# APPENDIX 8C – DTA REPORT EXAMPLES

# WESTSIDE MULTIMODAL IMPROVEMENTS STUDY

## DYNAMIC TRAFFIC ASSIGNMENT MODEL CALIBRATION, VALIDATION AND FUTURE SCENARIO RESULTS REPORT - DRAFT

FEBRUARY 5, 2024

DKS

1050 SW 6TH AVENUE, SUITE 600 • PORTLAND, OR 97204 • 503.243.3500 • DKSASSOCIATES.COM

## MODELING ANALYSIS PROVIDED BY OREGON METRO MODELING TEAM:

Peter Bosa – Dynamic Traffic Assignment Model Lead

Kyle Hauger – Regional Travel Demand Model Lead

## DOCUMENT PREPARED BY DKS ASSOCIATES:

Randy Johnson, PE, PTOE

Garth Appanaitis, PE

Kayla Fleskes-Lane, PE

## REVIEW BY PARAMETRIX:

Jennifer John

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

## INTRODUCTION AND DOCUMENT ORGANIZATION

This report provides the technical documentation supporting the Dynamic Traffic Assignment (DTA) mesoscopic modeling for the Westside Multimodal Improvements Study (WMIS). The WMIS is intended to provide recommendations for potential plans, projects, strategies, and technologies that will address the needs of the community within the study area and greater region. This project provides preliminary planning and needs identification and will help document the community's vision for transportation.

The DTA model will be used to help support the identification of future needs and the evaluation of various project alternatives. This modeling is intended to supplement the full scenario analysis being conducted using the Portland Metro Regional Travel Demand Model (RTDM). Given the scale and level of detail of the two tools, the DTA model is intended to help provide a more realistic representation of congestion and travel times on US-26 than the RTDM. Therefore, congestion and travel times along US-26 was the primary focus of the model development and calibration.

However, the model contains an area far larger than the Westside study area (described in more detail in following sections). This larger area was selected intentionally to allow ODOT, Metro and other partner agencies to utilize the model for future applications beyond the US-26 corridor. Additional calibration and validation will likely still be needed in the future to support these applications beyond the US-26 study corridor (e.g., evaluation of the changes to the I-405 interchange ramps, etc.).

This memorandum includes the following sections:

- **Study area** – The project study area and the extents of the DTA model.
- **Performance and tracking metrics** –DTA specific performance and tracking metrics that will be used to evaluate the project scenarios and specific projects.
- **Data collection** – The traffic data that was collected to support the model calibration and validation.
- **Sub area model development** – A description of key features of the DTA model.
- **Calibration procedures and validation targets** – A description of the process adjustments made to calibrate the model and the applicable calibration targets.
- **Base year model validation and calibration** – A description of the results of the model validation and calibration, including applicable performance metrics.
- **Future year model assumptions** – Changes made to the future year baseline model.
- **Future year model performance comparison** – A discussion of the future year baseline model performance relative to the base year model.
- **Future scenario evaluation** – A discussion of future scenario performance relative to the future year baseline model performance.
- **Summary of findings** – A summary of key findings from the model development process and scenario evaluation.

## STUDY AREA

The focus of this study is on the US 26 corridor from Brookwood Boulevard to the Sunset Tunnel where the highway splits to I-405, as shown in Figure 1. However, to capture the impacts within the study area, the regional model and dynamic traffic assignment model extend well beyond the project area, as described below.

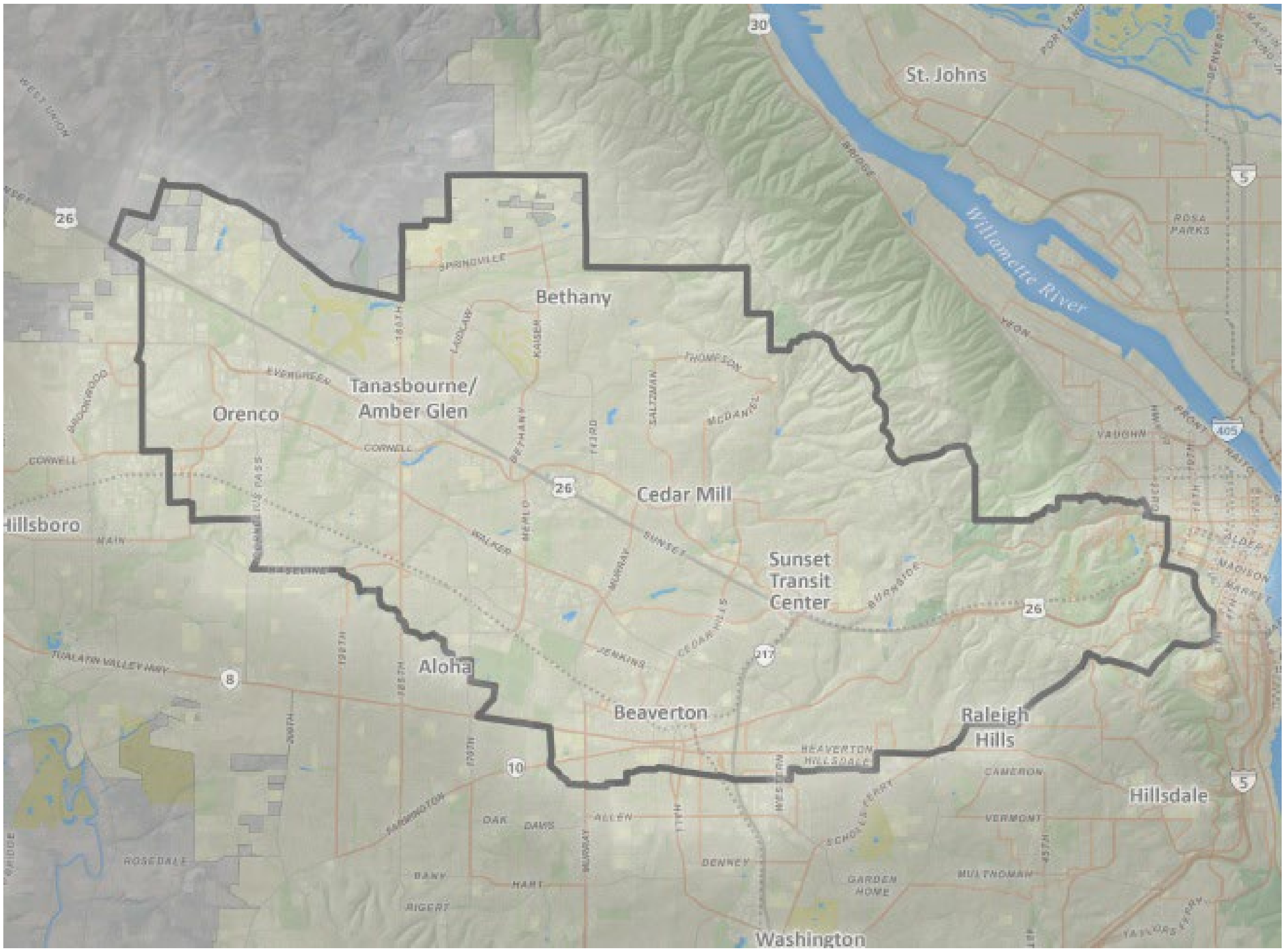



**FIGURE 1. PROJECT STUDY AREA**

## REGIONAL MODEL

The Oregon Metro Regional Travel Demand Model (RTDM) is a trip-based model that covers all of Washington, Clackamas, and Multnomah Counties in Oregon and Clark County in Washington State. It includes 2,162 transportation analysis zones (TAZs) and planning-level (collectors and above) auto, transit, and bike and pedestrian networks for the 4-county region. Figure 2 highlights the extent of the RTDM.

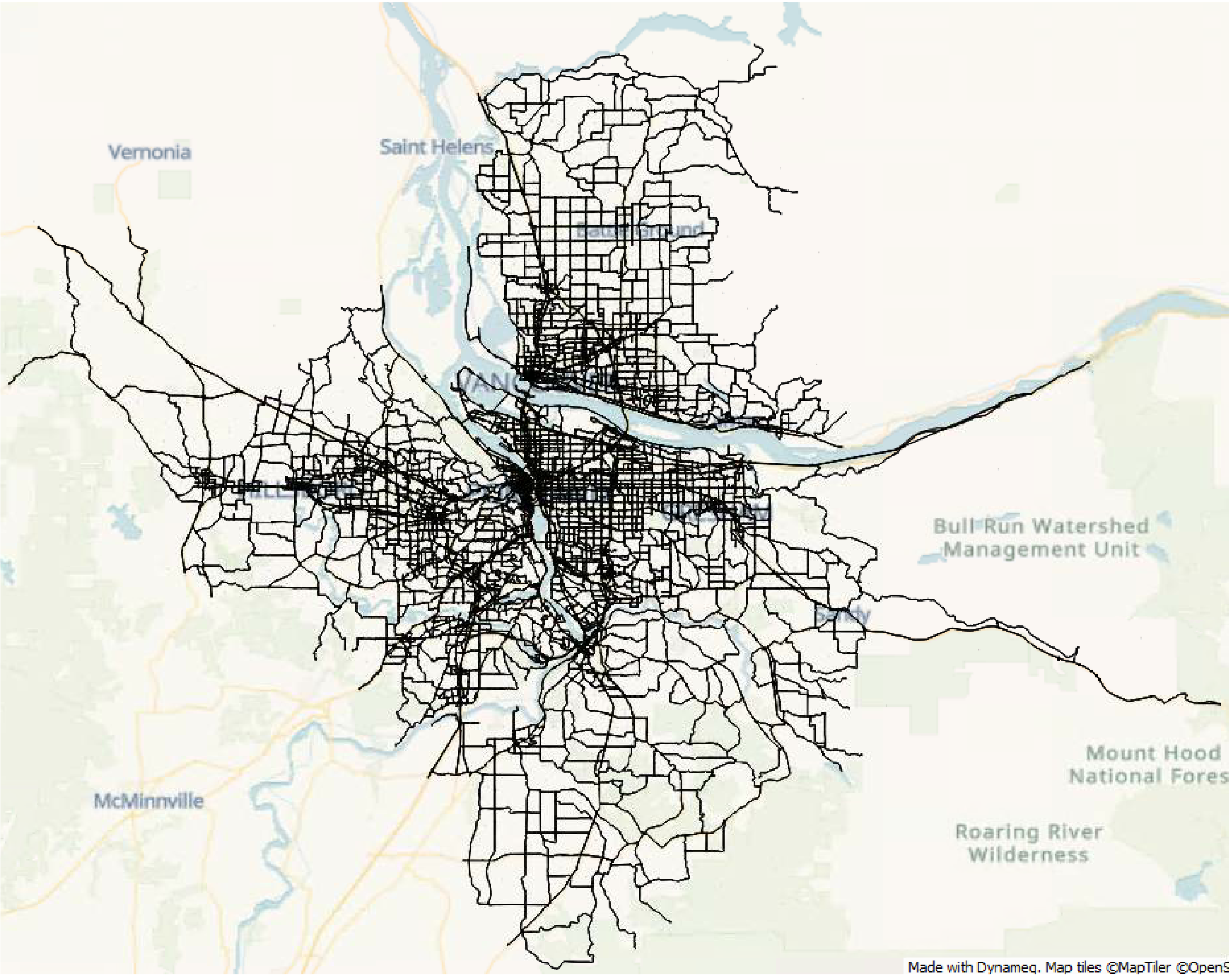



**FIGURE 2. REGIONAL MODEL AREA**

## DTA MODEL

Trip tables that are produced using the full RTDM are exported to Dynameq for assignment in a full 4-county dynamic traffic assignment (DTA). The regional DTA is meant to 'capacity-constrain' the initial trip tables by assigning them to a network that cannot exceed volume-to-capacity ratios of 1.0. After the initial regional DTA is run and converged, a subarea is cut from the regional network. The subarea DTAs are used for final assignments, and for the WMIS project, include most of Washington County and Multnomah County west of the Willamette River (588 TAZs), as shown in Figure 3. As noted previously, this model area extends beyond the project area shown in Figure 1.


**FIGURE 3. DTA MODEL AREA**

## PERFORMANCE AND TRACKING METRICS

The WMIS Evaluation Framework Memorandum[1] documents the evaluation approach and criteria for WMIS. Table 1 lists the applicable subset of modified metrics that were evaluated using the DTA model to supplement the RTDM analysis.

**TABLE 1: EVALUATION METRIC SUMMARY[A]**

| PRIORITY AREA | METRIC | METHODOLOGY |
|---|---|---|
| MOBILITY | Vehicle throughout | Vehicle throughput is reported for the selected weekday peak periods. |
| | Diversion onto local streets | Change in auto travel between highways and local roads (collectors, arterials) from traffic analysis. |
| | Vehicle Delay | Hours of congested travel on US-26, as measured by vehicle speeds. |

[A] *Per WMIS Evaluation Framework Memorandum.*

In addition to the evaluation metrics, the WMIS Evaluation Criteria memorandum also documents tracking metrics that are not included as explicit evaluation criteria to think broadly about regional needs and not preclude larger investments. However, these tracking metrics are measures often expected and generally understood by stakeholders. Several of these tracking metrics related to Mobility can also be evaluated using the DTA model, although these metrics are not reported in this memorandum due to the limitations with the model calibration and project schedule:

- Freight travel time (corridor delay, truck volumes)
- Reliability of alternate routes
- Intersection delay

[1] *Westside Multimodal Improvements Study Evaluation Framework*, Parametrix, October 19, 2022.

## DATA COLLECTION

The following sections describe what data was collected to help support the model calibration and validation, including traffic volumes, vehicle speeds and travel times.

### TRAFFIC VOLUMES

Traffic volumes from 2019 (to represent pre-COVID pandemic conditions) were compiled from the following readily available sources, in part, to reduce the cost of new data collection:

- Annual Average Daily Traffic (AADT) Volumes – Oregon Department of Transportation (ODOT) provides Interchange Ramp Diagrams with AADT volumes for the mainline by direction and for all interchange ramps.
- Permanent Automatic Traffic Recorder (ATR) Summaries - ODOT maintains ATRs at several points along US 26. Data from these ATRs are summarized to provide seasonal trends.
- PORTAL Ramp Data – PORTAL provides a centralized, electronic database that facilitates the collection, archiving, and sharing of transportation data and information for public agencies. The data stored in PORTAL includes 20-second granularity loop detector data from freeways in the Portland-Vancouver metropolitan region.

As shown in Figure 4 below, data from the ATR summary tables indicated that June represent peak seasonal conditions along US 26 within the study area. Therefore, hourly ramp data (based on data every 15-minute interval) was compiled from PORTAL for the month of June 2019 and filtered to Tuesday, Wednesday or Thursday only to represent an average weekday. The hourly data was compiled for 6-10 a.m. and 3-7 p.m.

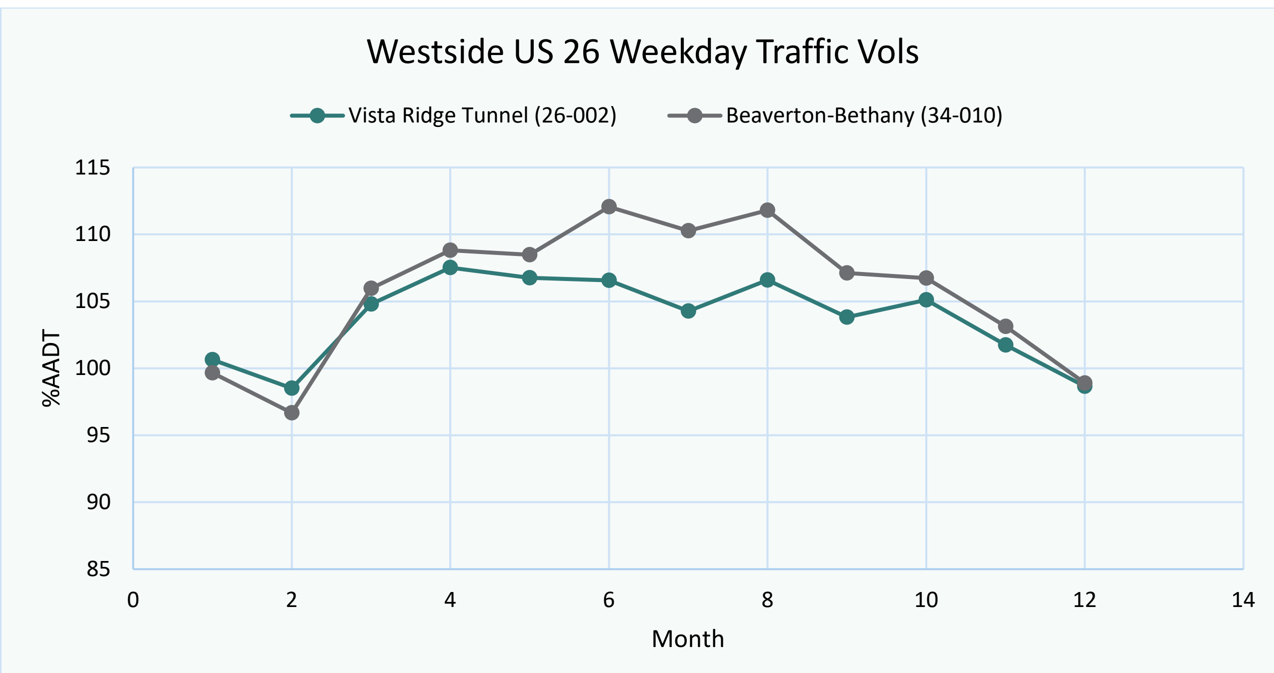



**FIGURE 4: MONTLHY TRAFFIC VOLUME TRENDS ALONG US-26 BASED ON AVERAGE WEEKDAY VOLUMES COMPARED TO AADT**

Given the scale of the model and the scope of the project, the DTA model relied on a simplified approach to balance traffic volumes across the network to assist with the validation and calibration of the DTA model. The AADT volumes were scaled by a factor of the hourly PORTAL ramp data to daily data then manually balanced to result in a traffic volume set for all the ramps and mainline segments between ramps. Given this averaging approach, some of the peak commuter trends may not be as well represented than if new traffic counts had been collected on the same day to represent a specific condition on US-26 (although this would have been a much more costly calibration effort and did not fit within the available project budget). Table 3 in the *Base Year Model Validation and Calibration* section below lists some of the key mainline location balanced traffic volumes.

