CALCULATING VEHICLE MILES TRAVELED (VMT)

Overview and Procedures

Oregon Department of Transportation

July 2025

Introduction and Purpose of This Document

This document summarizes and demonstrates the procedure for calculating household-based, light vehicle miles traveled (VMT) per capita. This calculation is used for transportation planning purposes to address the Transportation Planning Rules (TPR) requirements reflected in the Oregon Administrative Rules (OAR).

For the purposes of this document, VMT is defined in OAR 660-012-0005(64) as follows:

> *"Vehicle Miles Traveled (VMT)" means all jurisdiction household-based light vehicle travel regardless of where the travel occurs.*

This definition identifies three specific aspects of what is included in the VMT calculation that differs from prior methods of calculating VMT in Oregon. Specifically, this measure of VMT incorporates the following aspects:

1. All light vehicle trips related to households within a jurisdiction's Urban Growth Boundary (UGB), regardless of trip purpose or location where the travel occurs.
2. Based on this definition, the methodology seeks to account for all applicable vehicle travel, regardless of purpose, to a specific jurisdiction.
3. These calculations are applicable for Transportation System Plans (TSPs) and other purposes related to the greenhouse gas rules contained in OAR 660-044 and 660-012.

Table of Contents

List of Acronyms

ABM	Activity-Based Model
AP	Attraction-Production
HB	home-based
HOV	High-Occupancy Vehicle
MPO	Metropolitan Planning Organization
NHB	non-home-based
OAR	Oregon Administrative Rules
OD	Origin-Destination
OHAS	Oregon Household Activity Survey
PA	Production-Attraction
SOV	Single-Occupancy Vehicle
TAZ	Transportation Analysis Zone
TPAU	Transportation Planning Analysis Unit
TPR	Transportation Planning Rules
TSP	Transportation System Plan
UDA	User-Defined Attribute
UGB	Urban Growth Boundary
VMT	Vehicle Miles Traveled

Matrices

Matrix Type	Name	Calculation
A	Traffic Demand	Obtained from the Transportation Planning Analysis Unit (TPAU) or Metropolitan Planning Organization (MPO) and assigned per model period. Note that this is traffic demand by hour, for a total of 24 matrices for Metro, but applies to fewer matrices (with longer durations) in other areas.
A_N	Traffic Demand by Hour	Traffic demand for hour N
B	Average Trip Length	Software path analysis
C	Production-Attraction	Obtained from the jurisdiction (two matrices: one for home-based trips and the other for non-home-based trips)
D	Population	Obtained from the jurisdiction
U	Urban Growth Boundary (UGB) User-Defined Attribute (UDA)	Each Transportation Analysis Zone (TAZ) with a 1 if it is part of the UGB and a 0 if it is not
E	Full Average Trip Length	(Matrix B + minimum path lengths) × 0.5 for intrazonal trips
F	Light Vehicle VMT	$Matrix\ A_N \times Matrix\ E$ Used for each assigned period. For example, the hour of the day, for a total of 24 matrices in Metro, and less in other trip-based models
G	Total Assigned Light Vehicle Trips	$\Sigma\ Matrix\ A$
E_w	Weighted Average Trip Length	$\frac{Matrix\ F}{Matrix\ G}$
E_{ext}	Model Externals	The distances to and from external stations from TAZ, provided by Matrix E_w

Matrix Type	Name	Calculation
EX_{UHB}	Percentage of External HB Trips Within the UGB	$\left(\frac{(\Sigma_{Column} Matrix\ \mathrm{M})}{\Sigma_{Column}(Matrix\ \mathrm{O} * \mathrm{Matrix\ M})}\right) + \left(\frac{(\Sigma_{Row} Matrix\ \mathrm{M})}{\Sigma_{Row}(Matrix\ \mathrm{O} * \mathrm{Matrix\ M})}\right)$
EX_{UNHB}	Percentage of External NHB Trips Within the UGB	$\left(\frac{(\Sigma_{Column} Matrix\ \mathrm{N})}{\Sigma_{Column}(Matrix\ \mathrm{O} * \mathrm{Matrix\ N})}\right) + \left(\frac{(\Sigma_{Row} Matrix\ \mathrm{N})}{\Sigma_{Row}(Matrix\ \mathrm{O} * \mathrm{Matrix\ N})}\right)$
G_{ext}	Total Trips to External Stations	Taken from Matrix G
H	Home-Based Trips	Three PA matrices (All HB, HB Work, and Non-Work HB)
H_P	HB Proportion	$\frac{Matrix\ H}{Matrix\ H + Matrix\ H - T}$
H-B	HB Trips Balanced	$\frac{Matrix\ H + Matrix\ H^T}{2}$
H-T	Transposed HB Trips	$Matrix\ H^T$
I	NHB Trips	Three PA matrices (All NHB, NHB Work, and NHB Non-Work)
I_P	NHB Proportion	$\frac{Matrix\ I}{Matrix\ I + Matrix\ I - T}$
I-B	NHB Trips Balanced	$\frac{Matrix\ I + Matrix\ I^T}{2}$
I-T	Transposed NHB	$Matrix\ I^T$
J	All Trips	$Matrix\ H + Matrix\ I$
J-B	All Trips Balanced	$Matrix\ H - B + Matrix\ I - B$
K	All HB Trip Factor	(H-B)/(J-B)

Matrix Type	Name	Calculation
L	All NHB Trip Factor	(I-B)/(J-B)
M	HB Origin-Destination (OD)	Matrix A × Matrix K
M_{ext}	Total External HB Trips	Matrix G_{ext} × Matrix Z
N	NHB OD	Matrix A × Matrix L
N_{ext}	Total External NHB Trips	Matrix Z_{NHB} × Matrix G_{ext}
O	HB Trip Percentage Within the UGB	$(Matrix\ H_P * Matrix\ U) + (Matrix\ H_P^T * Matrix\ U^T)$
P	HB VMT Within the UGB	(Matrix M × Matrix O) × Matrix E_w
P_{ext}	External HB VMT Within the UGB	Matrix M_{ext} × Matrix EX_{UHB} × Matrix R
Q	NHB VMT	(Matrix N × Matrix Y) × Matrix E_w
Q_{ext}	External NHB VMT Originating from the UGB	Matrix N_{ext} × Matrix EX_{UNHB} × Matrix R
R	Average External Trip Lengths to and from the UGB	See text for calculation
R_1	Average Distance from Model for UGB Zones	Average of EX1 and EX2 rows and columns from E_{ext}
R_2	Average trip length difference (portion of trip external to the regional travel model)	Matrix S - R_1

Matrix Type	Name	Calculation
S	External Trip Lengths	Obtained from the Statewide Integrated Model (SWIM)
S_{ext}	External HB Light Vehicle VMT	$P_{ext} + Q_{ext}$
Y_A	UGB HB Vector Attraction	$(\Sigma_{Column}((\frac{Matrix\ H}{\Sigma_{Column}\ Matrix\ H}) * Matrix\ U))$
Y_P	UGB HB Vector Production	Y_A^T Note: If the UGB TAZ HB Vector Production is 0, change to 1 (100%)
Z_{HB}	Average Percentage of External HB Trips	$\left(\frac{\Sigma_{Column} Matrix\ M}{\Sigma_{Column}\ Matrix\ G}\right) + \left(\frac{\Sigma_{Row} Matrix\ M}{\Sigma_{Row}\ Matrix\ G}\right)$
Z_{NHB}	Average Percentage of External NHB Trips	$\left(\frac{\Sigma_{Column} Matrix\ N}{\Sigma_{Column}\ Matrix\ G}\right) + \left(\frac{\Sigma_{Row} Matrix\ N}{\Sigma_{Row}\ Matrix\ G}\right)$

Process Overview

The following steps demonstrate how to calculate household-based light vehicle VMT per capita from trip-based models used in Oregon. Household-based light vehicle VMT can be challenging to calculate from a trip-based model because those models have both:

- **Home-**based **(HB) trips:** Trips where either the origin or destination of the trip is at the home location, and
- **Non-**home-based **(NHB) trips:** Trips where neither the origin nor destination of the trip is the home location.

