trips.

TABLE 61. Load factors / tons per vehicle

	Heavy Trucks		Medium Trucks	
Commodity Group	**Internal**	**External**	**Internal**	**External**
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
Lumber or Wood Products, Furniture	16	19	3	8
Food, Fish, & Marine Products, Tobacco	18	20	4	7
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	15	17	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. Flows with origins or destinations in the central city are

assumed to be transported by medium trucks. All LTL and TL/PVT flows were allocated to medium trucks for those TAZs.

K.10 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.

K.11 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.

K.12 Create Initial Truck Trip Tables

LTL and TL/PVT vehicle tables are combined by truck type. These tables represent average weekday truck vehicle trips having an internal origin and/or destination, and prior to reconciliation of internal-external flows trips with external truck counts or projected volumes.

K.13 Estimate External Truck Trips

External truck base year control totals are currently derived from traffic counts and vehicle classification counts. Future year control totals employ a traffic count growth trends analysis. The results represent total truck volumes at the externals, including internal-external, external-internal, and through-trip shipments.

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 truck through-trips were developed independently of the commodity flow model. The 2006 Freight Data Collection study found that about half the total trucks counted while entering or leaving the region on the main Interstate highways and U.S routes were traveling through, with the vast majority of those using I-5. (Since each through-trip passes through 2 counting points, about ¼ of all external truck trips are through-trips) The truck model uses vehicle classification counts at each external station along with estimates of the through-trip percentage and a "seed" matrix that reflects the 2007 FDCS observed distribution of through-trips between stations to produce medium and heavy truck through-trip matrices that account for about half of total observed base year and forecasted future year truck volumes entering and leaving the region. Then, the external-internal and internal-external component of the truck matrices from the commodity flow model are scaled so that the combined E-I, I-E, and through-trips match the observed or forecasted truck counts.

K.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 as percent of weekday total:

TABLE 62. Diurnal peak factors - trucks

	Heavy Truck	Medium Truck	Reload Facility Midday
AM Peak 2-Hour	11.09%	12.99%	na

Midday 1-Hour	6.68%	8.20%	5.60%
PM Peak 2-Hour	8.52%	9.95%	na

K.15 Assign Truck Trips to Network

Average Weekday (AWD), peak, and off-peak trip tables are prepared for heavy and medium trucks. Prior to assignment to the highway network, a passenger-car equivalent (PCE) factor of 1.7 is applied to account for the extra space trucks take up on the road, the slower acceleration, and longer stopping times.

Heavy and medium truck PCEs are assigned to the roadway network along with other vehicle classes using a multi-class assignment. Coding for the truck mode is removed from links where truck prohibitions are in place. A truck path attribute is used to represent the additional truck travel time associated with steep upgrades, narrow lanes, difficult turns, etc on certain portions of the network.

A vehicle classification count program was undertaken as part of the Freight Data Collection program in 2006 which provided validation data for AWD truck volumes. Additional truck volume estimates have been obtained from the ODOT Automatic Traffic Recorder (ATR) database. Assigned truck volumes have typically been 10%-15% lower than counts, which reflects in part the exclusion of non-freight trucks as well as under-representation of pickup and delivery tour stops.

Appendix A – Metro Model Forecasting Model Structure