## VEHICLE SPEEDS AND TRAVEL TIMES

Speed and travel time data were drawn from the National Performance Management Research Data Set (NPMRDS, available only for the National Highway System [NHS]) and the commercial INRIX Speed dataset (access provided by ODOT), where NPMRDS data were not available. All data were accessed using the Regional Integrated Transportation Information System (RITIS) platform. While all speed data could be obtained from the commercial INRIX dataset, the NPMRDS was used where available due to its more clearly defined standards and methodology, and ongoing independent validation. Both data sources rely on cell phone location and vehicle navigation data to sample travel speeds.

NPMRDS and INRIX speed data are provided on the proprietary Traffic Message Channel (TMC) network. The TMC network is used for in-vehicle navigation, based on "decision points" like freeway exits and major street intersections.

Roadway corridors of interest within the study area have been broken up into smaller segments that align with the INRIX TMCs. Table 2 shows the corridors and segments for which travel times and speeds were compiled for use in model calibration and validation.

INRIX data is also used to produce space-time speed plots (see Figure 5 as an example) for the US-26 corridor. The space-time plots can be used to determine the location and duration of congestion and bottlenecks occurring along the corridor.

### TABLE 2: ROADWAY SEGMENTS USED IN TRAVEL TIME AND SPEED ANALYSIS

| Facility | From | To |
|---|---|---|
| **US-26 EB** | **NW Cornelius Pass Road SB off-ramp** | **I-405 split** |
| US-26 EB | NW Cornelius Pass Road SB off-ramp | NW 185th Ave off-ramp |
| US-26 EB | NW 185th Ave off-ramp | NW Bethany Blvd / NW Cornell Road off-ramp |
| US-26 EB | NW Bethany Blvd / NW Cornell Road off-ramp | NW Murray Blvd off-ramp |
| US-26 EB | NW Murray Blvd off-ramp | SW Cedar Hills Blvd off-ramp |
| US-26 EB | SW Cedar Hills Blvd off-ramp | OR-217 SB off-ramp |
| US-26 EB | OR-217 SB off-ramp | SW Scholls Ferry Road off-ramp |
| US-26 EB | SW Scholls Ferry Road off-ramp | Zoo off-ramp |

| | | |
|---|---|---|
| US-26 EB | Zoo off-ramp | I-405 split |
| **US-26 WB** | **I-405 merge** | **NW Cornelius Pass Road SB on-ramp** |
| US-26 WB | I-405 merge | Zoo off-ramp |
| US-26 WB | Zoo off-ramp | SW Scholls Ferry Road off-ramp |
| US-26 WB | SW Scholls Ferry Road off-ramp | OR-217 SB off-ramp |
| US-26 WB | OR-217 SB off-ramp | NW Murray Blvd off-ramp |
| US-26 WB | NW Murray Blvd off-ramp | NW Cornell Road / NW Bethany Blvd off-ramp |
| US-26 WB | NW Cornell Road / NW Bethany Blvd off-ramp | NW 185th Ave off-ramp |
| US-26 WB | NW 185th Ave off-ramp | NW Cornelius Pass Road SB on-ramp |
| **US-30 EB** | **NW Cornelius Pass Road** | **NW Nicolai St** |
| US-30 EB | NW Cornelius Pass Road | NW St Helens Rd |
| US-30 EB | NW St Helens Rd | NW Nicolai St |
| **US-30 WB** | **NW Nicolai St** | **NW Cornelius Pass Road** |
| US-30 WB | NW Nicolai St | NW St Helens Rd |
| US-30 WB | NW St Helens Rd | NW Cornelius Pass Road |
| **Barnes EB** | **OR-217** | **NW 23rd Ave** |
| Barnes EB | OR-217 | NW Skyline |
| Barnes EB | NW Skyline | NW 23rd Ave |
| **Barnes WB** | **NW 23rd Ave** | **OR-217** |
| Barnes WB | NW 23rd Ave | NW Skyline |
| Barnes WB | NW Skyline | OR-217 |
| **CornPass NB** | **US 26** | **US 30** |
| CornPass NB | US 26 | NW Skyline |
| CornPass NB | NW Skyline | US 30 |
| **CornPass SB** | **US 30** | **US 26** |
| CornPass SB | US 30 | NW Skyline |
| CornPass SB | NW Skyline | US 26 |

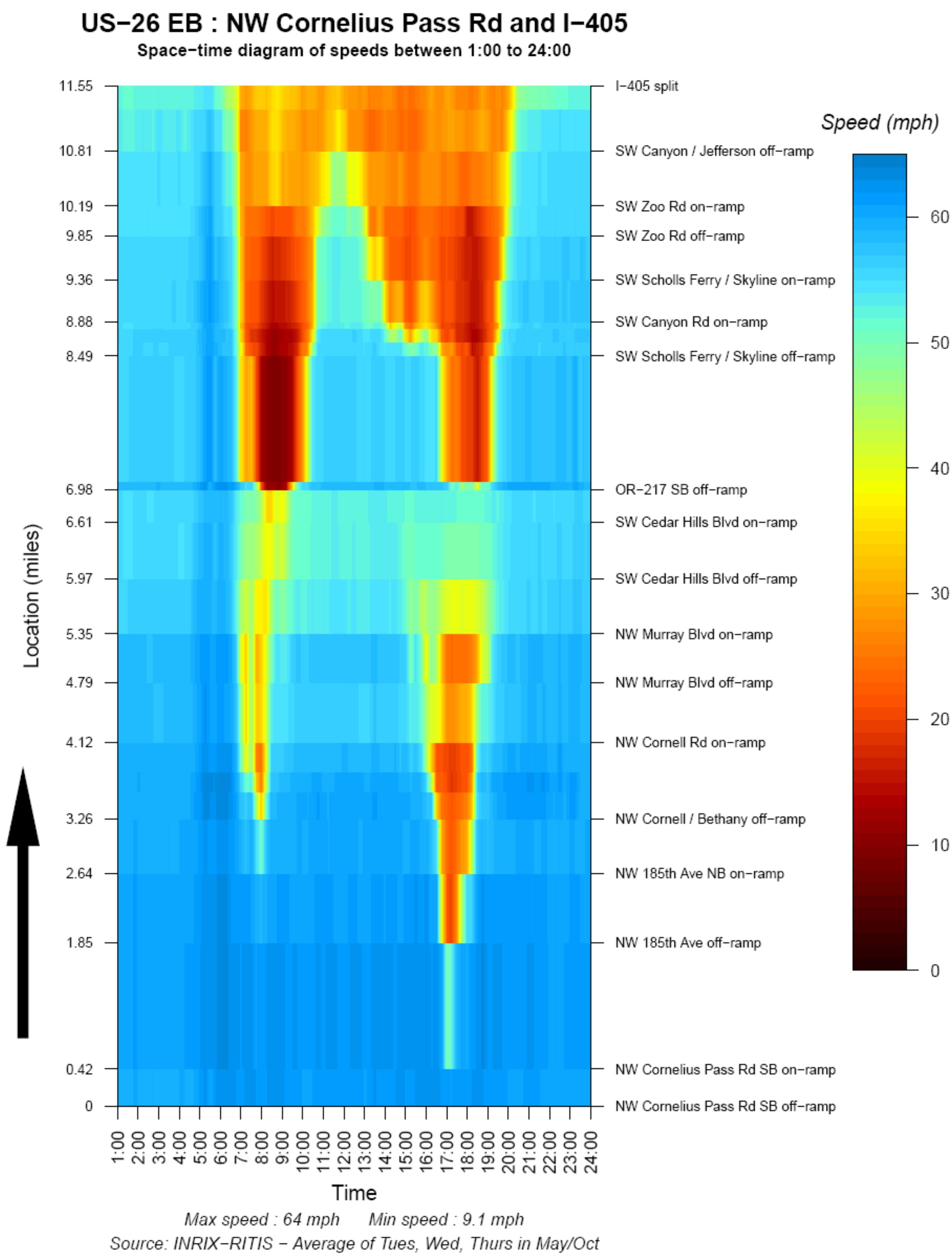



**FIGURE 5: SPACE-TIME PLOT OF AVERAGE DAILY SPEEDS ALONG US-26 EASTBOUND**

## DTA MODEL DEVELOPMENT AND CALIBRATION ADJUSTMENTS

The table below lists key elements of the DTA model. The following sections describe what demand and network adjustments were made to support calibration.

**TABLE 3: MODEL DEVELOPMENT ELEMENTS**

<table>
<tr><th>FEATURE</th><th>DESCRIPTION</th></tr>
<tr><td>TIME HORIZON</td><td>• Base Year is 2020 (pre-COVID), Future Year is 2045</td></tr>
<tr><td>TIME OF DAY</td><td>• AM 2-hr peak (7-9am) and PM 2-hr peak (4-6pm)</td></tr>
<tr><td>VEHICLE CLASSES</td><td>• Single-Occupancy Vehicles (SOVs), High-Occupancy Vehicles (HOVs), Medium Trucks, Heavy Trucks</td></tr>
<tr><td>VALUE OF TIME</td><td>• Values of time (VOT) used in the RTDM and DTA models vary by vehicle class and time of day (see following table). Since the DTA model was implemented for just the AM and PM peak periods, only the peak period VOTs are used in the DTA model.<br>
<table>
<tr><th></th><th>SOV</th><th>HOV</th><th>Medium Trucks</th><th>Heavy Trucks</th></tr>
<tr><td>Peak</td><td>$22.00</td><td>$38.00</td><td>$39.00</td><td>$61.00</td></tr>
<tr><td>Off Peak</td><td>$17.00</td><td>$25.00</td><td>$39.00</td><td>$61.00</td></tr>
<tr><td>Shoulder</td><td>$20.33</td><td>$33.67</td><td>$39.00</td><td>$61.00</td></tr>
</table>
VOT from I-205 Toll VOT Assumptions Memo, WSP, Jan 2021. All values in 2010$</td></tr>
<tr><td>SIGNALS</td><td>• Intersections with signals have phase and cycle times ‘optimized’ by the internal Dynameq algorithm.</td></tr>
<tr><td>RAMP METER RATES</td><td>• Ramp meter rates are closest approximate representation based on real-world meter rates designated by Oregon DOT.</td></tr>
</table>

### DEMAND DEVELOPMENT AND ADJUSTMENTS

Two time periods are analyzed with the DTA tools – AM peak period (7am-9am) and PM peak period (4pm-6pm). In order to provide adequate pre- and post-analysis period simulation time in the DTA networks – necessary to ensure that the 2-hour peaks are not influenced by improper demand outside the peaks – four hours of data for each peak period is compiled for the DTAs. This includes 1 hour of ‘warm up’ demand, 2 hours of peak demand, and 1 hour of ‘cool down’ demand. The result is trip tables for 6am-10am and 3pm-7pm.

Hourly trip tables from the Regional Travel Demand Model runs for each scenario were aggregated into the proper four-hour time periods listed above for the following vehicle classes: SOV, HOV, Heavy Trucks, and Medium Trucks. These four-hour trip tables were then sliced into 15-minute demand intervals based on the historically observed proportion of trips within each 15-minute slice relative to the whole hour. For example, the demand for 6am-7am is sliced into 15-minute demand using the following factors:

| timeperiod | hourly subtotal factors |
|---|---|
| 6:00 - 6:14 | 0.17 |
| 6:15 - 6:29 | 0.22 |
| 6:30 - 6:44 | 0.29 |
| 6:45 - 6:59 | 0.32 |

The result is that each four-hour trip table is divided into sixteen 15-minute time intervals for use in the DTA simulation.

These 15-minute demand trip tables are then assigned in the Base Year DTA, and the resulting modeled volumes are compared against observed counts at key locations. For purposes of this project, those locations were US-26 mainline between interchanges. The locations are shown in Table 3.

Several rounds of demand adjustment using the internal Dynameq algorithm were used to better adjust the demand in each 15-minute trip table so that the assigned results closely match the observed counts. This results in some trips in the trip tables being moved to different Origin-Destination zone pairs, as well as some temporal shift of demand – moving from one 15-minute time period to another. The Dynameq algorithm used in trip table adjustments works incrementally to minimize the location and temporal shifts of trips between zone-pairs.

Once the model is determined to adequately match the observed counts (based on statistical measures such as R-squared values; see discussion below in the *Base Year Model Validation and Calibration – Demand/Throughput* section for more details), a ratio of the original trip tables to the final adjusted trip tables is calculated for the Base Year DTA. This adjustment ratio is then applied to all future year demand trip tables to ensure that the same adjustments to the demand required in the Base Year is replicated in future years. This results in the final set of trip tables that are assigned and analyzed. A discussion on model validation is included in following sections.

## NETWORK ADJUSTMENTS

The Dynameq DTA software package allows the user to adjust three primary link attributes for assignment calibration:

- *Free Speed*: The speed of traffic in the absence of congestion (in mph).
- *Effective Length Factor*: A multiplication factor that is applied to the effective length of a vehicle while it is on the link.
- *Response Time Factor*: A multiplication factor that is applied to the driver response time of the vehicle while it is on the link. A higher response time factor leads to a lower maximum saturation flow.

Together, these three variables control the traffic flow parameters of the software, increasing or decreasing the rate at which congestion builds at specific points in the network. As part of the model calibration, the variables can be adjusted to better match model assignment results against observed speed and count data. For WMIS, these network attributes were adjusted for the US-26 corridor—for both eastbound and westbound traffic—as well as a few key arterials and collectors in the West Hills to prevent over assignment to these facilities. Appendix A lists the adjustments that were made to the model parameters.

## BASE YEAR MODEL VALIDATION AND CALIBRATION

The DTA model will be used to help support the identification of future needs and the evaluation of various project alternatives. This modeling is intended to supplement the full scenario analysis being conducted using the RTDM. Given the scale and level of detail of the two tools, the DTA model is intended to help provide a more realistic representation of congestion and travel times on US-26 than the RTDM. Therefore, congestion and travel times along US-26 was the primary focus of the model development and calibration.

This section describes the base year model validation and calibration. The validation and calibration were primarily based on a comparison of vehicle demand/throughput, travel times and congestion along US-26.

### DEMAND/THROUGHPUT

Analysis of observed counts vs. model throughput (volumes) was limited to the US-26 corridor between Cornelius Pass Road and I-405 on mainline locations, typically at locations located between interchanges. Table 3 compares observed counts (Obs) and DTA modeled throughput volumes (DTA) for each hour in the a.m. 2-hr and p.m. 2-hr peak periods.

There are no widely adopted standards for acceptable model fit for mesoscopic models. However, R-squared and slope of fit lines are generally considered reasonable ‘goodness-of-fit’ indicators. Figure 5 shows these metrics for all mainline locations in the US-26 corridor (eastbound and westbound). Most hours of analysis show a very high level of fit, with R-squared values > .90 and slopes between 0.94 and 1.00. The exception is the 7-8 a.m. hour, in which the R-squared is a marginal .73 and a slope of 0.90.