In trip-based models, home-based trips retain information about the originating (or destination) household in a way that allows for the VMT generated by those trips to be directly attributed back to the household. Therefore, VMT generated from home-based trips can easily be attributed to a particular geography.

In contrast, NHB trips are generated (summed up) at the household location but when they are distributed to origin and destination points throughout the model, the original household location is lost. Therefore, because trip-based models do not specifically associate NHB VMT with a particular household location, the process for determining NHB VMT requires assumptions and approximations. This increases the complexity of the process of determining NHB VMT and attributing it to the Transportation Analysis Zone (TAZ) of a particular household in a subject geography such as a city or county.

At a high-level this process includes first determining the number of model-wide NHB vehicle trips by home location. This can be performed as a precise accounting exercise using the NHB trips created during the trip generation step. However, using the number of NHB trips created during the trip generation step does not account for the mode split of those trips. The methodology therefore includes a process to estimate the percentage of non-auto trips generated by a jurisdiction and removes that percentage from the total NHB trips generated by a TAZ.

While this method to account for the NHB trip mode split is an assumption, it is supported by travel modeling research that indicates that there is a strong relationship between the mode of a home-based trip and the mode of a NHB trip. One way to think about it is that someone that takes transit to work does not use their personal vehicle for a mid-day NHB trip because their vehicle has been left at the home location. A secondary benefit of using this assumption is that jurisdictions that take actions to reduce home-based auto trips (and their VMT) will benefit by seeing a corresponding decrease in VMT for their NHB trips.

After accounting for the (assumed) mode split for NHB trips, the total number of NHB trips generated by all households in the jurisdictional UGB is then multiplied by the average trip length of all NHB trips. The resulting total is an estimate of the amount of NHB VMT that all households in a jurisdiction produce.

The detailed procedural steps on the following pages help to fully explain the mathematic steps to calculate the household VMT within the context of Metro's travel demand model.

Key Components and Exclusions for VMT per Capita Evaluation

The following data are the primary components applied to estimate VMT per capita.

- Traffic Demand **(Matrix A):** Hourly assigned trip by vehicle class
- Average Trip Length **(Matrix B):** Obtained through model assignment
- Production-Attraction (PA) **(Matrix C)**: To determine HB and NHB trip purposes
- Population **(Matrix D):** To calculate VMT per capita

These are the four types of trips to capture for the calculation of VMT based on the location of origin and destination.

Trip Type[A]	Description
UGB (Model Extent)	A light vehicle trip that originates within the UGB and can end either in a TAZ within the UGB or elsewhere within the regional model boundary.
Intrazonal	A light vehicle trip that originates within a TAZ within the UGB and ends within the same TAZ.
Non-Home-Based Trips	A light vehicle trip that occurs anywhere within the regional model and is "linked" to a home-based trip that originated within the UGB.
Interregional	Light vehicle trips that start in the UGB and leave the area within the regional model.

A. All trip types include those originating from "group quarters."

A visual representation of each of the four types of trips can be found on the following page in Figure 1.

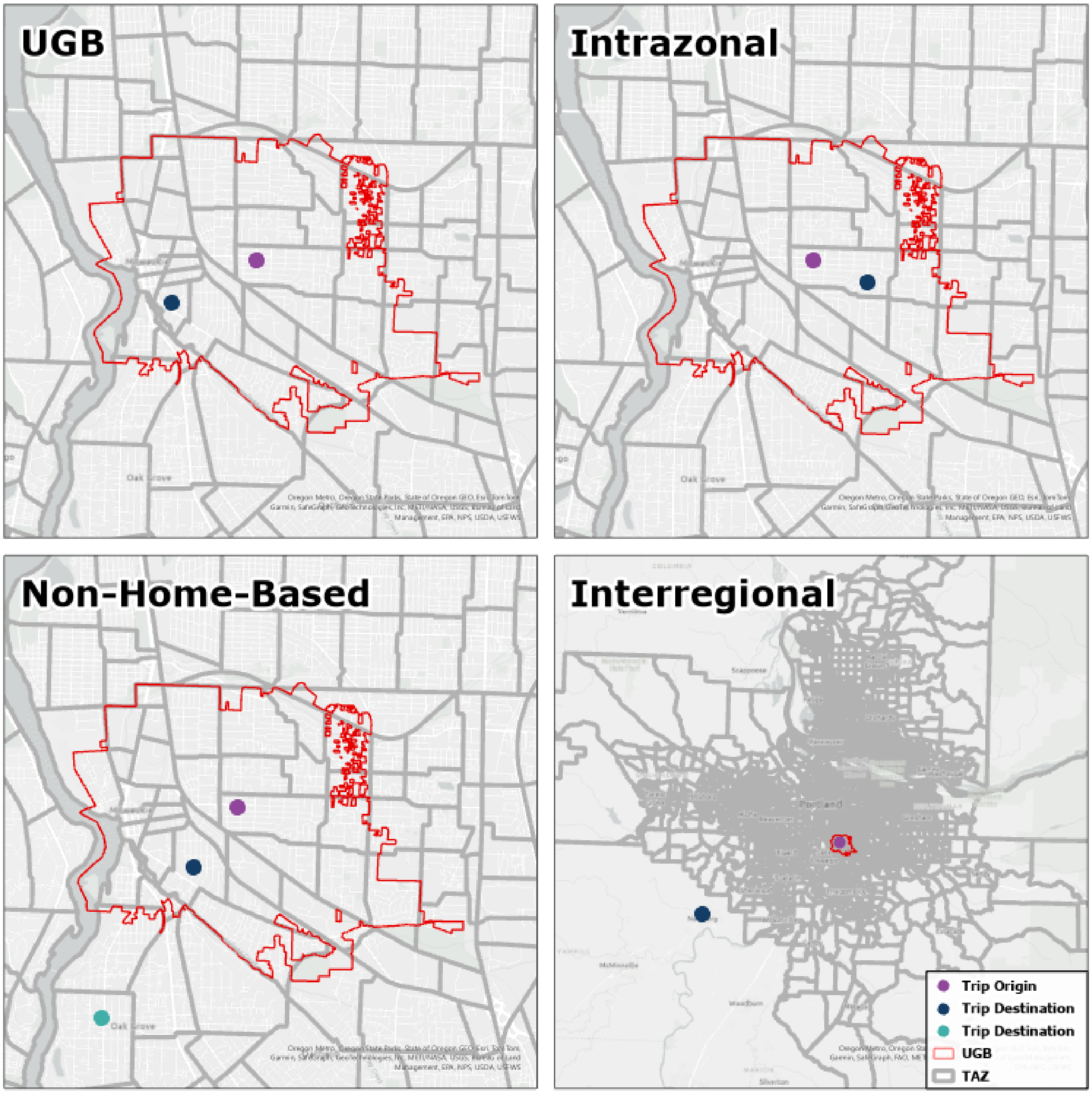

Figure 1. Household-Based Trip Variations That Count Toward VMT

As described below, the commercial vehicles trip type contributes to VMT generated from within the jurisdictional UGB, but at this time, the VMT from that trip type is not counted as part of the VMT per capita metric.

Trip Type	Description	Reason	Example
Commercial Vehicles	A trip generated by freight vehicles, postal trucks, delivery trucks, and e-commerce vehicles	These trips are identified within the ABM or TPAU-based trip-based models at a regional scale and would need to be proportioned to each jurisdiction separately	A USPS driver on their typical route within the City of Milwaukie

Visitor trips are accounted for in the overall VMT per capita calculation for a jurisdiction. The JEMnR platform used in Oregon's trip-based model allows hotel rooms to be represented. The conversion process from hotel rooms to households occurs on the front end of the modeling process, and it would be challenging to remove this conversion process (which lumps hotel rooms into other households) from models. Within the model, hotel rooms are first converted into households, and then assigned shopping, recreation, other, and NHB trips (though not school, college, or work trips) based on household trip generation rates. The trips are then assigned to the model network like any other trip.

The definition of VMT in OAR 660-012-0005(64) does not explicitly include, exclude, or mention VMT generated by visitors. However, the intent is to capture VMT generated by households (even "temporary" households composed of visitors). Modifications that a jurisdiction makes to improve non-driving mode networks or facility quality can also be used by visitors, and parking policies are a factor in driving behavior for permanent residents and visitors alike.

There is a potential opportunity to sum up the VMT from commercial vehicle trips and report that VMT at a regional scale (i.e., Metropolitan Planning Organization [MPO]-level) or even proportionally distribute total commercial VMT to local jurisdictions. At this time, the commercial vehicle VMT is not part of the household-based definition and will not be part of the modeling work in TSPs. In the future, it may be beneficial to set up procedures that estimate commercial vehicle VMT, as it may be valuable for other greenhouse gas reporting needs, even though it is not currently within the definition of the VMT-per-capita metric.

Procedure to Calculate VMT per Capita

The VMT calculation procedures outlined in this document are visualized using a simplified model network represented by four TAZs and two external stations. TAZ 1 and TAZ 4 in this simplified model network are within a jurisdictional UGB, which is denoted by the green line in Figure 2. TAZ 2 and TAZ 3 are within the regional model boundary, which is denoted by the red line in Figure 2. EX1 and EX2 are external stations outside both the UGB and the regional model.

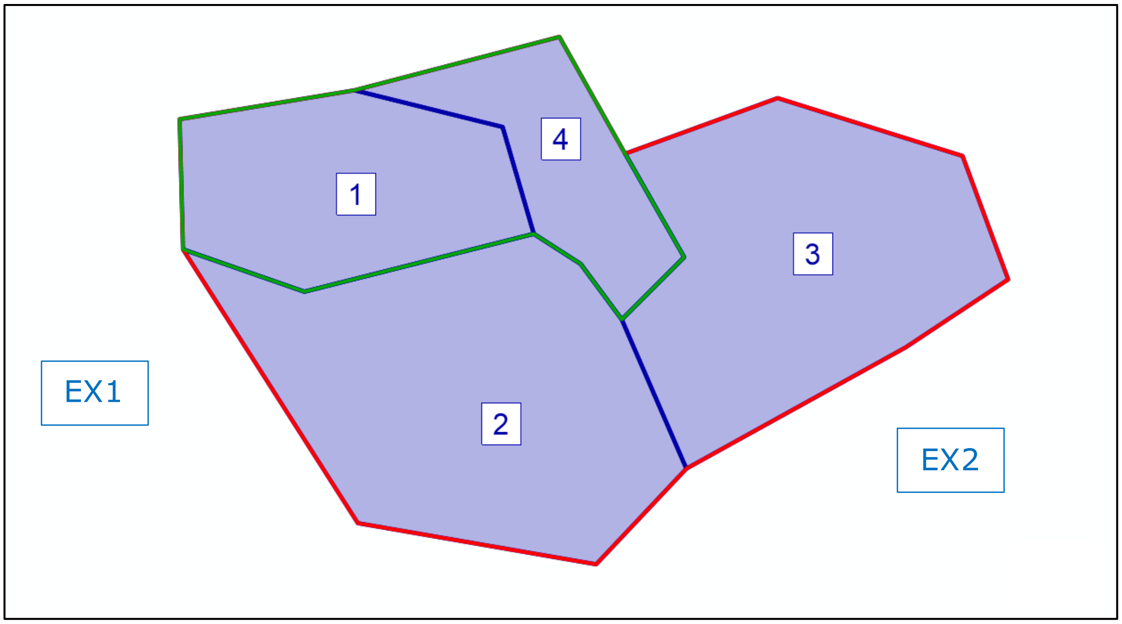

Figure 2. Simplified Model TAZ Network

The following steps provide guidance on how to complete the calculation.

Calculation Steps

The following calculation steps are grouped into four categories:

- **Setup (Steps 1 to 4):** General preparation of data and matrices needed for calculations.
- **HB Portion (Steps 5 to 7):** Calculations specific to the portions of travel direction associated with the home location.
- **NHB Portion (Step 8):** Calculations for portions of travel that are not directly associated with the home location but are assigned to a home location for accounting purposes.
- **External Trip Portion (Step 9):** These are trips that leave or originate outside the regional travel model boundary but can be associated with a jurisdictional household. Note that only the VMT for the portion of the trip that occurs within the boundary of the travel demand model is counted for the purposes of the VMT per capita calculation.

Setup (Steps 1 to 4)

The following four steps provide initial preparation of the model data and matrices for the following calculations.

Step 1 (OPTIONAL) – Flag TAZ for results aggregation (e.g., jurisdictional UGB)

Note: This step is optional because it can be used to simplify the calculations and the size of the matrices that are developed in subsequent steps. Smaller matrices may be beneficial for data management; however, calculating VMT for all zones within the model allows for calculating multiple areas concurrently and provides the benefit of backchecking the results (e.g., the VMT sum of the individual components will be equal to the total VMT).

Create a user-defined attribute **Matrix U** to flag all TAZs within the target jurisdiction UGB.

TAZ	UGB
1	1
2	0
3	0
4	1
EX1	0
EX2	0

Step 2 – Identify average trip length for each Origin-Destination (OD) pair

Reassign the OD Traffic Demand **(A)**, recording a path analysis during the assignment to obtain the Average Trip Length **(B)** matrices. Squares highlighted in yellow in the table below represent intrazonal trips and will be calculated in Step 3.