### TABLE 3: COMPARISON OF OBSERVED COUNTS VS DTA MODEL THROUGHPUT

| Direction | Segment | DTA 7-8 AM | Obs 7-8 AM | Diff DTA-Obs | % Diff from Obs | DTA 8-9 AM | Obs 8-9 AM | Diff DTA-Obs | % Diff from Obs |
|---|---|---|---|---|---|---|---|---|---|
| Westbound | I-405 NB to SW Jefferson St | 5203 | 5188 | 15 | 0% | 5141 | 5401 | -260 | -5% |
| | SW Jefferson St to SW Zoo Road | 5668 | 5551 | 117 | 2% | 6011 | 5735 | 276 | 5% |
| | SW Zoo Road to SW Scholls Ferry Road | 5555 | 5477 | 78 | 1% | 5888 | 5664 | 224 | 4% |
| | SW Scholls Ferry Road to SW Baltic Ave | 5076 | 4859 | 217 | 4% | 4514 | 5019 | -505 | -10% |
| | SW Cedar Hills Blvd to SW Murray Blvd | 5275 | 5156 | 119 | 2% | 5415 | 5349 | 66 | 1% |
| | SW Murray Blvd to NW Bethany Boulevard / NW Cornell Road | 4788 | 4695 | 93 | 2% | 4765 | 4830 | -65 | -1% |
| | NW Bethany Boulevard / NW Cornell Road to NW 185th Avenue | 3490 | 3830 | -340 | -9% | 3753 | 3760 | -7 | 0% |
| | NW 185th Avenue to NE Cornelius Pass Road (OR-127) | 2926 | 2827 | 99 | 4% | 2979 | 2855 | 124 | 4% |
| | West of NE Cornelius Pass Road (OR-217) | 2012 | 2128 | -116 | -5% | 2012 | 2172 | -160 | -7% |
| Eastbound | West of NE Cornelius Pass Road (OR-217) | 2687 | 2611 | 76 | 3% | 2348 | 2312 | 36 | 2% |
| | NE Cornelius Pass Road (OR-127) to NW 185th Avenue | 2754 | 3151 | -397 | -13% | 2699 | 2825 | -126 | -4% |
| | NW 185th Avenue to NW Bethany Boulevard / NW Cornell Road | 3163 | 3917 | -754 | -19% | 3330 | 3580 | -250 | -7% |
| | NW Bethany Boulevard / NW Cornell Road to SW Murray Blvd | 3691 | 4486 | -795 | -18% | 3797 | 4150 | -353 | -9% |
| | SW Murray Blvd to SW Cedar Hills Blvd | 4154 | 4695 | -541 | -12% | 3824 | 4334 | -510 | -12% |
| | SW Cedar Hills Blvd to OR-217 | 4608 | 5033 | -425 | -8% | 4285 | 4639 | -354 | -8% |
| | OR-217 to SW Scholls Ferry Road | 3800 | 4507 | -707 | -16% | 3014 | 4104 | -1090 | -27% |
| | SW Scholls Ferry Road to SW Zoo Road | 3226 | 5033 | -1807 | -36% | 3800 | 4559 | -759 | -17% |
| | SW Zoo Road to SW Jefferson St | 3828 | 5178 | -1350 | -26% | 4392 | 4706 | -314 | -7% |
| | SW Jefferson St to I-405 / SW Market St | 3820 | 4870 | -1050 | -22% | 4118 | 4394 | -276 | -6% |

| Direction | Segment | DTA 4-5 PM | Obs 4-5 PM | Diff DTA-Obs | % Diff from Obs | DTA 5-6 PM | Obs 5-6 PM | Diff DTA-Obs | % Diff from Obs |
|---|---|---|---|---|---|---|---|---|---|
| Westbound | I-405 NB to SW Jefferson St | 5407 | 5448 | -41 | -1% | 5583 | 5595 | -12 | 0% |
| | SW Jefferson St to SW Zoo Road | 6055 | 5833 | 222 | 4% | 6428 | 5993 | 435 | 7% |
| | SW Zoo Road to SW Scholls Ferry Road | 5963 | 5760 | 203 | 4% | 6420 | 5921 | 499 | 8% |
| | SW Scholls Ferry Road to SW Baltic Ave | 5351 | 5147 | 204 | 4% | 5628 | 5213 | 415 | 8% |
| | SW Cedar Hills Blvd to SW Murray Blvd | 5973 | 5457 | 516 | 9% | 5058 | 5561 | -503 | -9% |
| | SW Murray Blvd to NW Bethany Boulevard / NW Cornell Road | 5183 | 4873 | 310 | 6% | 5003 | 4912 | 91 | 2% |
| | NW Bethany Boulevard / NW Cornell Road to NW 185th Avenue | 4189 | 4066 | 123 | 3% | 4096 | 3936 | 160 | 4% |
| | NW 185th Avenue to NE Cornelius Pass Road (OR-127) | 3340 | 2681 | 659 | 25% | 3422 | 2824 | 598 | 21% |
| | West of NE Cornelius Pass Road (OR-217) | 2406 | 1870 | 536 | 29% | 2645 | 2030 | 615 | 30% |
| Eastbound | West of NE Cornelius Pass Road (OR-217) | 1938 | 1793 | 145 | 8% | 1946 | 1800 | 146 | 8% |
| | NE Cornelius Pass Road (OR-127) to NW 185th Avenue | 2728 | 2768 | -40 | -1% | 2735 | 2665 | 70 | 3% |
| | NW 185th Avenue to NW Bethany Boulevard / NW Cornell Road | 3426 | 3596 | -170 | -5% | 3546 | 3483 | 63 | 2% |
| | NW Bethany Boulevard / NW Cornell Road to SW Murray Blvd | 3960 | 4058 | -98 | -2% | 4096 | 3930 | 166 | 4% |
| | SW Murray Blvd to SW Cedar Hills Blvd | 4568 | 4358 | 210 | 5% | 4591 | 4220 | 371 | 9% |
| | SW Cedar Hills Blvd to OR-217 | 4797 | 4611 | 186 | 4% | 4796 | 4437 | 359 | 8% |
| | OR-217 to SW Scholls Ferry Road | 4181 | 4236 | -55 | -1% | 4025 | 4061 | -36 | -1% |
| | SW Scholls Ferry Road to SW Zoo Road | 3728 | 4657 | -929 | -20% | 4436 | 4521 | -85 | -2% |
| | SW Zoo Road to SW Jefferson St | 4241 | 4778 | -537 | -11% | 4754 | 4628 | 126 | 3% |
| | SW Jefferson St to I-405 / SW Market St | 4218 | 4520 | -302 | -7% | 4543 | 4400 | 143 | 3% |

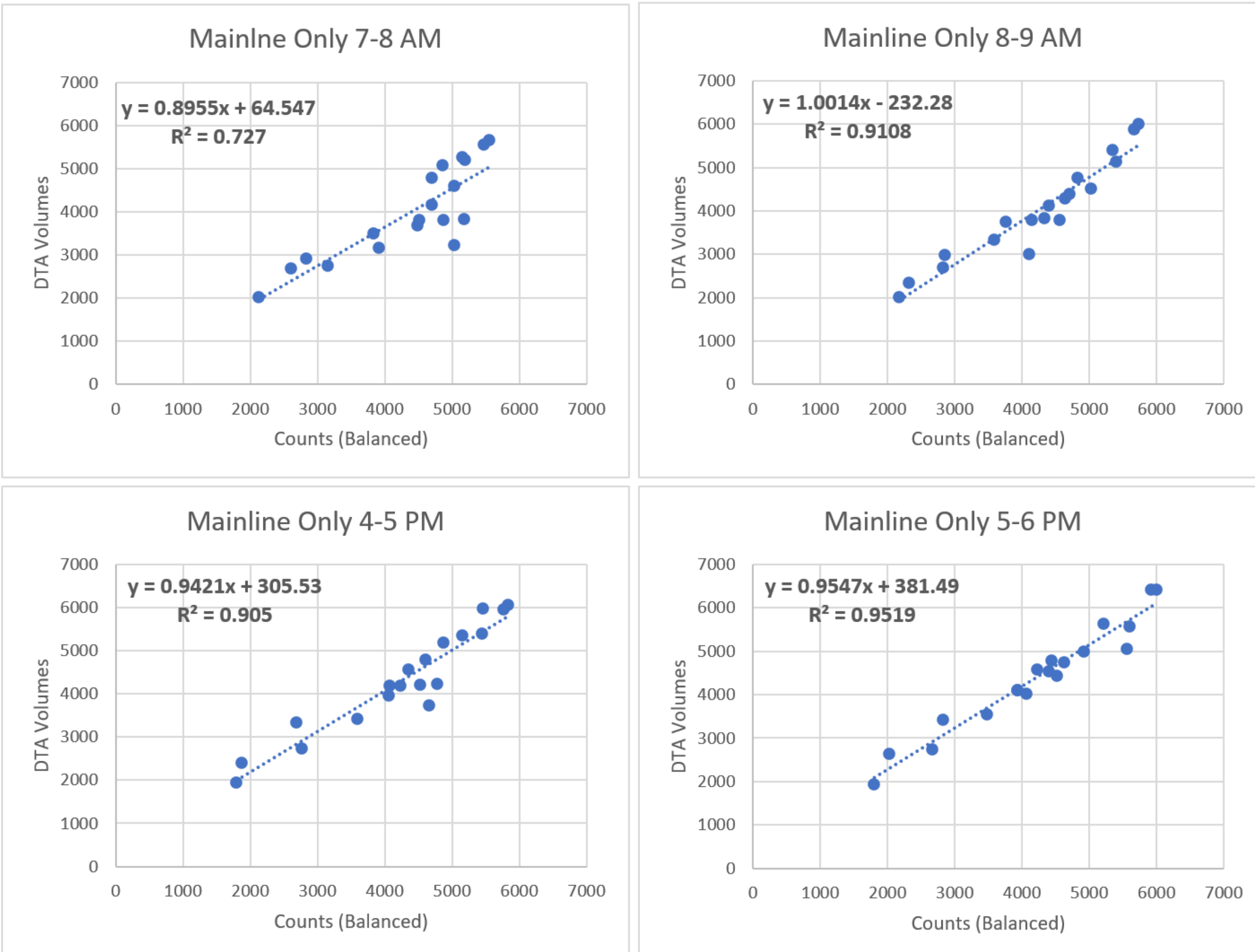



**FIGURE 6: GOODNESS-OF-FIT FOR OBSERVED COUNTS VS DTA MODEL THROUGHPUT**

## TRAVEL TIMES

Table 2 shows the corridors and segments for which travel times and speeds were compiled for use in model calibration and validation. DTA model data was analyzed for each of these segments for each hour in the a.m. 2-hr and p.m. 2-hr peak periods.

Again, there are no widely adopted standards for acceptable model fit for mesoscopic models. However, the ODOT Analysis Procedures Manual (APM) provides useful criteria for travel time validation for microsimulations. This guidance borrows from the *FHWA Traffic Analysis Toolbox Volume III*. Table 4 lists the travel time calibration criteria adapted from the APM. While these metrics are meant for calibration of microsimulations, a mesoscopic model that introduces route choice will inherently have more broad variables and less detail of travel network that make them more difficult to calibrate to real world data. Therefore, the intent is not to meet the below criteria within the DTA model but to use it as a gauge to understand the level of calibration.

**TABLE 4: TRAVEL TIME CALIBRATION CRITERIA ADAPTED FROM THE ODOT APM**

| THRESHOLD | CRITERIA |
|---|---|
| ROUTE WITH OBSERVED TRAVEL TIMES < 7 MINUTES | Modeled travel time with +/- 1 minute |
| ROUTE WITH OBSERVED TRAVEL TIMES > 7 MINUTES | Modeled travel time with +/- 15 percent |

Figure 7 shows the percentage of roadway segments for US-26 and US-30 that are within, faster, or slower than acceptable travel times based on the criteria specified in the ODOT APM. The large majority (approximately 65-70 percent) of the travel time segments fall within the ODOT APM criteria.

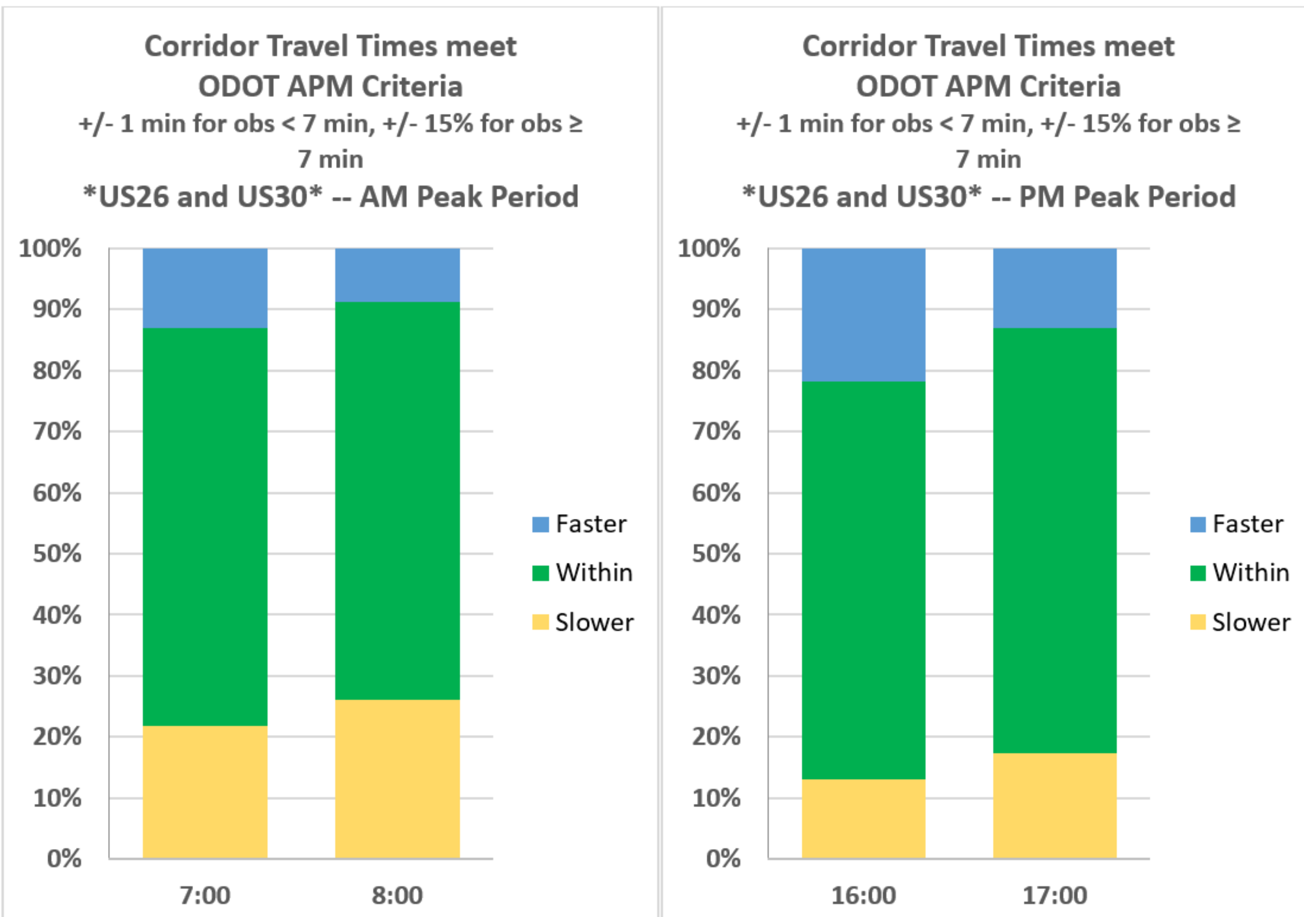



FIGURE 7: TRAVEL TIME CALIBRATION CRITERIA FOR US-26 AND US-30

## CONGESTION AND BOTTLENECK LOCATIONS

Space-time speed plots of both ‘observed’ INRIX speed data and DTA model outputs can be useful to determine if the DTA model is accurately capturing the location and duration of major congestion areas and bottlenecks in the project corridor. This analysis was performed on eastbound and westbound US-26 in the project corridor. Note that INRIX speed data is captured at a lower fidelity (i.e., longer segments) while the DTA model reports results at a higher fidelity (i.e., each model link). For example, Scholls Ferry off-ramp to OR-217 off-ramp is one segment in the INRIX data but is represented by multiple segments in the DTA model. This results in some areas of the DTA model appearing to have less congestion than the INRIX data.

### EASTBOUND CONGESTION

Based on the INRIX data, there are several congestion spots on US-26 eastbound in both the a.m. and p.m. peak periods as shown in Figure 8. The first occurs at the terminus of US-26 as it meets I-405 and Portland central city in an area referred to as the Sunset Tunnel. Congestion from lane-changing and spillback from I-405 create congestion that propagates upstream several miles, often to the interchange with OR-217.

The second congestion spot occurs at the Murray Blvd on-ramp and propagates upstream to the 185$^{th}$ Ave interchange. This Murray Blvd bottleneck is much more prominent in the PM 2-hour peak period, as shown in Figure 9. While the DTA model was calibrated to capture the Sunset Tunnel bottleneck fairly well, the Murray Blvd bottleneck proved to be very difficult to recreate in Dynameq. Given the relatively few adjustments available to the modelers to impact traffic behavior, it was determined that this particular congestion spot was beyond the capabilities of the software to fully capture with the current budget constraints of the project.

However, while the exact bottleneck dimensions were not fully recreated in the Dynameq model, the overall model calibration is still considered to be fairly good given the comparisons of travel times and speeds along US-26 and the intended use for the project. Additional calibration and validation will likely still be needed in the future to support these applications beyond the US-26 study corridor (e.g., evaluation of the changes to the I-405 interchange ramps, etc.).

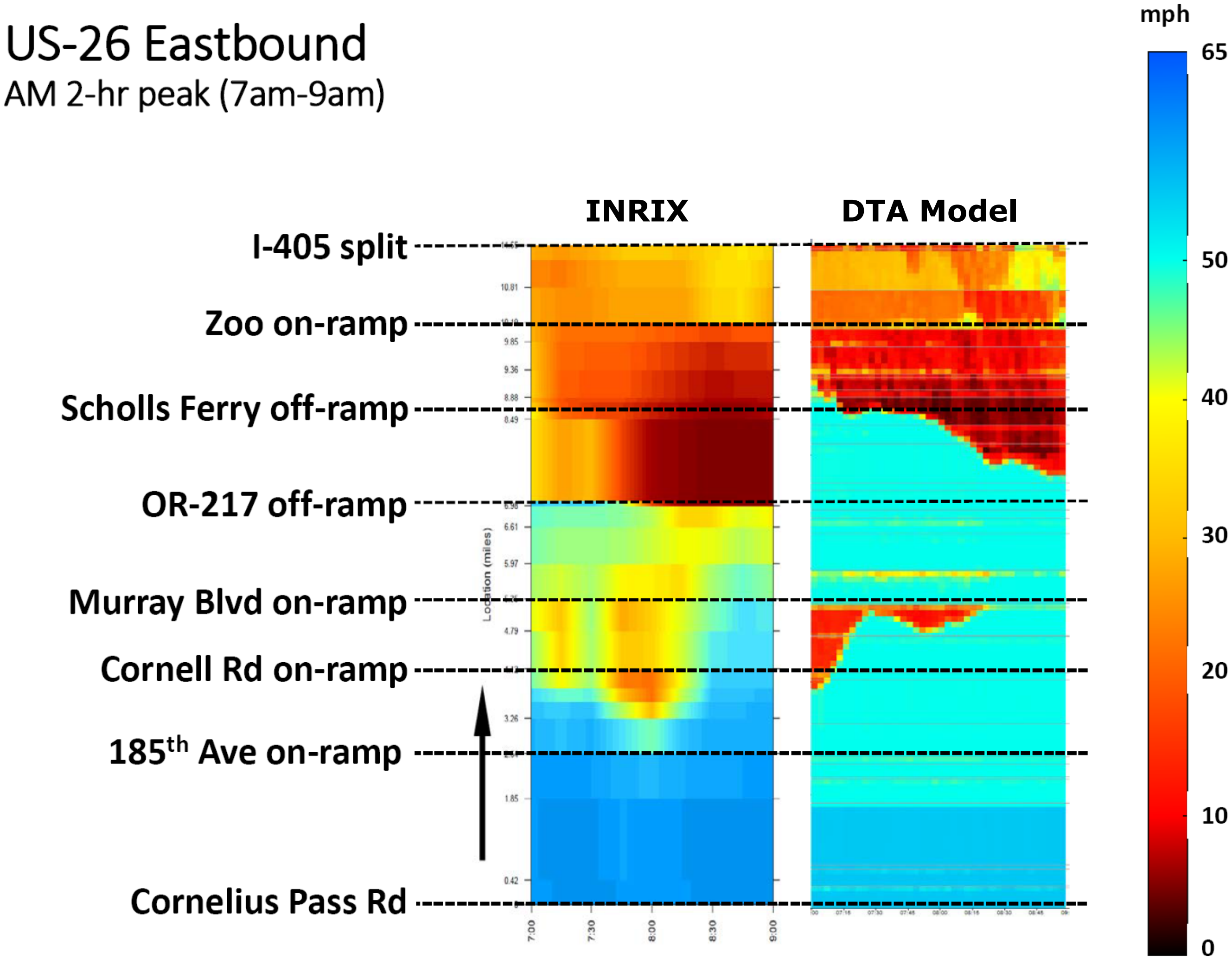



**FIGURE 8: US-26 EASTBOUND AM 2-HOUR PEAK CONGESTION PLOT**

*Note: iter41_mod represents the calibrated base year model.*

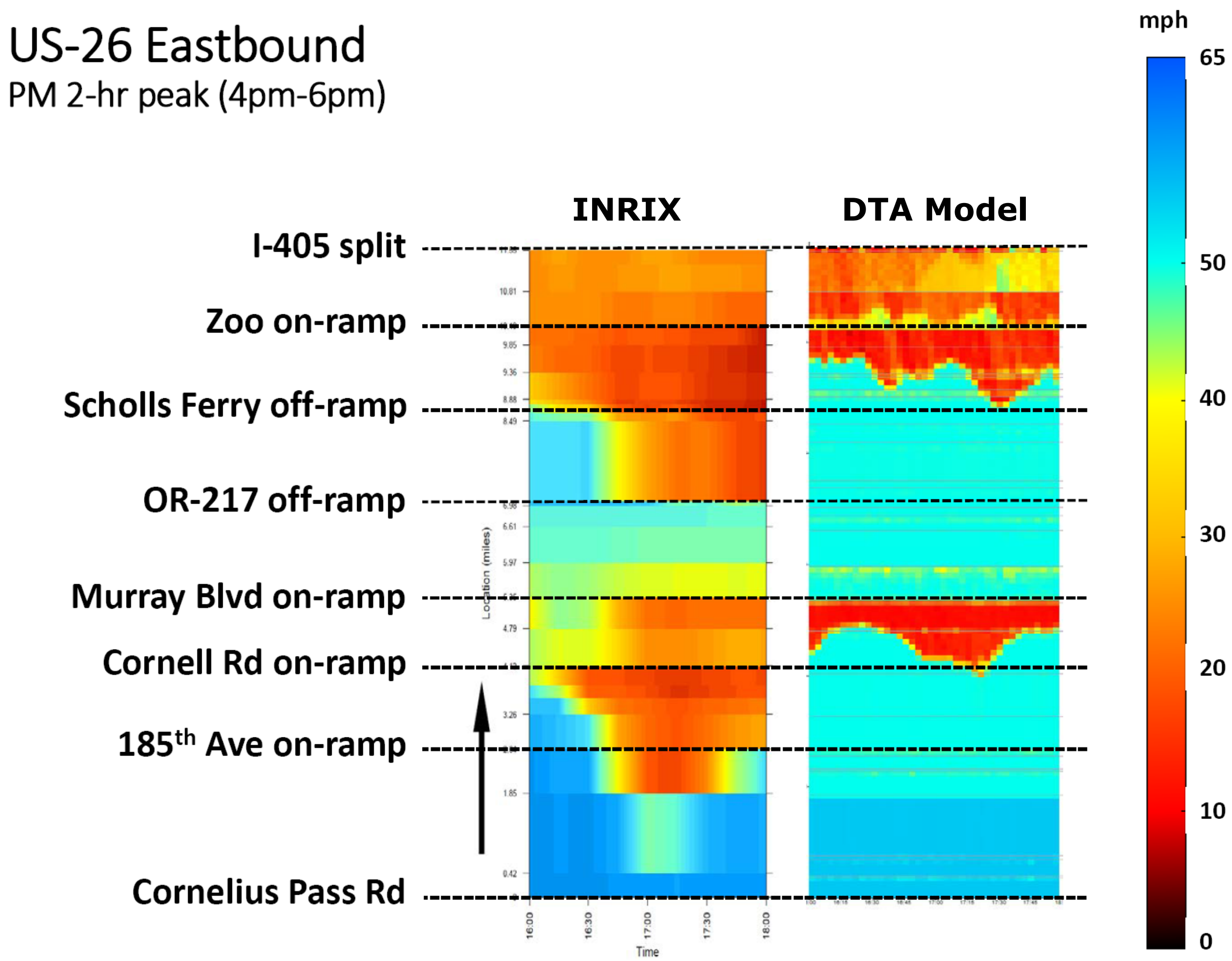



**FIGURE 9: US-26 EASTBOUND PM 2-HOUR PEAK CONGESTION PLOT**

*Note: iter41_mod represents the calibrated base year model.*

## WESTBOUND CONGESTION

The INRIX data shows a single congestion hotspot on US-26 westbound in both the a.m. and p.m. peak periods, as shown in Figure 10 and Figure 11. The hotspot is located at Murray Blvd and can extend upstream to OR-217 interchange in the p.m. hours. While the DTA does not fully capture the extent or duration of this bottleneck, it does capture some of the slowdown occurring at this location.

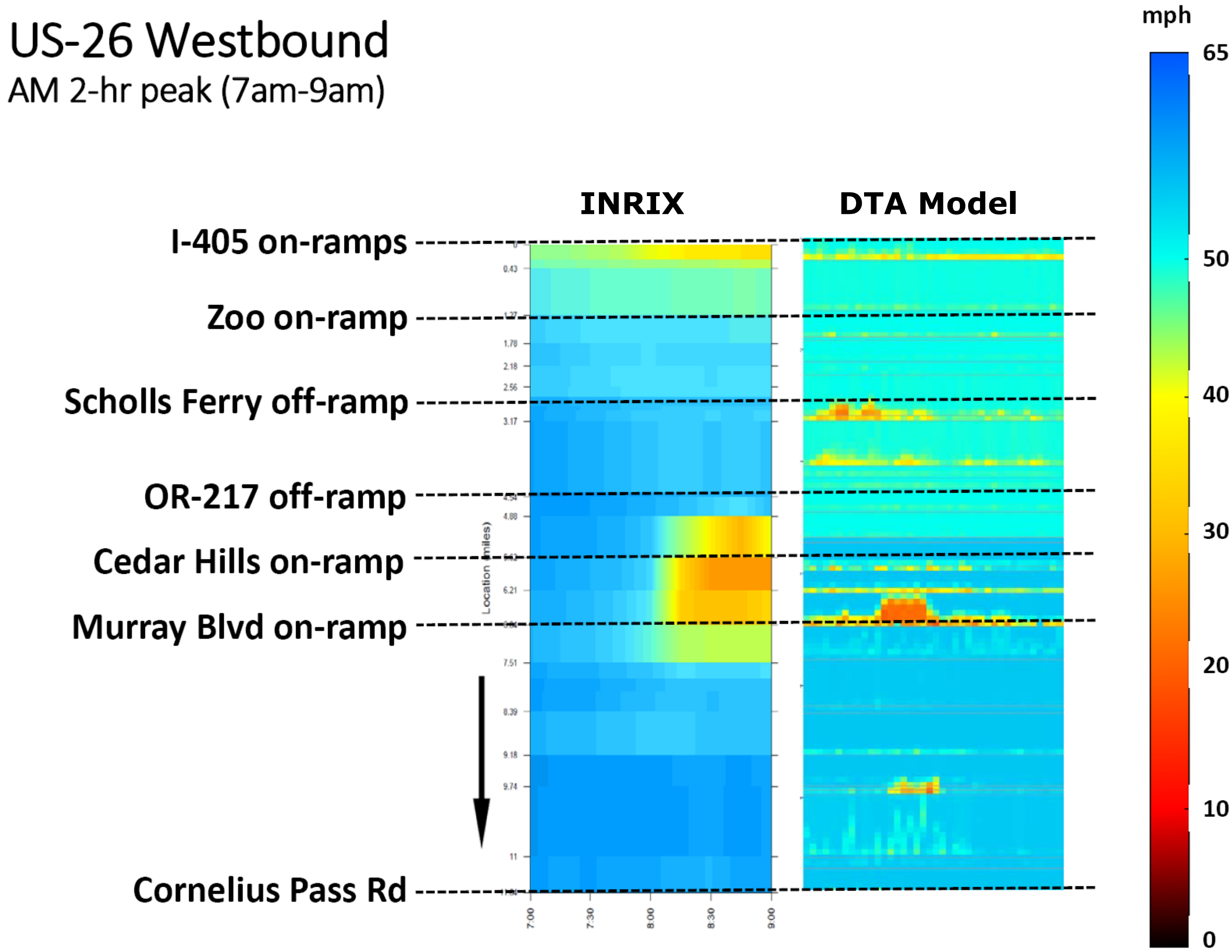



**FIGURE 10: US-26 WESTBOUND AM 2-HOUR PEAK CONGESTION PLOT**

*Note: iter41_mod represents the calibrated base year model.*

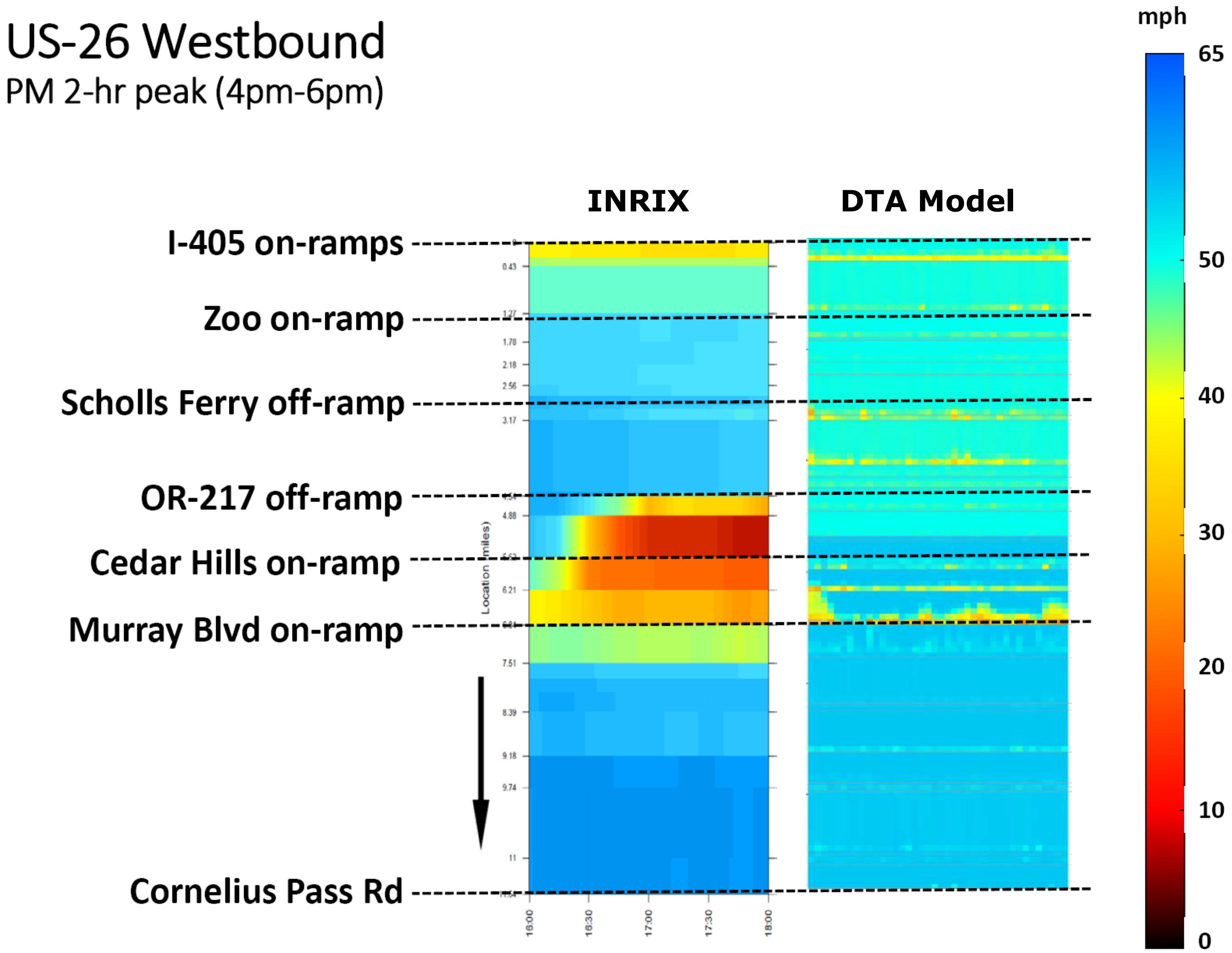



**FIGURE 11: US-26 WESTBOUND AM 2-HOUR PEAK CONGESTION PLOT**

*Note: iter41_mod represents the calibrated base year model.*

## FUTURE YEAR MODEL ASSUMPTIONS

The 2045 Future Year DTAs are based on the 2045 Financially Constrained (FC) scenario from the 2023 RTP update. In addition to containing the roadway projects and improvements contained within the 2045 FC, the 2045 DTAs assume the same network adjustments listed for the 2020 Base Year DTA calibration.