Average Trip Length (B)						
TAZ	1	2	3	4	EX1	EX2
1		4	3	2	21	24
2	4.25		4.75	3	24	29
3	2.75	5		4.2	23	28
4	1.75	3.1	4.1		21	25
EX1	20	25	23	22		85
EX2	25	30	27	26	80	

Step 3 – Estimate trip length for intrazonal trips

As previously mentioned, the assignment performed in Step 2 will not populate the intrazonal trip lengths in the average trip length **(B)** matrix. Intrazonal trip length is the average length of a trip that starts and ends within the same zone. To estimate the intrazonal average trip length, assume that the average intrazonal vehicle trip length is equal to half the distance to the nearest TAZ centroid. This distance can be calculated for each TAZ by taking the minimum trip length of each row in the assigned average trip length **(B)** matrix and multiplying it by 0.5. Minimum average trip lengths are highlighted in blue below. Add these values to the average trip length **(B)** matrix to create a full average trip length **(E)** matrix.

Average Trip Length (B)						
TAZ	1	2	3	4	EX1	EX2
1	2 × 0.5	4	3	2	21	24
2	4.25	3 × 0.5	4.75	3	24	29
3	2.75	5	2.75 × 0.5	4.2	23	28
4	1.75	3.1	4.1	1.75 × 0.5	21	25
EX1	20	25	23	22	20 × 0.5	85
EX2	25	30	27	26	80	25 × 0.5

Full Average Trip Length (E)						
TAZ	1	2	3	4	EX1	EX2
1	1	4	3	2	21	24
2	4.25	1.5	4.75	3	24	29
3	2.75	5	1.38	4.2	23	28
4	1.75	3.1	4.1	0.88	21	25
EX1	20	25	23	22	10	85
EX2	25	30	27	26	80	12.5

Step 4 – Calculate total daily light vehicle VMT for all trips

A. To calculate the light vehicle VMT **(F),** multiply the traffic demand **(A)** matrix by the full average trip length **(E)** matrix for light vehicles. Light vehicles include both single occupancy vehicles (SOVs) and high occupancy vehicles (HOVs).
B. Calculate the hourly light vehicle VMT matrix by multiplying the hourly trip **(A_N)** and the full average trip length **(E)** matrix for light vehicles. This will be calculated 24 times, or once for each hour of the day.
C. Sum the 24 light vehicle VMT matrices (one for each hour of the day) to obtain the total light vehicle VMT matrix **(Σ [$A_N \times E$] = F)**
D. To calculate a weighted average trip length **(E_W)** matrix, divide the total light vehicle VMT **(F)** matrix by the total light vehicles trips **(G)** matrix:

$$\frac{All\ Vehicle\ Miles\ Traveled}{All\ Trips\ Taken} = \frac{Matrix\ F}{Matrix\ G} = Matrix\ E_W$$

This concludes the steps for the initial preparation of the model data and matrices for the following calculations.

HB Portion (Steps 5 to 7)

The following steps calculate the VMT for the portion of trips directly associated with travel to or from the place of residence (household). The process in these steps includes both programming comments and the R programming code (*R code is in italics*) and is specific to the Metro regional travel demand model. However, the R code can be used (with minor modification) for the other trip-based models in Oregon. Variations of the code have been already developed for the models maintained by TPAU which include the Bend-Redmond Model (BRM) and CALM (Corvallis-Albany-Lebanon Model). In addition, code has already been developed and tested for SKATS (Salem-Keizer MPO) model and will be developed for the LCOG (Eugene-Springfield MPO) in the second half of 2025.

Step 5 – Summarize all home-based production-to-attraction (PA) passenger vehicle trips

The following matrices are referred to below:

- VEHdist = Matrix of weighted average zone-to-zone trip lengths from daily OD assignments.
- TOT_VEH_OD_ALL = Total OD SOV and HOV vehicles from summing daily OD trip tables used in 24 hourly assignments.

Definitions:

- hw = home-based work
- hc = home-based college
- ho = home-based other
- hr = home-based recreation
- hs = home-based shop
- *da = drive alone (SOV)
- *dp = drive w/ passengers (HOV)
- *prtrtl = Drive portion of Park-and-Ride (PnR) transit trip (drive to/from PnR lot)

Note that the “*” in the terms above denote that they are concatenated to the trip types in the code below. For example, “hwda” indicates home-based work trips that are drive alone (SOV).

Calculate:

- *hbWorkVEH <- mf.hwda + mf.hwdp + mf.hwprtrtl*
- *hbNonWorkVEH <- mf.hcda + mf.hcdp + mf.hoda + mf.hodp + mf.hrda + mf.hrdp + mf.hsda + mf.hsdp + mf.hsprtrtl + mf.hrprtrtl + mf.hoprtrtl + mf.hcprtrtl*

Metro model specific code

Remove trips to/from Portland International Airport (PDX) from hbNonWorkVEH:

- Only home-based work trips are allowed to/from PDX
- All other PDX trips are replaced by trip tables produced by the Metro airport model

hbNonWorkVEH[pdxtaz,] <- 0

hbNonWorkVEH[,pdxtaz] <- 0

Step 6 – Create balanced trip tables

- Convert HB Trip Purpose PA vehicle trip tables to daily OD vehicle trip tables
- Use daily peaking factors to convert PA tables to OD
- Peaking factors differ by trip purpose
- PA and AP directions have different factors, determined from the Oregon Household Activity Survey (OHAS
- Refer to peakingFactorsAllday_for_ODOT.csv for daily peaking factors by direction

Metro model specific code

Items in bold: PA to OD - apply peaking factors
Items in blue: AP to OD - apply peaking factors and then transpose

BAL_hbWorkVEH <-

- ***(hbWorkVEH * 0.5586)*** + *t((hbWorkVEH] * 0.4614)*

BAL_hbNonWorkVEH <-

- ***((mf.hcda + mf.hcdp + mf.hcprtrtl) * 0.5505)*** + *t((mf.hcda + mf.hcdp + mf.hcprtrtl) * 0.4495)* +
- ***((mf.hoda + mf.hodp + mf.hoprtrtl) * 0.4989)*** + *t((mf.hoda + mf.hodp + mf.hoprtrtl) * 0.5011)* +
- ***((mf.hrda + mf.hrdp + mf.hrprtrtl) * 0.4979)*** + *t((mf.hrda + mf.hrdp + mf.hrprtrtl) * 0.5021)* +
- ***((mf.hsda + mf.hsdp + mf.hsprtrtl) * 0.3581)*** + *t((mf.hsda + mf.hsdp + mf.hsprtrtl) * 0.6419)*

Airport trips (all airport trip tables from airport model are already in OD format).

AIRPORT_TRIPS <- SOV_airportTrips + HOV_airportTrips

School and external PA trip tables are converted just like HB trips. External trips assume the same daily peaking factors as HB "other" trips (ho).

External trips use HB "other" (ho) peaking factors:

BAL_EXT_VEH <- ***(mf.awdext * 0.4989)*** + *t(mf.awdext * 0.5011)*

BAL_SCH_VEH <- ***(mf.schveh * 0.6017)*** + *t(mf.schveh * 0.3983)*

Add airport and school trips to HB daily OD trip tables:

TOT_BAL_HB <- BAL_hbWorkVEH + BAL_hbNonWorkVEH + BAL_SCH_VEH + AIRPORT_TRIPS

TOT_BAL_EXT <- BAL_EXT_VEH

Determine the total assigned VMT using total OD trip tables from assignments:

- Start with TOT_VEH_OD_ALL, which is all OD vehicle trips.
- Multiply by VMTdist, which is the Average Trip Length **(B)** matrix calculated in Step 2.