## FUTURE YEAR BASELINE MODEL PERFORMANCE

This section documents the future baseline model throughput, travel times, congestion and diversion expected under the future baseline scenario.

### TRAFFIC THROUGHPUT

Traffic volumes produced from the DTA model are reported in Table 5 for the a.m. and p.m. peak hour for a 2020 Base and 2045 No Build model. The 2020 Base condition assumes existing conditions as they were in 2020 and the 2045 No Build assumes no changes will be made to the US-26 corridor between 2020 and 2045. Analysis was focused on mainline locations between Cornelius Pass Road and I-405 along US-26, typically at locations between interchanges. Table 5 compares DTA modeled throughput volumes for each hour in the a.m. 2-hour and p.m. 2-hour peak periods for both scenarios.

Overall, most westbound segments show an increase in throughput between the 2020 and 2045 scenarios as modeled through the DTA model for both the a.m. and the p.m. peak. Over the whole corridor heading westbound between the 7-8 a.m. hour, throughput increased about 15% and about 24% for the 8-9 a.m. hour. The largest increase was between NW 185$^{th}$ and NE Cornelius Pass Road with an increase of 72% during the 8-9 a.m. hour.

There was also generally a slight increase in throughput for most segments eastbound, with the exception of the 8-9 a.m. peak hour. During the 8-9 a.m. peak hour, the eastbound approach saw a consistent decrease in throughput from NW 185$^{th}$ Avenue to SW Zoo Road in the 2045 No Build Scenario despite growth in vehicle demand across the region. The highest decrease in throughput in the eastbound direction occurred between OR-217 and SW Scholls Ferry Road at 22% for the 8-9 a.m. hour. This decrease in throughput is due in large part to congestion bottlenecks further upstream which limit the vehicle demand that is able to make it to this section of US-26 (see *Congestion and Bottleneck Locations* discussion below and Figure 17 in particular, which highlights speeds along US-26). This is directly related to the fundamental diagram, which generalizes the relationships between speed, density and flow rate. US-26 effecitvely operates in oversaturated conditions, resulting in lower speeds and lower flow rates (and therefore, lower throughput).

#### TABLE 5: COMPARISON OF TRAFFIC VOLUME THROUGHPUT BETWEEN THE 2020 BASE SCENARIO AND 2045 NO BUILD SCENARIO

| Direction | Segment | 2020 Base 7-8 AM | 2045 NB 7-8 AM | Diff 2020-2045 | % Diff from 2020 | 2020 Base 8-9 AM | 2045 NB 8-9 AM | Diff 2020-2045 | % Diff from 2020 |
|---|---|---|---|---|---|---|---|---|---|
| Westbound | I-405 NB to SW Jefferson St | 5628 | 5928 | 300 | 5% | 5401 | 5554 | 153 | 3% |
| Westbound | SW Jefferson St to SW Zoo Road | 6296 | 6606 | 310 | 5% | 5735 | 6449 | 714 | 12% |
| Westbound | SW Zoo Road to SW Scholls Ferry Road | 6213 | 6563 | 350 | 6% | 5664 | 6367 | 703 | 12% |
| Westbound | SW Scholls Ferry Road to SW Baltic Ave | 5647 | 5601 | -46 | -1% | 5019 | 5237 | 218 | 4% |
| Westbound | SW Cedar Hills Blvd to SW Murray Blvd | 5811 | 5523 | -288 | -5% | 5349 | 5545 | 196 | 4% |
| Westbound | SW Murray Blvd to NW Bethany Boulevard / NW Cornell Road | 5184 | 5473 | 289 | 6% | 4830 | 5420 | 590 | 12% |
| Westbound | NW Bethany Boulevard / NW Cornell Road to NW 185th Avenue | 3913 | 5521 | 1608 | 41% | 3760 | 5251 | 1491 | 40% |
| Westbound | NW 185th Avenue to NE Cornelius Pass Road (OR-127) | 3519 | 5019 | 1500 | 43% | 2855 | 4905 | 2050 | 72% |
| Westbound | West of NE Cornelius Pass Road (OR-217) | 2579 | 3459 | 880 | 34% | 2172 | 3458 | 1286 | 59% |
| Eastbound | West of NE Cornelius Pass Road (OR-217) | 2594 | 3233 | 639 | 25% | 2312 | 2868 | 556 | 24% |
| Eastbound | NE Cornelius Pass Road (OR-127) to NW 185th Avenue | 2951 | 3695 | 744 | 25% | 2825 | 3445 | 620 | 22% |
| Eastbound | NW 185th Avenue to NW Bethany Boulevard / NW Cornell Road | 3421 | 3956 | 535 | 16% | 3580 | 3403 | -177 | -5% |
| Eastbound | NW Bethany Boulevard / NW Cornell Road to SW Murray Blvd | 3868 | 4201 | 333 | 9% | 4150 | 3607 | -543 | -13% |
| Eastbound | SW Murray Blvd to SW Cedar Hills Blvd | 4267 | 4304 | 37 | 1% | 4334 | 3435 | -899 | -21% |
| Eastbound | SW Cedar Hills Blvd to OR-217 | 4751 | 4976 | 225 | 5% | 4639 | 3943 | -696 | -15% |
| Eastbound | OR-217 to SW Scholls Ferry Road | 3594 | 3875 | 281 | 8% | 4104 | 3219 | -885 | -22% |
| Eastbound | SW Scholls Ferry Road to SW Zoo Road | 3391 | 3202 | -189 | -6% | 4559 | 4243 | -316 | -7% |
| Eastbound | SW Zoo Road to SW Jefferson St | 3905 | 3961 | 56 | 1% | 4706 | 5145 | 439 | 9% |
| Eastbound | SW Jefferson St to I-405 / SW Market St | 3898 | 3914 | 16 | 0% | 4394 | 4433 | 39 | 1% |

| Direction | Segment | 2020 Base 4-5 PM | 2045 NB 4-5 PM | Diff 2020-2045 | % Diff from 2020 | 2020 Base 5-6 PM | 2045 NB 5-6 PM | Diff 2020-2045 | % Diff from 2020 |
|---|---|---|---|---|---|---|---|---|---|
| Westbound | I-405 NB to SW Jefferson St | 5448 | 5923 | 475 | 9% | 5595 | 5885 | 290 | 5% |
| Westbound | SW Jefferson St to SW Zoo Road | 5833 | 6770 | 937 | 16% | 5993 | 6734 | 741 | 12% |
| Westbound | SW Zoo Road to SW Scholls Ferry Road | 5760 | 6700 | 940 | 16% | 5921 | 6646 | 725 | 12% |
| Westbound | SW Scholls Ferry Road to SW Baltic Ave | 5147 | 5318 | 171 | 3% | 5213 | 5580 | 367 | 7% |
| Westbound | SW Cedar Hills Blvd to SW Murray Blvd | 5457 | 6011 | 554 | 10% | 5561 | 5942 | 381 | 7% |
| Westbound | SW Murray Blvd to NW Bethany Boulevard / NW Cornell Road | 4873 | 5413 | 540 | 11% | 4912 | 5467 | 555 | 11% |
| Westbound | NW Bethany Boulevard / NW Cornell Road to NW 185th Avenue | 4066 | 4638 | 572 | 14% | 3936 | 4946 | 1010 | 26% |
| Westbound | NW 185th Avenue to NE Cornelius Pass Road (OR-127) | 2681 | 3856 | 1175 | 44% | 2824 | 3859 | 1035 | 37% |
| Westbound | West of NE Cornelius Pass Road (OR-217) | 1870 | 2703 | 833 | 45% | 2030 | 2797 | 767 | 38% |
| Eastbound | West of NE Cornelius Pass Road (OR-217) | 1793 | 2892 | 1099 | 61% | 1800 | 2715 | 915 | 51% |
| Eastbound | NE Cornelius Pass Road (OR-127) to NW 185th Avenue | 2768 | 4099 | 1331 | 48% | 2665 | 3826 | 1161 | 44% |
| Eastbound | NW 185th Avenue to NW Bethany Boulevard / NW Cornell Road | 3596 | 4285 | 689 | 19% | 3483 | 3628 | 145 | 4% |
| Eastbound | NW Bethany Boulevard / NW Cornell Road to SW Murray Blvd | 4058 | 4419 | 361 | 9% | 3930 | 3881 | -49 | -1% |
| Eastbound | SW Murray Blvd to SW Cedar Hills Blvd | 4358 | 4496 | 138 | 3% | 4220 | 4471 | 251 | 6% |
| Eastbound | SW Cedar Hills Blvd to OR-217 | 4611 | 4947 | 336 | 7% | 4437 | 4957 | 520 | 12% |
| Eastbound | OR-217 to SW Scholls Ferry Road | 4236 | 4513 | 277 | 7% | 4061 | 4499 | 438 | 11% |
| Eastbound | SW Scholls Ferry Road to SW Zoo Road | 4657 | 4047 | -610 | -13% | 4521 | 4497 | -24 | -1% |
| Eastbound | SW Zoo Road to SW Jefferson St | 4778 | 4623 | -155 | -3% | 4628 | 5340 | 712 | 15% |
| Eastbound | SW Jefferson St to I-405 / SW Market St | 4520 | 4200 | -320 | -7% | 4400 | 5037 | 637 | 14% |

## TRAVEL TIMES

The travel times for four roadways (US 26, US 30, Barnes Road, & Cornelius Pass Road) were compared between the 2020 Base Model and the 2045 No Build Model for both the a.m. and p.m. peak. Travel times were calculated for 13 segments between the three roadways for the respective eastbound and westbound or northbound and southbound direction. The lengths of these segments are shown in Figure 12 below.

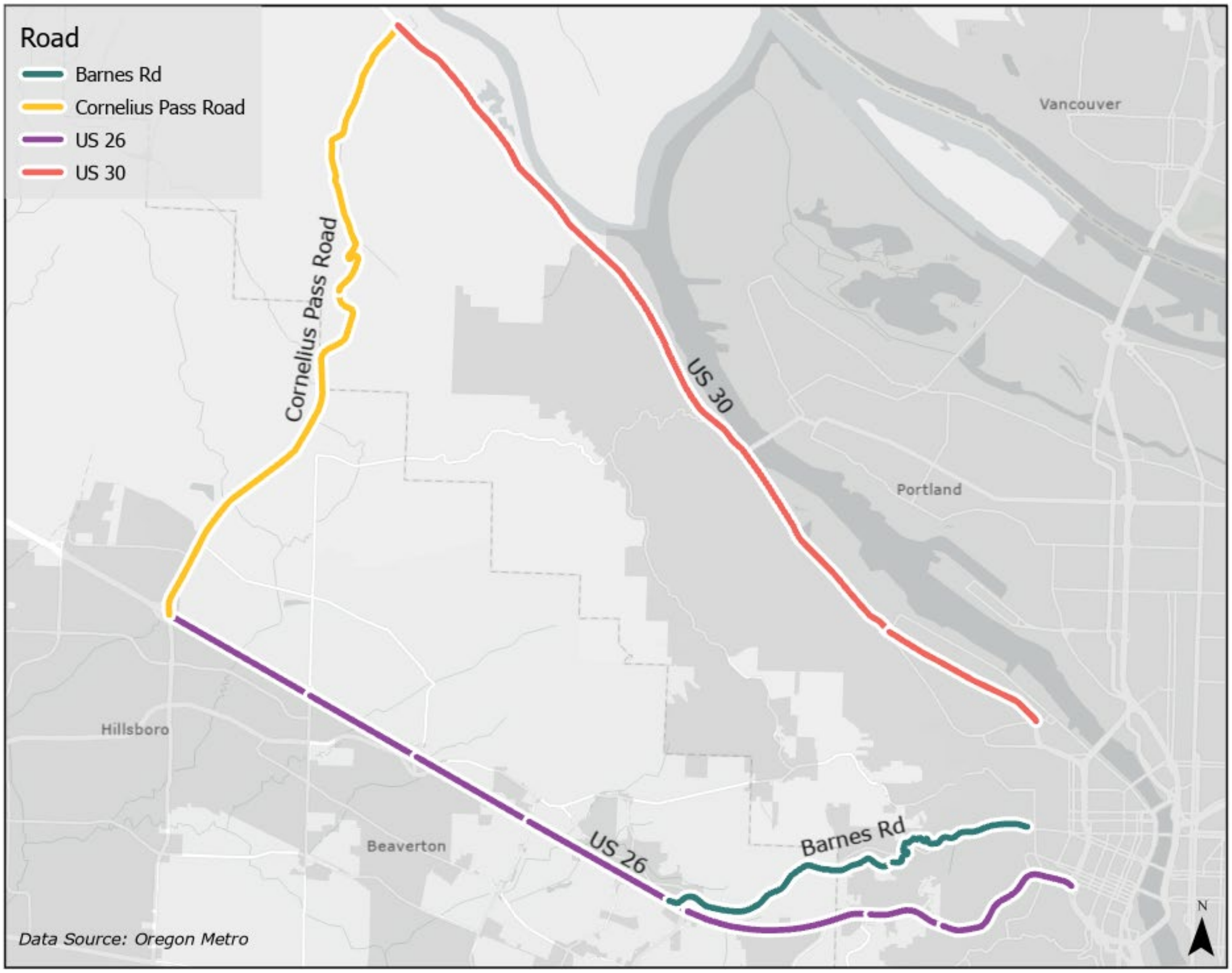



**FIGURE 12. ANALYSIS STUDY AREA ROAD SEGMENTS**

### A.M. PEAK

The a.m. peak saw the largest increase in travel time between the two models along US-30. The travel time between 8-9 a.m. in the eastbound direction along this corridor more than doubled between the two models. The other corridor that saw an increase in congestion was US-26 which increased an average of 26% over both time periods and in both directions. Cornelius Pass Road saw significant increases in only the northbound direction and Barnes Road saw increases of less than 10% in the eastbound direction. The average travel time by roadway in minutes is shown in Table 6 below.

**TABLE 6: COMPARISON OF TRAVEL TIMES (MINUTES) BETWEEN THE 2020 BASE AND 2045 NO BUILD IN THE AM PEAK**

| | | 2020 Base 7-8 AM | 2045 NB 7-8 AM | Diff 2020-2045 | % Diff from 2020 | 2020 Base 8-9 AM | 2045 NB 8-9 AM | Diff 2020-2045 | % Diff from 2020 |
|---|---|---|---|---|---|---|---|---|---|
| WB/SB | US-26 | 14.4 | 17.5 | 3.1 | 22% | 13.9 | 18.5 | 4.6 | 33% |
| WB/SB | US-30 | 14.4 | 14.8 | 0.4 | 3% | 14.4 | 14.6 | 0.2 | 1% |
| WB/SB | Barnes Road | 9.9 | 10.4 | 0.5 | 5% | 9.9 | 10.4 | 0.5 | 5% |
| WB/SB | Cornelius Pass Road | 13.4 | 13.4 | 0 | 0% | 13.6 | 13.4 | -0.2 | -1% |
| EB/NB | US-26 | 28.4 | 33 | 4.6 | 16% | 33.5 | 43.7 | 10.2 | 30% |
| EB/NB | US-30 | 14.7 | 22.6 | 7.9 | 54% | 14.8 | 36.5 | 21.7 | 147% |
| EB/NB | Barnes Road | 15.4 | 16.7 | 1.3 | 8% | 22.8 | 23.6 | 0.8 | 4% |
| EB/NB | Cornelius Pass Road | 13.6 | 14.8 | 1.2 | 9% | 14.3 | 15.7 | 1.4 | 10% |

The 13 segments were also analyzed based on their placement within the ODOT: Travel Time Index[2]. According to this index, travel times that are below half of the posted speed limit are considered severely congested, and travel times no less than 10% below the posted speed limit show no congestion. For both hours in the 2020 Base, about 52% of segments showed no congestion. In the 2045 model, this number went down to about 35% of segments. The heaviest congestion is seen in the 8-9 a.m. 2045 No Build model with 37% of segments exhibiting severe congestion. Changes in congestion can be seen in Figure 13.

---

[2] ODOT, *2022 Statewide Congestion Overview*. 4/12/2023.

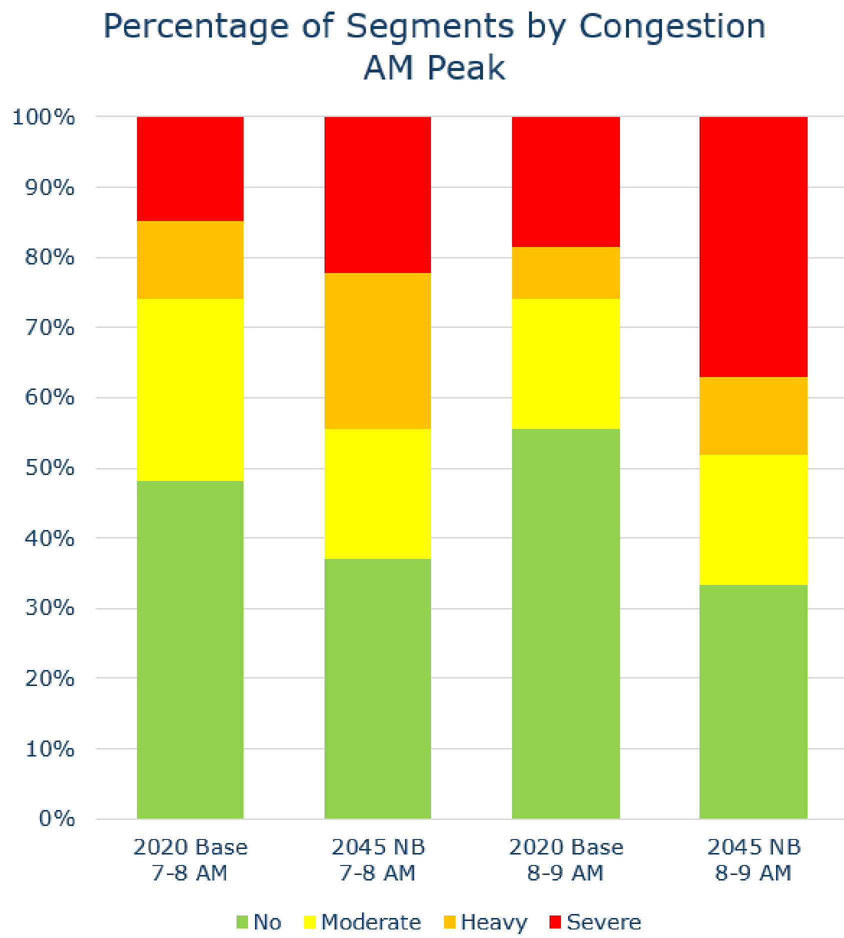



**FIGURE 13: SEGMENTS BY LEVEL OF CONGESTION ACCORDING TO THE ODOT TRAVEL TIME INDEX AM PEAK**

### P.M. PEAK

The p.m. peak saw the largest increase in overall travel time along US-26 with an increase of almost 20%. Increases in travel times in the p.m. peak were more moderate when compared to travel time increases in the a.m. peak. US-30 travel times were relatively stable between the two models and Barnes Road and Cornelius Pass Road saw increases of around 5%. Changes in travel time can be found in Table 7.

**TABLE 7: COMPARISON OF TRAVEL TIMES (MINUTES) BETWEEN THE 2020 BASE AND 2045 NO BUILD IN THE PM PEAK**

| | | 2020 Base 4-5 PM | 2045 NB 4-5 PM | Diff 2020-2045 | % Diff from 2020 | 2020 Base 5-6 PM | 2045 NB 5-6 PM | Diff 2020-2045 | % Diff from 2020 |
|---|---|---|---|---|---|---|---|---|---|
| WB/SB | US-26 | 13.9 | 15.3 | 1.4 | 10% | 14.0 | 17.0 | 3 | 21% |
| WB/SB | US-30 | 14.5 | 14.6 | 0.1 | 1% | 14.5 | 14.4 | -0.1 | -1% |
| WB/SB | Barnes Road | 10.2 | 10.4 | 0.2 | 2% | 10.4 | 10.7 | 0.3 | 3% |
| WB/SB | Cornelius Pass Road | 13.3 | 13.5 | 0.2 | 2% | 13.2 | 13.5 | 0.3 | 2% |
| EB/NB | US-26 | 22.5 | 24.7 | 2.2 | 10% | 22.2 | 27.6 | 5.4 | 24% |
| EB/NB | US-30 | 14.6 | 14.8 | 0.2 | 1% | 14.8 | 14.6 | -0.2 | -1% |
| EB/NB | Barnes Road | 10.5 | 11.5 | 1 | 10% | 10.6 | 11.3 | 0.7 | 7% |
| EB/NB | Cornelius Pass Road | 13.4 | 14.1 | 0.7 | 5% | 13.4 | 14.5 | 1.1 | 8% |

Like the a.m. peak, segments were analyzed according to the Congestion: Travel Time Index. In 2020 about 60% of segments saw no congestion across the p.m. peak while in 2045 about 44% saw no congestion. The largest percentage of congestion was exhibited during the 5-6 p.m. hour in the 2045 No Build Model at 60% of segments showing some form of congestion. Changes in congestion can be seen in Figure 13.

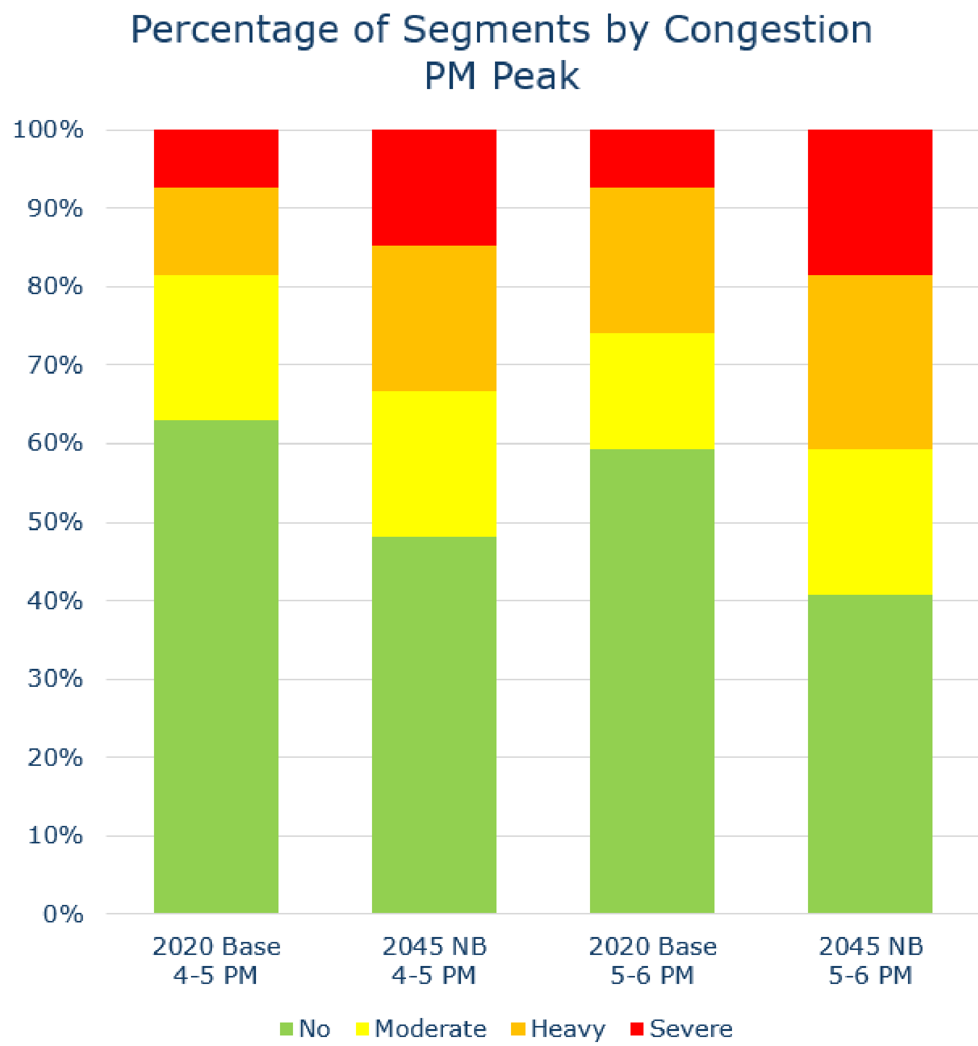



**FIGURE 14: SEGMENTS BY LEVEL OF CONGESTION ACCORDING TO THE ODOT TRAVEL TIME INDEX PM PEAK**

## CONGESTION AND BOTTLENECK LOCATIONS

In addition to examining segment travel times, plots were created showing vehicle speeds at various points along the US-26 corridor.

### WESTBOUND SPEEDS

Congestion can be seen in both the a.m. and the p.m. peak hours from the Murray Blvd on-ramp to the OR-217 off-ramp. Figure 15 and Figure 16 show congestion plots for the 2020 Base Model and the 2045 No Build Model as well as the previously shown INRIX data reflecting recent conditions. The 2045 No Build Model shows worse conditions for this stretch of US-26 for both the a.m. and the p.m. peak hour when compared to the Base Model. In the a.m., speeds reduce significantly on US-26 between Murray Boulevard and OR-217 when compared to the 2020 Base data. In the p.m. the No Build Model shows similar conditions to the INRIX data. The main difference between the p.m. peak No Build and the 2020 INRIX is that congestion in the No Build starts around the Cedar Hills Boulevard on ramp as opposed to around the OR-217 off-ramp.

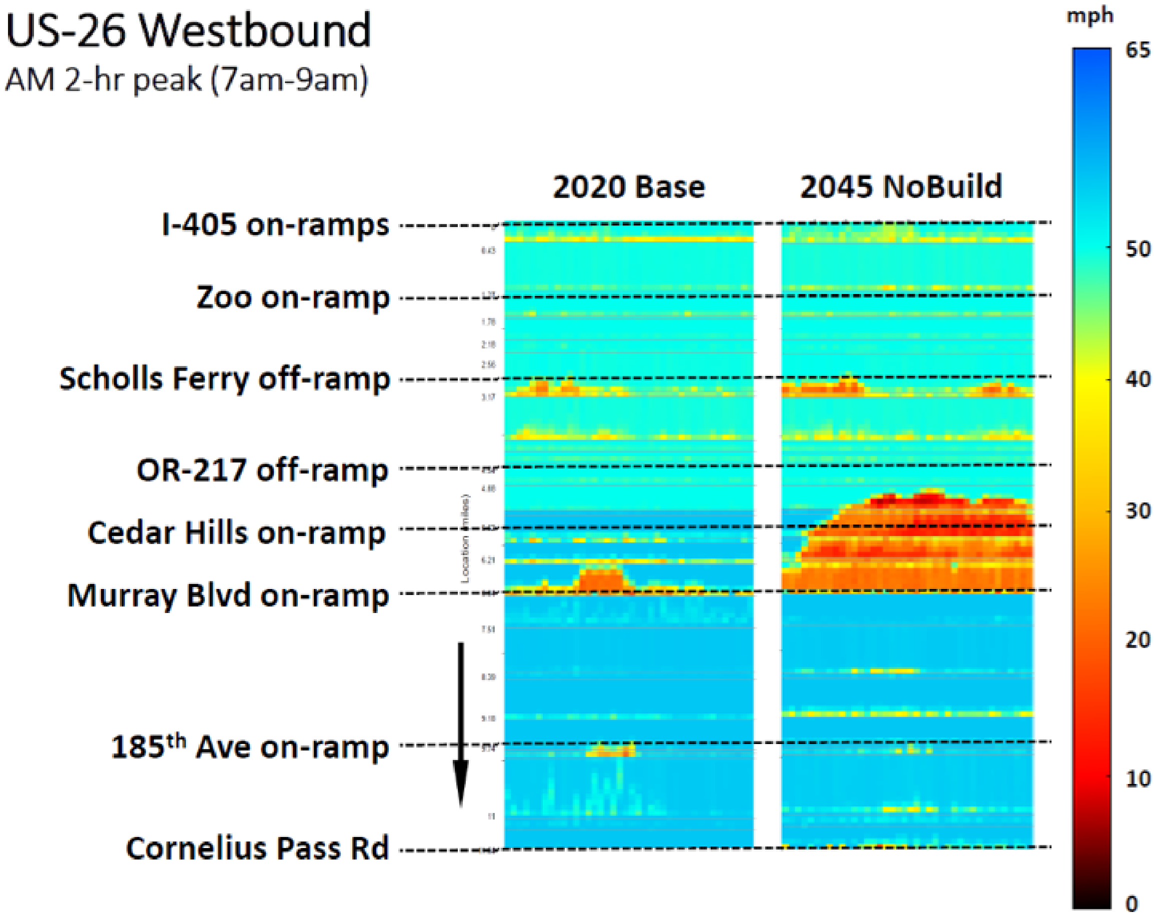



**FIGURE 15: CONGESTION PLOT OF MODELED SPEEDS ALONG US-26 WESTBOUND AM PEAK**

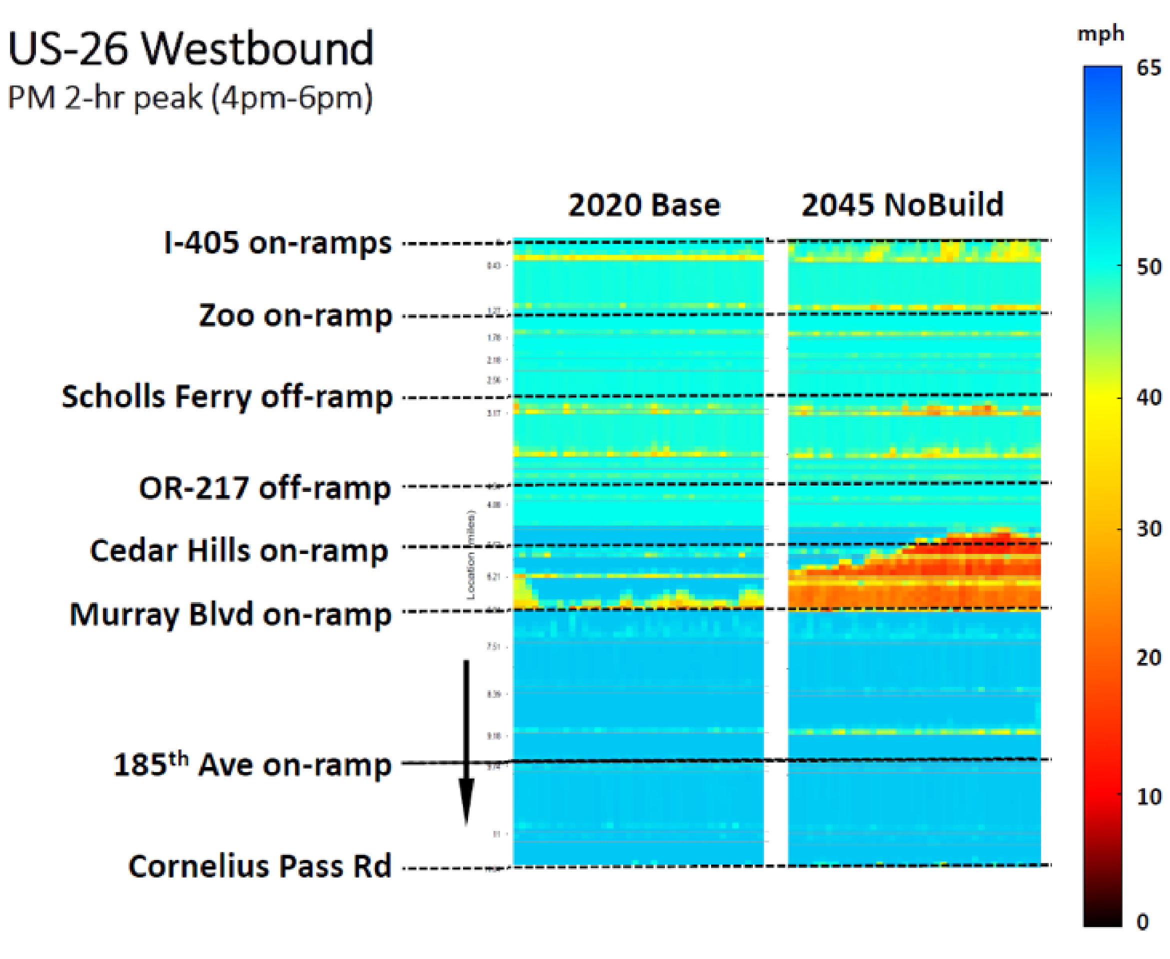



FIGURE 16: CONGESTION PLOT OF MODELED SPEEDS ALONG US-26 WESTBOUND PM PEAK

## EASTBOUND SPEEDS

When compared to westbound congestion during the same period, eastbound congestion is overall worse. Between the a.m. and p.m. peak hour, congestion is worse in the a.m. than it is in the p.m. Congestion in the a.m. builds over multiple hours with congestion extending from the I-405 split to the Murray Boulevard on-ramp. In the p.m., congestion builds from the I-405 split to Scholls Ferry off-ramp. Congestion worsens later in the a.m., around 8:00 a.m., and extends further in the No Build than in the 2020 Base. Congestion plots can be seen in Figure 16 and Figure 17.