Determine the total assigned VMT for the entire model region:

- *TOT_VEH_VMT_OD_ALL <- sum(TOT_VEH_OD_ALL * VEHdist)*

Determine the HB VMT for the entire model region:

- *TOT_HB_VMT_OD_ALL <- sum(TOT_BAL_HB * VEHdist)*

Determine the external VMT for the entire model region:

- *TOT_EXT_VMT_OD_ALL <- sum(TOT_BAL_EXT * VEHdist)*

Determine the NHB VMT for entire model region: Total VMT - HB VMT - Ext VMT = NHB VMT. The total NHB VMT will be used to apportion the final NHB VMT to each TAZ:

- *TOT_NH_VMT_OD_ALL <- TOT_VEH_VMT_OD_ALL - TOT_HB_VMT_OD_ALL - TOT_EXT_VMT_OD_ALL*

Determine the total NHB trip productions by TAZ:

- *TOT_NH_PROD <- ma.nhwpr + ma.nhnwpr*

Calculate the percentage of NHB trips by vehicle (VEH) for use in Step 8 below. Determine the total vehicle trip productions:

- *PROD_VEH_TRIPS <- rowSums(mf.vehicletrips)*

Determine total person trip productions:

- *PROD_PERSON_TRIPS <- rowSums(mf.persontrips)*

Calculate the VEH share of all person trips. Note that this can produce some “division by zero” errors for some zones without any person trips. Replace these values with zero (0):

- *VEH_SHARE <- PROD_VEH_TRIPS / PROD_PERSON_TRIPS*
- *VEH_SHARE[VEH_SHARE[]=='NaN'] <- 0*

Apply VEH share to total NBH productions. This becomes the “pool” of NHB trip productions used in Step 8:

- *TOT_NH_VEH_PROD <- TOT_NH_PROD * VEH_SHARE*

This section within the text box is a programming loop that cycles through all of the listed jurisdictions.

Metro model specific code

Calculate VMT by Individual Jurisdiction (JURIS), referred to as "UGB" in this guidance:

```
for (i in 1:length(JURIS_ENS)) {
  # Setup district TAZ lookup
  zones               <- c(1:numzones)
  dist                <- get(paste("ensemble",JURIS_ENS[i],sep='.'))
  dist_zones          <- zones[dist[]==1]
  JURIS_DEF           <- data.frame(zones,dist)
  names(JURIS_DEF)    <- c("TAZ","JURIS")
```

Step 7 – Calculate for application at the individual jurisdiction level.

This step consists of similar calculations listed under Step 5 and 6.

Metro-specific variable: JURIS_DEF$JURIS

Generalized trip-based model variable: UGB as described in this documentation.

****** VERY IMPORTANT ******

All math is applied to PA matrices BEFORE transposing into AP format

Metro model specific code

Calculate external trips and use HB other (ho) peaking factors:

- *BAL_EXT_VEH_JURIS <- (mf.awdext * 0.4989 * JURIS_DEF$JURIS) + t(mf.awdext * 0.5011 * JURIS_DEF$JURIS)*
- *BAL_SCH_VEH_JURIS <- (mf.schveh * 0.6017 * JURIS_DEF$JURIS) + t(mf.schveh * 0.3983 * JURIS_DEF$JURIS)*

Use daily peaking factors to convert PA tables to OD:

- **Items in bold: PA to OD - apply peaking factors**
- Items in blue: AP to OD - apply peaking factors and then transpose

BAL_hbWorkVEH_JURIS <-

- ***(hbWorkVEH * 0.5586 * JURIS_DEF$JURIS)*** + *t((hbWorkVEH) * 0.4614 * JURIS_DEF$JURIS)*

BAL_hbNonWorkVEH_JURIS <-

- ***((mf.hcda + mf.hcdp + mf.hcprtrtl) * 0.5505 * JURIS_DEF$JURIS)*** + *t((mf.hcda + mf.hcdp + mf.hcprtrtl) * 0.4495 * JURIS_DEF$JURIS)* +
- ***((mf.hoda + mf.hodp + mf.hoprtrtl) * 0.4989 * JURIS_DEF$JURIS)*** + *t((mf.hoda + mf.hodp + mf.hoprtrtl) * 0.5011 * JURIS_DEF$JURIS)* +
- ***((mf.hrda + mf.hrdp + mf.hrprtrtl) * 0.4979 * JURIS_DEF$JURIS)*** + *t((mf.hrda + mf.hrdp + mf.hrprtrtl) * 0.5021 * JURIS_DEF$JURIS)* +
- ***((mf.hsda + mf.hsdp + mf.hsprtrtl) * 0.3581 * JURIS_DEF$JURIS)*** + *t((mf.hsda + mf.hsdp + mf.hsprtrtl) * 0.6419 * JURIS_DEF$JURIS)*

Add airport and school trips:

- *AIRPORT_TRIPS_JURIS <- matrix(0, numzones, numzones)*
- *AIRPORT_TRIPS_JURIS[dist_zones,] <- AIRPORT_TRIPS[dist_zones,]*

TOT_BAL_HB_JURIS <- BAL_hbWorkVEH_JURIS + BAL_hbNonWorkVEH_JURIS + BAL_SCH_VEH_JURIS + AIRPORT_TRIPS_JURIS

*HB_VMT_JURIS <- round(sum(TOT_BAL_HB_JURIS * VEHdist),0)*

This concludes the steps for the calculation of the HB trip VMT.

NHB Portion (Step 8)

The following step calculates the VMT for NHB trips, which are not directly associated with travel to or from the place of residence. Because the place of residence cannot be known with any certainty for a given NHB trip in a trip-based model, VMT associated with these trips is estimated based on the number of NHB trips created during the trip generation step for a TAZ, reduced by the percentage of non-auto-based trips generated by the jurisdiction, then multiplied by the average length of all NHB trips within the specific travel demand model.

As noted in the Process Overview section, due to limitations of trip-based models, any estimation of NHB VMT linked to a place of residence requires assumptions. The methodology presented in this step makes assumptions about the trip length for NHB trips by applying an average value across all NHB trips.

Therefore, a limitation of this methodology is that it will not capture variance in the distance of NHB trips and would not be sensitive to areas with longer or shorter NHB trips. For example, locations that may tend to result in shorter NHB trips (e.g., a home near a mixed-use area that includes a place of employment and a retail store) may benefit from shorter NHB trips that are not reflected in this methodology.

Another potential refinement to the methodology is being investigated that would make a different assumption about NHB trips. This process would attempt to use the actual trip distances of specific NHB trips in combination with an assumption about what home location initially produced the trips. This alternative method (included in this documentation as Appendix B) is currently <u>not approved for use</u> by ODOT.

Step 8 – Calculate NHB VMT

*NH_VMT_JURIS <- round((sum(TOT_NH_VEH_PROD[dist_zones]) / sum(TOT_NH_VEH_PROD[])) * TOT_NH_VMT_OD_ALL,0)*

External Trip Portion (Step 9)

Step 9 – Calculate external VMT

Currently, methods calculate the total VMT within the model region created by external trips (those generated by an origin within the model area and with a destination outside the model area and those originating from outside the model area with a destination inside the model area):

*EXT_VMT_JURIS <- round(sum(BAL_EXT_VEH_JURIS * VEHdist),0)*

FUTURE WORK

Integrate regional travel demand models with SWIM to determine the portion of VMT that occurs outside the travel demand model area. See Appendix A for draft approach.

Reporting Results

This section creates additional values for reporting out. Variables include jurisdictional population; employment; and VMT by HB, NHB, and EXT.

TOTAL VMT calculation:

- *TOT_VMT_JURIS <- HB_VMT_JURIS + NH_VMT_JURIS + EXT_VMT_JURIS*

Population and employment calculation:

- *JURIS_POP <- round(sum(mf.hia[dist_zones,1:16])*1 + sum(mf.hia[dist_zones,17:32])*2 + sum(mf.hia[dist_zones,33:48])*3 + sum(mf.hia[dist_zones,49:64])*hh_4_plus_factor[year],0)*
- *JURIS_EMP <- round(sum(TOT_EMP[dist_zones]),0)*
    - *VMT_CAP_ALL_JURIS <- round(TOT_VMT_JURIS / JURIS_POP,2)*
    - *VMT_CAP_HB_JURIS <- round(HB_VMT_JURIS / JURIS_POP,2)*
    - *VMT_CAP_NH_JURIS <- round(NH_VMT_JURIS / JURIS_POP,2)*
    - *VMT_CAP_EXT_JURIS <- round(EXT_VMT_JURIS / JURIS_POP,2)*

Create/append the dataframe for reporting results:

- *JURIS_RPT <- c(JURIS_NAMES[i], JURIS_POP, JURIS_EMP, HB_VMT_JURIS, NH_VMT_JURIS, EXT_VMT_JURIS, TOT_VMT_JURIS, VMT_CAP_ALL_JURIS, VMT_CAP_HB_JURIS, VMT_CAP_NH_JURIS, VMT_CAP_EXT_JURIS)*

```
 if (i == 1) {
   report_df <- data.frame(t(JURIS_RPT)) }
else {
   juris_df        <- data.frame(t(JURIS_RPT))
   report_df       <- rbind(report_df, juris_df)}
}
```

```
names(report_df) <- c("JURISDICTION", "POP", "EMP", "HB_VMT", "NH_VMT", "EXT_VMT", "TOT_VMT", "VMT_CAP_ALL", "VMT_CAP_HB", "VMT_CAP_NH", "VMT_CAP_EXT")
```

Produce output:

```
finalFileName <- paste("./_rtpReports/CFEC_VMT_per_CAPITA_by_jurisdiction_v3_",year,"_",alternative,".csv",sep="")

write.csv(report_df, file=finalFileName, row.names = FALSE)
```

Appendix A: External Trip (Outside Regional Travel Demand Model) VMT Method for Future Testing

Note: Steps A1 through Step A4 deal with external (to the model) trip distance and are intended for future implementation. These steps account for vehicle miles traveled (VMT) outside of the regional model area by using the Statewide Integrated Model (SWIM) to estimate inter-regional trip distribution and travel distances.

Initial testing has identified that other procedural external model adjustments (part of the SWIM and travel demand model development process) need to be resolved prior to implementing these steps for sufficient confidence in the results. As of July 2025, this method is <u>not currently approved</u> by the Oregon Department of Transportation (ODOT).

Step A1 – Calculate external trip length beyond model extents

To consider external trip lengths to and from the jurisdiction's Urban Growth Boundary (UGB), obtain external trip lengths **(S)** for trips to the jurisdictional UGB Transportation Analysis Zones (TAZs) from external stations and trips from the jurisdictional UGB TAZs to external stations using the SWIM (provided by ODOT's Transportation Planning Analysis Unit).

<table>
<tr><th colspan="7">SWIM (S)</th></tr>
<tr><td>TAZ</td><td>1</td><td>2</td><td>3</td><td>4</td><td>EX1</td><td>EX2</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td>55</td><td>65</td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td><td>55</td><td>65</td></tr>
<tr><td>EX1</td><td rowspan="2">50</td><td></td><td></td><td rowspan="2">50</td><td></td><td></td></tr>
<tr><td>EX2</td><td></td><td></td><td></td><td></td></tr>
</table>

Extract the model externals portion **(E_{ext})** of the model average trip length from the weighted average trip length matrix **(E_w)**. The matrix below represents the weighted average trip length for trips that either start within a TAZ and end at an external station or trips that start at an external station and end within a TAZ.

External Weighted Average Trip Length **(E_{ext})**						
TAZ	1	2	3	4	EX1	EX2
1					21	24
2					24	29
3					23	28
4					21	25
EX1	20	25	23	22		
EX2	25	30	27	26		

Calculate the average distance to and from the model for the jurisdictional UGB TAZ (TAZ 1 and TAZ 4) for each external station.

External Weighted Average Trip Length for UGB TAZ							
TAZ	1	2	3	4	EX1	EX2	Avg.
1					21	24	
2							
3							
4					21	25	
EX1	20			22			21
EX2	25			26			25.5
Avg.					21	24.5	

External Weighted Average Trip Length for UGB TAZ (R_1)			
TAZ	UGB	EX1	EX2
UGB		$\frac{21+21}{2}$	$\frac{24+25}{2}$
EX1	$\frac{20+22}{2}$		
EX2	$\frac{25+26}{2}$		

Calculate the difference between the average trip length from SWIM and the distances from Matrix E_{ext} for UGB TAZ.

SWIM (S)			
TAZ	UGB	EX1	EX2
UGB		55	65
EX1	50		
EX2	60		

−

Average E_{ext} (R_1)			
TAZ	UGB	EX1	EX2
UGB		21	24.5
EX1	21		
EX2	25.5		

=

Average Trip Length Difference (R_2)			
TAZ	UGB	EX1	EX2
UGB		34	40.5
EX1	29		
EX2	34.5		

Step A2 – Sum the total external trip length (the portion within the model and portion outside of the model extents)

To capture externals trips length to and from the UGB **(R)**, use the model external trip length as the starting point **(E_{ext})**.

External Weighted Average Trip Length **(E_{ext})**						
TAZ	1	2	3	4	EX1	EX2
1					21	24
2					24	29
3					23	28
4					21	25
EX1	20	25	23	22		
EX2	25	30	27	26		

Substitute the external average trip length from SWIM, if applicable.

TAZ	1	2	3	4	EX1	EX2
1					55	65
2					24	29
3					23	28
4					55	65
EX1	50	25	23	50		
EX2	60	30	27	60		

If the external weighted average trip length **(E_{ext})** is 0, then the value remains 0. If the SWIM average trip length **(S)** is greater than o, then the external average trip length in Matrix R is the same. If the SWIM average trip length is 0, then the corresponding value in **Matrix R** is the value from the external weighted average trip length **(E_{ext})** matrix, plus the difference calculated in Matrix R_2.

In summary:

If Matrix S > 0, then Matrix R = Matrix S

If Matrix S < 0, then Matrix R = Matrix E_{ext} + Matrix R_2

External Trip Lengths to and from the UGB **(R)**						
TAZ	1	2	3	4	EX1	EX2
1					55	65
2					24+34	29+40.5
3					23+34	28+40.5
4					55	65
EX1	50	25+29	23+29	50		
EX2	60	30+34.5	27+34.5	60		

Step A3 – Estimate the external HB VMT

Calculate the average HB percentage for externals. This is done through the summation of the attractions and productions for both the Origin-Destination (OD) **(G)** and home-bound (HB) OD **(M)** matrices.