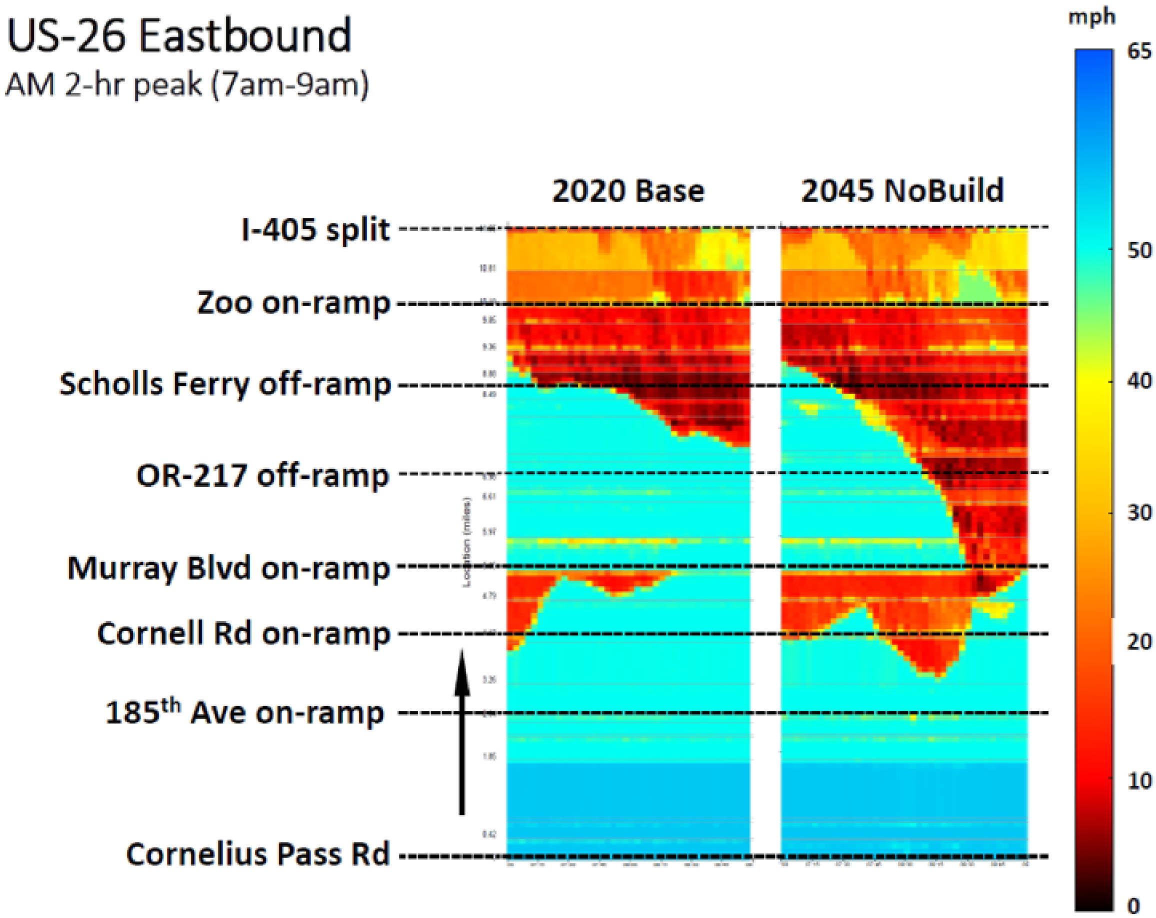



**FIGURE 17: CONGESTION PLOT OF MODELED SPEEDS ALONG US-26 EASTBOUND AM PEAK**

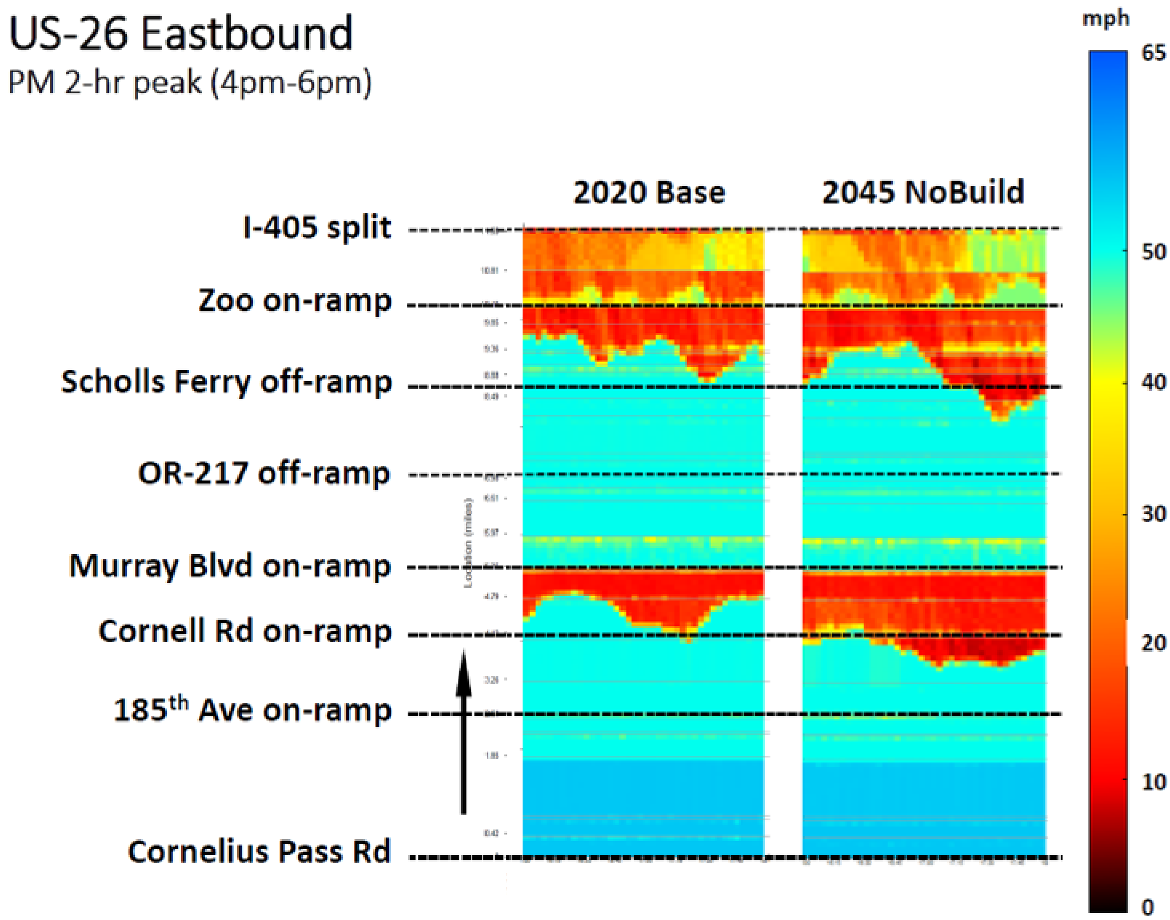



**FIGURE 18: CONGESTION PLOT OF MODELED SPEEDS ALONG US-26 EASTBOUND PM PEAK**

## DIVERSION

While some increase in traffic along parallel routes is to be expected by 2045, increased congestion along US-26 due to increases in traffic volumes has the potential to cause additional diversion to other streets as drivers will choose to take alternate routes to avoid the congestion and save on travel time. In the a.m. peak heading in the eastbound direction along US-30 EB from NW Cornelius Pass Road to NW St Helens Road, between 2020 and 2045 No Build there was a 67% and a 186% increase in travel time for the 7-8 a.m. and 8-9 a.m. hours respectively. There was also an increase in travel time of about 13% heading northbound along Cornelius Pass Road between US-26 and NW Skyline. This could represent drivers diverting from US-26 onto Cornelius Pass Road to get to US-30. Some of this increase could also be representative of an increase in trips for the four-roadway system. There was no significant increase in travel time along US-30 between NW St Helens Road and NW Nicolai Street meaning that drivers choosing to take US-30 as opposed to US-26 might be adding traffic to St Helens Road instead. There are no significant diversion trends seen in westbound traffic during the a.m. peak. Percent changes in travel time can be seen in Figure 18.

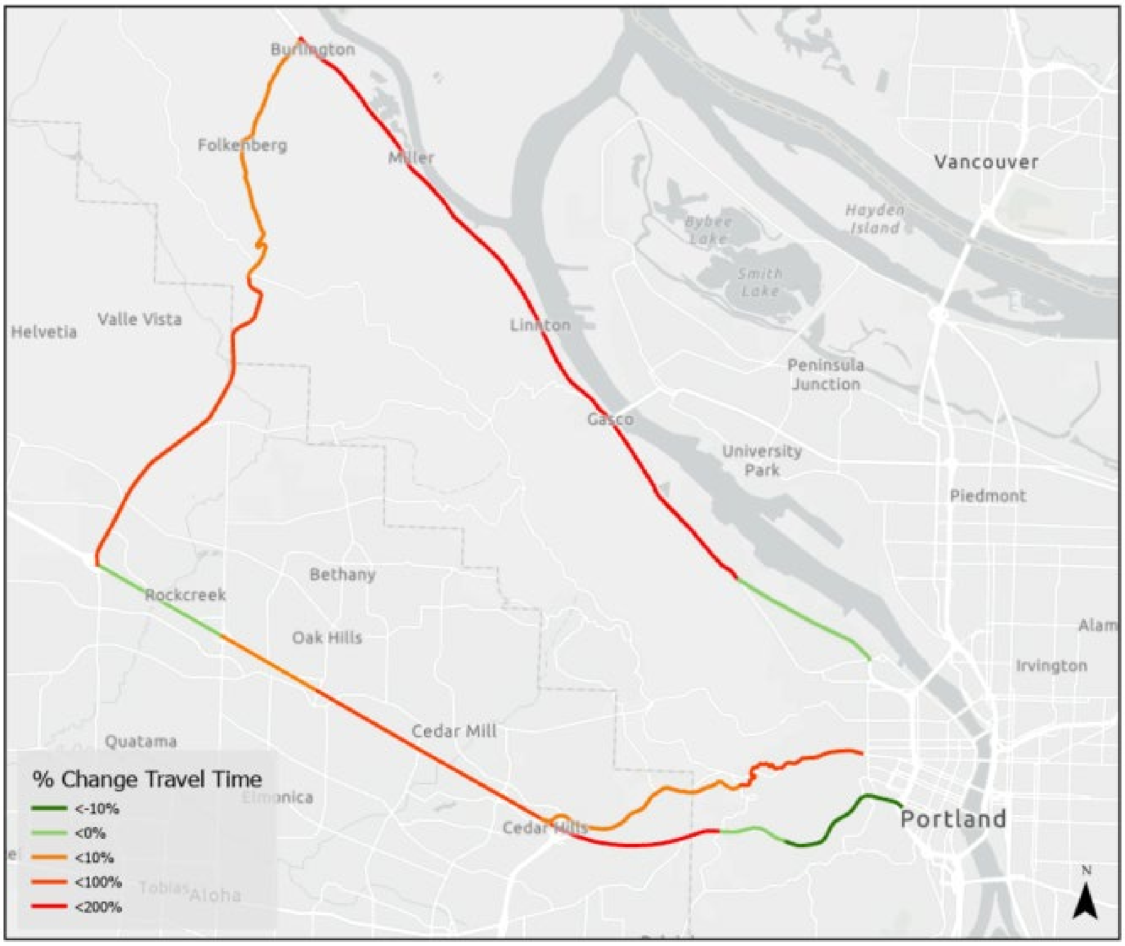



**FIGURE 19: PERCENT CHANGE IN TRAVEL TIME BETWEEN 2020 BASE AND 2045 NO BUILD EASTBOUND AM PEAK (NORTHBOUND CORNELIUS PASS ROAD)**

In the p.m. there are no sizable increases in travel time heading in the eastbound or westbound direction except for increases along US-26. Heading eastbound there is around a 10% increase in travel times along Barnes Road. This travel time increase occurs predominantly between OR-217 and NW Skyline. This could represent individuals diverting from US-26 to take Barnes Road into Portland as opposed to remaining on US-26 which is similar to what can be seen in the a.m. peak in the same direction.

## FUTURE YEAR SCENARIO EVALUATION

### SCENARIO DESCRIPTIONS

Five different build scenarios were developed to test a variety of transportation project themes within the project area using the RTDM:

- Scenario 1 – System Management – Includes projects such as faster transit, transit subsidies, carpooling, biking and ramp meters.

- Scenario 2 – Relatively short-term improvements – More transit, park and rides, minor improvements to US-26 interchanges.
- Scenario 3 – Existing infrastructure improvements - Widen Cornelius Pass Rd, widen US-26, add carpool lane, more overcrossings.
- Scenario 4 – New infrastructure improvements – I-405/US-26 interchange, I-405 exit closures, new MAX tunnel, new Northern Connector and North Willamette bridge.
- Scenario 5 (Tolling Scenario) –Toll lanes on US-26/Hwy 217 to manage congestion.

Of these five scenarios, one was selected for evaluation within the DTA model. Scenario 5 includes tolling on US-26/Hwy 217 to better manage congestion and traffic demand. The following model assumptions were made to implement tolling:

- On-ramp tolls: $0.75 toll per on-ramp from 5am-9pm
- Two US-26 mainline toll locations: US-26 west of OR 217 and west of the Sunset Tunnel
  - Mainline toll is equivalent to the ramp toll ($0.75) during off-peak hours and four-times the ramp toll ($3) during peak hours with a goal to maintain a speed for 45 mph on the freeway during most hours of the day.

Note that pricing implemented for this scenario is meant to test a structure for analysis purposes only. Additional analysis would be needed prior to any implementation of tolling in this corridor .

## SCENARIO RESULTS

### TRAFFIC THROUGHPUT

Traffic volumes along US-26 were produced from the DTA model under Scenario 5. These volumes were compared to the previously documented DTA model volumes for the 2045 No Build Scenario. Applying tolling as defined in Scenario 5 caused an overall decrease in traffic volumes throughout most segments of US-26 during both the a.m. and p.m. peak hour as drivers sought alternate modes or alternate routes to avoid the tolls.

All traffic volumes for both scenarios can be seen in Table 8. Key highlights from the table include:

- In the a.m. peak hour, there was a decrease in traffic along all segments in the westbound direction with the largest decrease occurring from I-405 NB to Baltic Ave.
- There was an increase in traffic volumes from OR-217 to I-405 headed eastbound during the 7-8 a.m. hour and from NW Bethany Boulevard to Scholls Ferry Road headed eastbound during the 8-9 a.m. hour.
- In the p.m. peak hour, all segments except NW Bethany Boulevard to SW Murray Blvd in the eastbound direction saw a decrease in volume during both hours.
  - The largest decrease was seen during the 4-5 p.m. peak hour in the westbound direction especially from I-405 NB to Baltic Ave like in the a.m.