OD **(G)**					
TAZ	1	2	3	4	Pro.
1	65	240	360	15	680
2	230	45	170	125	570
3	375	155	220	185	935
4	20	110	190	5	325
Attr.	690	550	940	330	

HB OD **(M)**					
TAZ	1	2	3	4	Pro.
1	54	213	290	12	569
2	204	0	52	121	378
3	302	47	53	179	581
4	15	107	184	0	306
Attr.	576	367	579	312	

Create a matrix of the average percentage of external HB trips (**Z_{HB}**) by dividing HB OD attraction and HB OD production by the corresponding OD attraction and production.

TAZ	1	2	3	4	Production
1					$\frac{569}{680} = 84\%$
2					$\frac{378}{570} = 66\%$
3					$\frac{581}{935} = 62\%$
4					$\frac{306}{325} = 94\%$
Attraction	$\frac{575}{690} = 84\%$	$\frac{367}{550} = 67\%$	$\frac{579}{940} = 62\%$	$\frac{312}{330} = 94\%$	

Percentage of External HB Trips (**Z_{HB}**)						
TAZ	1	2	3	4	EX1	EX2
1					84%	84%
2					66%	66%
3					62%	62%
4					94%	94%
EX1	84%	67%	62%	94%		
EX2	84%	67%	62%	94%		

Calculate the average UGB HB percentage for externals through the summation of the attractions and productions for HB OD **(M)** and UGB HB OD matrices.

HB OD **(M)**					
TAZ	1	2	3	4	Pro.
1	54	213	290	12	569
2	204	0	52	121	378
3	302	47	53	179	581
4	15	107	184	0	306
Attr.	576	367	579	312	

TAZ	1	2	3	4	Pro.
1	54	213	266	12	545
2	204	0	0	121	326
3	277	0	0	179	456
4	15	107	184	0	306
Attr.	551	320	450	312	

Create a matrix of the average percentage of HB trip from UGB using UGB HB OD attraction and production **(M*O),** divided by the HB OD attraction and production **(M)**.

TAZ	1	2	3	4	Production
1					$\frac{545}{569} = 96\%$
2					$\frac{326}{378} = 86\%$
3					$\frac{456}{581} = 78\%$
4					$\frac{306}{306} = 100\%$
Attraction	$\frac{551}{576} = 96\%$	$\frac{320}{367} = 87\%$	$\frac{450}{579} = 78\%$	$\frac{312}{312} = 100\%$	

Percentage of HB Trips Within the UGB **(EX_{UHB})**						
TAZ	1	2	3	4	EX1	EX2
1					96%	96%
2					86%	86%
3					78%	78%
4					100%	100%
EX1	96%	87%	78%	100%		
EX2	96%	87%	78%	100%		

Create a new matrix from Matrix G that contains only trips to and from external stations **(G_{ext})**.

Apply the average percentage of external HB trips **(Z_{HB})** to the model OD trip **(G_{ext})** to obtain the external HB trips **(M_{ext})**.

Apply the matrix of the average percentage of external HB trips within the UGB **(EX_{UHB})** to the external HB trips **(M_{ext})** to obtain the external HB trips within the UGB.

Multiply the external HB trips within the UGB by the externals trips length **(R)** to obtain the external HB VMT within the UGB **(P_{ext})**.

Step A4 – Estimate the non-home based (NHB) external VMT

To capture the external NHB VMT originating from the UGB **(Q_{ext})**, calculate the average NHB percentage for externals. Sum the attractions and productions for OD **(G)** and NHB OD **(N)** matrices.

OD **(G)**					
TAZ	1	2	3	4	Pro.
1	65	240	360	15	680
2	230	45	170	125	570
3	375	155	220	185	935
4	20	110	190	5	325
Attr.	690	550	940	330	

TAZ	1	2	3	4	Pro.
1	11	27	70	3	111
2	26	45	118	4	192
3	73	108	167	6	354
4	5	3	6	5	19
Attr.	114	183	361	18	

Create a matrix of the average percentage of NHB trips **(Z_{NHB})** using NHB OD attraction and production divided by the OD attraction and production, similar to the process in Step A4.

TAZ	1	2	3	4	EX1	EX2
1					16%	16%
2					34%	34%
3					38%	38%
4					6%	6%
EX1	16%	33%	38%	6%		
EX2	16%	33%	38%	6%		

$$\frac{354}{935} = 38\%$$

Calculate the average UGB NHB from UGB percentage for externals. Sum the attractions and productions for NHB OD **(N)** and NHB trip from UGB matrices **(N*O).**

NHB OD **(N)**					
1	11	27	70	3	111
2	26	45	118	4	192
3	73	108	167	6	354
4	5	3	6	5	19
Attr.	114	183	361	18	

NHB OD from UGB **(N*O)**					
1	6	16	41	2	65
2	22	39	102	3	166
3	69	102	158	6	335
4	5	3	6	5	19
Attr.	102	160	307	16	

Create a matrix of the average percentage of NHB trips originating from the UGB using the NHB OD from UGB attraction and production, divided by the total NHB OD attraction and production **(EX_{UNHB})**.

Average Percentage of External NHB Trips Within the UGB **(EX_{UNHB})**						
TAZ	1	2	3	4	EX1	EX2
1					58%	58%
2					86%	86%
3					95%	95%
4					100%	100%
EX1	90%	87%	85%	88%		
EX2	90%	87%	85%	88%		

= 86%

Apply the average percentage of external NHB trips **(Z_{NHB})** to the model OD trip **(G_{ext})** to obtain the external NHB trips **(N_{ext})**.

Apply the average percentage of external NHB trips within the UGB **(EX_{UHNB})** to the external HB trips **(N_{ext})** to obtain the external NHB trips originating from the UGB.

Multiply the external NHB trips originating from the UGB by the externals trips length **(R)** to obtain the external NHB VMT originating from the UGB **(Q_{ext}).**

To calculate the external NHB-work **($Q1_{ext}$)** and external NHB-nonwork **($Q2_{ext}$)** VMT originating from the UGB, repeat **Step A4** using the corresponding attributes.

Step A5 – Calculate the total household VMT per capita by selected geography

Sum the external HB VMT within the UGB **(P_{ext})** and the external NHB VMT originating from the UGB **(Q_{ext})** to obtain the external HB light vehicle VMT (S) that starts in the UGB and leaves the model area.

To obtain the total HB VMT per capita in the desired UGB, sum **(P)**, **(Q)**, and **(S_{ext})**. Divide this value by the UGB population **(D)** to calculate the final VMT per capita.

$$\frac{(Matrix\,P\ +\ Matrix\,Q\ +\ Matrix\,S)}{Matrix\,D} = VMT\,per\,capita$$

The process of capturing VHT should follow similar steps for VMT procedures.

This concludes the steps to calculate trips which are external to the travel demand model.

Appendix B: Non-Home-Based Method for Future Testing

As of the initial publication of the methodology for calculating vehicle miles traveled (VMT) per capita in July 2025, the method contained in Appendix B is not currently approved for use by the Oregon Department of Transportation (ODOT). However, this method presents two potential refinements that may be further investigated. The first refinement seeks to understand if and how specific non-home-based (NHB) trips in a trip-based model could be traced back to a household in a specific jurisdiction. If those NHB trips (Transportation Analysis Zone [TAZ] X to TAZ Y) can be identified, a second refinement would measure the length of each of those NHB trips. Once all NHB trips attributed to a specific jurisdiction are identified, and the length of each trip is calculated, the total VMT of all non-home-based (NHB) trip attributed to a specific jurisdiction would be summed and added to the overall home-based and external VMT total for that jurisdiction.

The following steps calculate the VMT for the portion of trips that are not directly associated with home-based (HB) travel. Because the home location cannot be known with any certainty, it is estimated based on the probability of other home-based trips arriving at that location.

These steps would occur instead of the Step 8 in the methodology workflow.

Step B1 – Estimate the NHB trip portion

Initial calculations are first applied to prepare the procedures for estimating NHB trip components. While some of these preparatory steps could be conducted prior to the HB calculations in order to reduce redundancy, they are provided here since they include critical components necessary for the NHB calculations. As these methods are refined, conducting them at this step in the process (after Step 8) should still be fine. These components are noted below as the following two stages:

- Initial preparation for NHB – this could be completed earlier in the process)
- Core NHB calculations

Initial Preparation for NHB

Excluding externals, for directional traffic assignment the PA Matrix **(C)** must be converted to an OD matrix. Transpose the vehicle trip by purpose type PA matrices **(C)** to calculate balanced trip by purpose type Origin-Destination (OD) matrices using **Equation 1**[1]. The following table summarizes the trip matrices used and created during this step:

[1]Equation 1: $OD = (PA_{transpose} * 0.5) + PA * 0.5$

Matrix Type	Trip Purpose – Matrix Titles						
	HB			NHB			Total
	Total	Work	Non-work	Total	Work	Non-work	
PA vehicle trip matrix	(H)	(H_1)	(H_2)	(I)	(I_1)	(I_2)	(J)
Transpose PA vehicle trip matrix	(H-T)	$(H_1\text{-}T)$	$(H_2\text{-}T)$	(I-T)	$(I_1\text{-}T)$	$(I_2\text{-}T)$	(J-T)
Balanced vehicle trip matrix	(H-B)	$(H_1\text{-}B)$	$(H_2\text{-}B)$	(I-B)	$(I_1\text{-}B)$	$(I_2\text{-}B)$	(J-B)

Example:

HB PA (H)				
TAZ	1	2	3	4
1	50	400	550	0
2	0	0	0	0
3	50	100	50	0
4	20	230	350	0

\+

Transposed HB PA (H-T)				
TAZ	1	2	3	4
1	50	0	50	20
2	400	0	100	230
3	550	0	50	350
4	0	0	350	0

2

Transposed HB PA (H-B)				
TAZ	1	2	3	4
1	50	200	300	10
2	200	0	50	115
3	300	50	50	175
4	10	115	350	0

Divide the balanced matrices **(H-B, I-B)** by the total balanced matrix **(J-B)** to get factor matrices. The factor matrices represent what percentage of trips in a given zone are estimated to be HB or NHB for the following trip purposes:

Trip Purpose	Equation	Factor Matrix
HB	(H-B)/(J-B)	(K)
HB – Work	(H_1-B)/(J-B)	(K_1)
HB – Nonwork	(H_2-B)/(J-B)	(K_2)
NHB	(I-B)/(J-B)	(L)
NHB – Work	(I_1-B)/(J-B)	(L_1)
NHB – Nonwork	(I_2-B)/(J-B)	(L_2)

Multiply the demand matrix **(A)** by the factor matrices to obtain the OD vehicle trip for the following trip purposes:

- HB (M)
- HB – work (M1)
- HB – nonwork (M2)
- NHB (N)
- NHB – work (N1)
- NHB – nonwork (N2)

Core NHB Calculations

The following step captures NHB VMT originating from within the jurisdictional UGB. The trip by type information typically contains two NHB types (i.e., NHB-work and NHB-non-work); therefore, two types of VMT need to be considered. The total NHB values can be used in the calculation if no specific NHB trip type is given. The following steps use the total values as an example.

The HB Production-Attraction (PA) matrix **(H)** will be used to create an HB PA percentage matrix. Sum the HB attractions and divide the HB PA matrix **(H)** by them.

HB PA (H)				
TAZ	1	2	3	4
1	50	400	550	0
2	0	0	0	0
3	50	100	50	0
4	20	230	350	0
Total	120	730	950	0

→

HB PA (H)				
TAZ	1	2	3	4
1	$\frac{50}{120}$	$\frac{400}{730}$	$\frac{550}{950}$	$\frac{0}{0}$
2	$\frac{0}{120}$	$\frac{0}{730}$	$\frac{0}{950}$	$\frac{0}{0}$
3	$\frac{50}{120}$	$\frac{100}{730}$	$\frac{50}{950}$	$\frac{0}{0}$
4	$\frac{20}{120}$	$\frac{230}{730}$	$\frac{350}{950}$	$\frac{0}{0}$

TAZ	1	2	3	4
1	41.7%	54.8%	57.9%	0.0%
2	0.0%	0.0%	0.0%	0.0%
3	41.7%	13.7%	5.3%	0.0%
4	16.7%	31.5%	36.8%	0.0%

Sum the HB PA percentage attraction (columns) within the UGB to obtain the UGB HB vector attraction matrix.

UGB	HB PA Percentage (H_K)				
	TAZ	1	2	3	4
1	1	41.7%	54.8%	57.9%	0.0%
0	2	0.0%	0.0%	0.0%	0.0%
0	3	41.7%	13.7%	5.3%	0.0%
1	4	16.7%	31.5%	36.8%	0.0%
UGB Total		58%	86%	95%	0%

↓

UGB HB Vector Attraction **(Y_A)**			
1	2	3	4
58%	86%	95%	0%

Create a UGB HB vector production matrix **(Y_P)** by transposing the UGB HB vector attraction matrix.

UGB HB Vector Attraction **(Y_A)**			
1	2	3	4
58%	86%	95%	0%

UGB HB Vector Production **(Y_P)**	1	58%
	2	86%
	3	95%
	4	0%

To fully capture the trip, considering zones with zero attractions, a factor of 1 (100%) will be used if a zone is within the UGB and has 0% production.

UGB HB Vector Production		58%
	2	86%
	3	95%
	4	0%

	58%
2	86%
3	95%
4	100%

Step B2 – Calculate the NHB trip portion of household VMT

To obtain the NHB VMT originating from the jurisdictional UGB **(Q)**:

- Multiply the NHB OD vehicle trip **(N)** by the UGB vector HB production **(Y_P)** to obtain the NHB trip originating from the UGB **(Q_1)**.
- Multiply the NHB trip within the UGB **(Q_1)** by the weighted average[2] trip length matrix **(E_W)** to calculate for the **NHB VMT originating from the UGB (Q)**.

$$\text{Matrix } N \times \text{Matrix } Y_P \times \text{Matrix } E_W = \text{Matrix } Q$$

Step B3 – Calculate the NHB work and NHB non-work trip portion of household VMT

To calculate the NHB-work **(Q_W)** and NHB-nonwork **(Q_{NW})** VMT originating from the UGB, repeat **Step B2** using the corresponding attributes.

This concludes the steps for the calculation of NHB trips.

[2] Weighted average trip length Matrix E_W is a two-dimensional OD matrix that is averaged across time periods.