**TABLE 8: COMPARISON OF TRAFFIC VOLUMES BETWEEN THE 2045 NO BUILD SCENARION AND 2045 SCENARIO 5 (TOLLING SCENARIO)**

| | | 2045 NB 7-8 AM | 2045 S5 7-8 AM | Diff NB to S5 | % Diff from NB | 2045 NB 8-9 AM | 2045 S5 8-9 AM | Diff NB to S5 | % Diff from NB |
|---|---|---|---|---|---|---|---|---|---|
| Westbound | I-405 NB to SW Jefferson St | 5928 | 3089 | -2839 | -48% | 5554 | 3197 | -2357 | -42% |
| | SW Jefferson St to SW Zoo Road | 6606 | 3425 | -3181 | -48% | 6449 | 3530 | -2919 | -45% |
| | SW Zoo Road to SW Scholls Ferry Road | 6563 | 3406 | -3157 | -48% | 6367 | 3525 | -2842 | -45% |
| | SW Scholls Ferry Road to SW Baltic Ave | 5601 | 2795 | -2806 | -50% | 5237 | 2886 | -2351 | -45% |
| | SW Cedar Hills Blvd to SW Murray Blvd | 5523 | 4843 | -680 | -12% | 5545 | 4809 | -736 | -13% |
| | SW Murray Blvd to NW Bethany Boulevard / NW Cornell Road | 5473 | 4720 | -753 | -14% | 5420 | 4518 | -902 | -17% |
| | NW Bethany Boulevard / NW Cornell Road to NW 185th Avenue | 5521 | 4657 | -864 | -16% | 5251 | 4379 | -872 | -17% |
| | NW 185th Avenue to NE Cornelius Pass Road (OR-127) | 5019 | 4345 | -674 | -13% | 4905 | 4152 | -753 | -15% |
| | West of NE Cornelius Pass Road (OR-217) | 3459 | 3140 | -319 | -9% | 3458 | 2943 | -515 | -15% |
| Eastbound | West of NE Cornelius Pass Road (OR-217) | 3233 | 2654 | -579 | -18% | 2868 | 2239 | -629 | -22% |
| | NE Cornelius Pass Road (OR-127) to NW 185th Avenue | 3695 | 2763 | -932 | -25% | 3445 | 2474 | -971 | -28% |
| | NW 185th Avenue to NW Bethany Boulevard / NW Cornell Road | 3956 | 3118 | -838 | -21% | 3403 | 3151 | -252 | -7% |
| | NW Bethany Boulevard / NW Cornell Road to SW Murray Blvd | 4201 | 3668 | -533 | -13% | 3607 | 3771 | 164 | 5% |
| | SW Murray Blvd to SW Cedar Hills Blvd | 4304 | 3567 | -737 | -17% | 3435 | 3435 | 0 | 0% |
| | SW Cedar Hills Blvd to OR-217 | 4976 | 4191 | -785 | -16% | 3943 | 4258 | 315 | 8% |
| | OR-217 to SW Scholls Ferry Road | 3875 | 3956 | 81 | 2% | 3219 | 4046 | 827 | 26% |
| | SW Scholls Ferry Road to SW Zoo Road | 3202 | 3740 | 538 | 17% | 4243 | 3774 | -469 | -11% |
| | SW Zoo Road to SW Jefferson St | 3961 | 4169 | 208 | 5% | 5145 | 3885 | -1260 | -24% |
| | SW Jefferson St to I-405 / SW Market St | 3914 | 3983 | 69 | 2% | 4433 | 3532 | -901 | -20% |

| Direction | Segment | 2045 NB 4-5 PM | 2045 S5 4-5 PM | Diff NB to S5 | % Diff from NB | 2045 NB 5-6 PM | 2045 S5 5-6 PM | Diff NB to S5 | % Diff from NB |
|---|---|---|---|---|---|---|---|---|---|
| Westbound | I-405 NB to SW Jefferson St | 5923 | 3067 | -2856 | -48% | 5885 | 3602 | -2283 | -39% |
| | SW Jefferson St to SW Zoo Road | 6770 | 3530 | -3240 | -48% | 6734 | 4133 | -2601 | -39% |
| | SW Zoo Road to SW Scholls Ferry Road | 6700 | 3508 | -3192 | -48% | 6646 | 4150 | -2496 | -38% |
| | SW Scholls Ferry Road to SW Baltic Ave | 5318 | 2637 | -2681 | -50% | 5580 | 3162 | -2418 | -43% |
| | SW Cedar Hills Blvd to SW Murray Blvd | 6011 | 4266 | -1745 | -29% | 5942 | 5189 | -753 | -13% |
| | SW Murray Blvd to NW Bethany Boulevard / NW Cornell Road | 5413 | 3922 | -1491 | -28% | 5467 | 4644 | -823 | -15% |
| | NW Bethany Boulevard / NW Cornell Road to NW 185th Avenue | 4638 | 3396 | -1242 | -27% | 4946 | 4049 | -897 | -18% |
| | NW 185th Avenue to NE Cornelius Pass Road (OR-127) | 3856 | 3028 | -828 | -21% | 3859 | 3232 | -627 | -16% |
| | West of NE Cornelius Pass Road (OR-217) | 2703 | 2251 | -452 | -17% | 2797 | 2470 | -327 | -12% |
| Eastbound | West of NE Cornelius Pass Road (OR-217) | 2892 | 1960 | -932 | -32% | 2715 | 2159 | -556 | -20% |
| | NE Cornelius Pass Road (OR-127) to NW 185th Avenue | 4099 | 2912 | -1187 | -29% | 3826 | 3114 | -712 | -19% |
| | NW 185th Avenue to NW Bethany Boulevard / NW Cornell Road | 4285 | 3316 | -969 | -23% | 3628 | 3410 | -218 | -6% |
| | NW Bethany Boulevard / NW Cornell Road to SW Murray Blvd | 4419 | 3725 | -694 | -16% | 3881 | 3972 | 91 | 2% |
| | SW Murray Blvd to SW Cedar Hills Blvd | 4496 | 3232 | -1264 | -28% | 4471 | 3542 | -929 | -21% |
| | SW Cedar Hills Blvd to OR-217 | 4947 | 3535 | -1412 | -29% | 4957 | 3930 | -1027 | -21% |
| | OR-217 to SW Scholls Ferry Road | 4513 | 2889 | -1624 | -36% | 4499 | 3170 | -1329 | -30% |
| | SW Scholls Ferry Road to SW Zoo Road | 4047 | 2549 | -1498 | -37% | 4497 | 3051 | -1446 | -32% |
| | SW Zoo Road to SW Jefferson St | 4623 | 2897 | -1726 | -37% | 5340 | 3335 | -2005 | -38% |
| | SW Jefferson St to I-405 / SW Market St | 4200 | 2808 | -1392 | -33% | 5037 | 3222 | -1815 | -36% |

### DIVERSION

Under Scenario 5 conditions, there is significantly less traffic volume along US-26. While some drivers choose to use other modes of travel, other drivers divert to parallel routes. An example of this is shown in Figure 19, which depicts percent change in travel time for westbound (southbound Cornelius Pass Road).

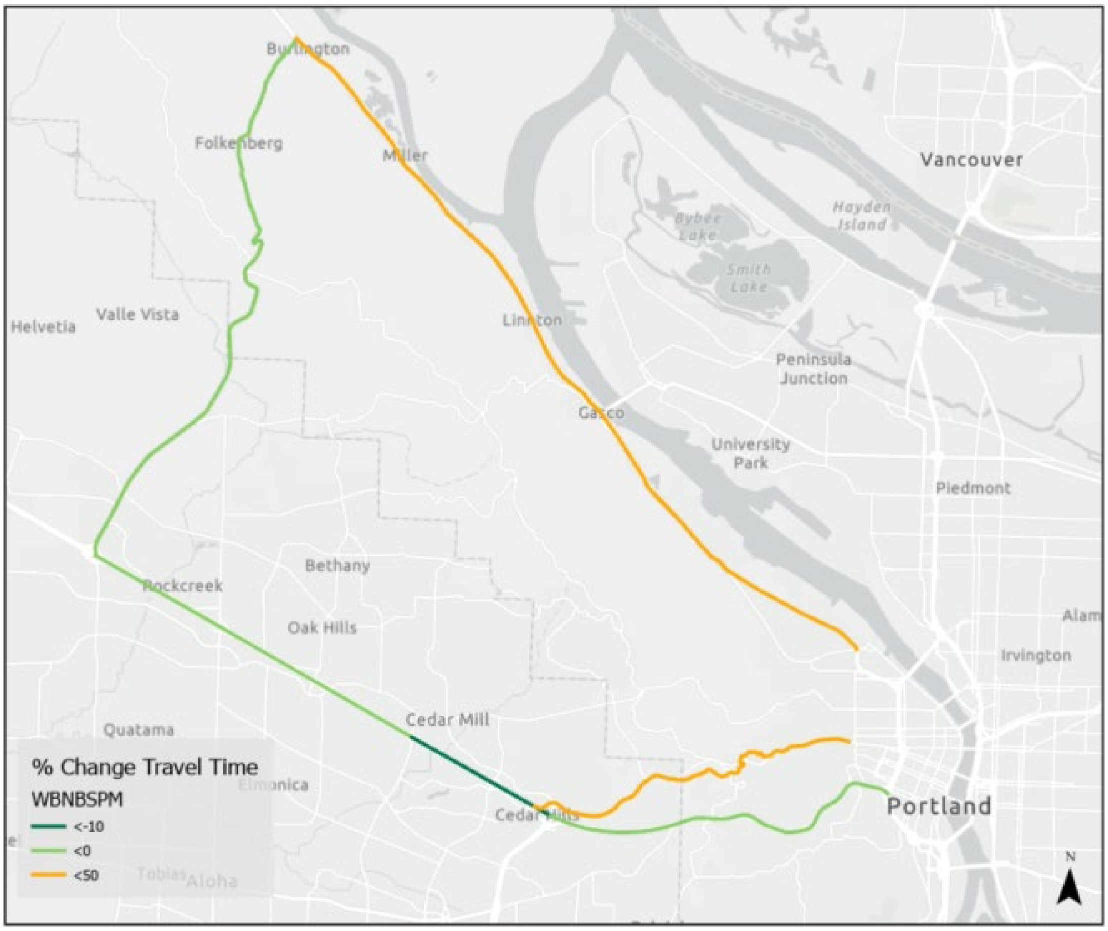



**FIGURE 20: PERCENT CHANGE IN TRAVEL TIME BETWEEN 2045 BASE AND 2045 SCENARIO 5 CONDITIONS WESTBOUND IN THE PM (SOUTHBOUND CORNELIUS PASS ROAD)**

When compared to the 2045 Base Scenario results, there is an increase in travel time:

- Along Cornelius Pass Road headed northbound from US-26 to US-30 during the a.m. peak.
- Along Barnes Road headed westbound from Downtown Portland to US-26 during the a.m. and the p.m. peak as well as eastbound during the p.m. peak.
  - The increase in travel time along Barnes Road could represent an increase in vehicles using Barnes Road for westbound travel out of Portland, for a longer stretch than they did previously.
- Northbound on Cornelius Pass Road in both the a.m. and p.m. peak
- Westbound on OR-30 during the p.m. peak.

- This could represent trips being diverted to side streets to get to both US-30 and Cornelius Pass Road (e.g. Skyline Boulevard).

## TRAVEL TIMES

The average travel times for four roadways (US-26, US-30, Barnes Road, and Cornelius Pass Road) were compared between the 2045 No Build and the 2045 Scenario 5 model for both the a.m. and p.m. peaks. 2045 No Build travel times are the same as those discussed in Table 6 and Table 7. New travel times were determined for the same set of segments as displayed previously in Figure 12.

### A.M. Peak

During the a.m. peak, there is an overall decrease in travel time along US-26 in both directions. In the westbound direction, there is an increase in travel time along US-30 and Barnes Road, and no real change along Cornelius Pass Road. In the eastbound direction, there is a decrease in travel time along US-30 and Barnes Road, but an increase in travel time along Cornelius Pass Road.

**TABLE 9: COMPARISON OF TRAVEL TIMES (MINUTES) BETWEEN SCENARIO 5 AND THE NO BUILD AM PEAK**

| | | 2045 NB 7-8 AM | 2045 S5 7-8 AM | Diff NB to S5 | % Diff from NB | 2045 NB 8-9 AM | 2045 S5 8-9 AM | Diff NB to S5 | % Diff from NB |
|---|---|---|---|---|---|---|---|---|---|
| WB/SB | US-26 | 17.5 | 13.6 | -3.9 | -22% | 18.5 | 13.6 | -4.9 | -26% |
| WB/SB | US-30 | 14.8 | 15.4 | 0.6 | 4% | 14.6 | 17.0 | 2.4 | 16% |
| WB/SB | Barnes Road | 10.4 | 11.6 | 1.2 | 12% | 10.4 | 11.4 | 0.9 | 9% |
| WB/SB | Cornelius Pass Road | 13.4 | 13.4 | 0.0 | 0% | 13.4 | 13.3 | -0.1 | -1% |
| EB/NB | US-26 | 33.0 | 14.6 | -18.4 | -56% | 43.7 | 18.1 | -25.6 | -58% |
| EB/NB | US-30 | 22.6 | 15.2 | -7.4 | -33% | 36.5 | 14.9 | -21.6 | -59% |
| EB/NB | Barnes Road | 16.7 | 13.8 | -2.9 | -17% | 23.6 | 18.3 | -5.3 | -22% |
| EB/NB | Cornelius Pass Road | 14.8 | 15.0 | 0.3 | 2% | 15.7 | 19.7 | 4.0 | 26% |

Though there is an increase in travel time along some of these corridors, there is an overall decrease in congestion throughout the whole system. Under the Scenario 5 conditions, the percentage of congested segments drops from about 65% to 35%. Changes can be seen in Figure 20.

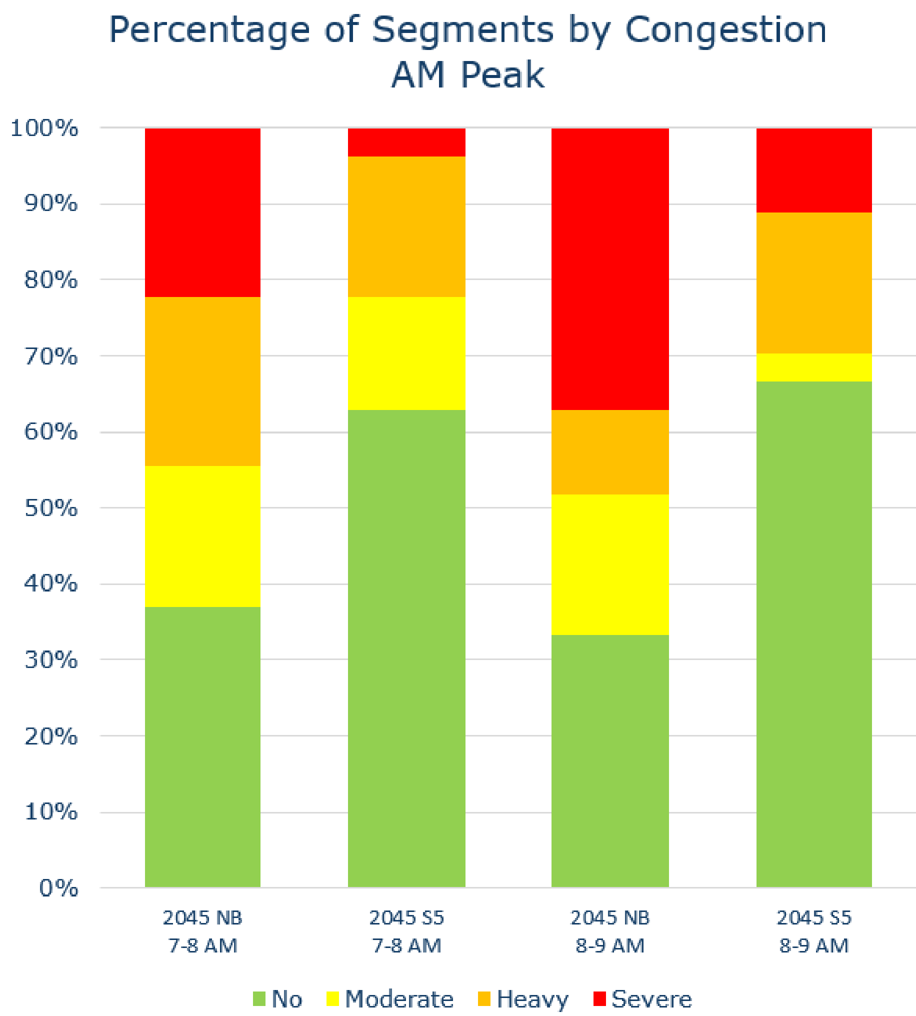



**FIGURE 21: SEGMENTS BY LEVEL OF CONGESTION ACCORDING TO THE ODOT TRAVEL TIME INDEX AM PEAK**

### P.M. Peak

During the p.m. peak, there is a similar trend to the a.m. peak in that there is an overall decrease in travel time along US-26, but an increase in travel time along other segments. Travel time headed eastbound on US-26 decreased the most. The largest increase in travel time occurred along Barnes Road heading westbound. There was also an increase in travel time heading northbound along Cornelius Pass Road. Changes in travel time during the p.m. peak hour can be seen in Table 10.

**TABLE 10: COMPARISON OF TRAVEL TIMES (MINUTES) BETWEEN SCENARIO 5 AND THE NO BUILD PM PEAK**

| | | 2045 NB 4-5 PM | 2045 S5 4-5 PM | Diff NB to S5 | % Diff from NB | 2045 NB 5-6 PM | 2045 S5 5-6 PM | Diff NB to S5 | % Diff from NB |
|---|---|---|---|---|---|---|---|---|---|
| WB/SB | US-26 | 15.3 | 13.5 | -1.8 | -12% | 17.0 | 13.6 | -3.4 | -20% |
| | US-30 | 14.6 | 14.8 | 0.2 | 1% | 14.4 | 14.5 | 0.1 | 1% |
| | Barnes Road | 10.4 | 10.9 | 0.5 | 5% | 10.7 | 11.9 | 1.2 | 12% |
| | Cornelius Pass Road | 13.5 | 13.5 | 0.0 | 0% | 13.5 | 13.5 | 0.0 | 0% |
| EB/NB | US-26 | 24.7 | 14.1 | -10.6 | -43% | 27.6 | 14.2 | -13.4 | -49% |
| | US-30 | 14.8 | 14.8 | 0.0 | 0% | 14.6 | 14.6 | 0.0 | 0% |
| | Barnes Road | 11.5 | 11.7 | 0.1 | 1% | 11.3 | 11.7 | 0.5 | 4% |
| | Cornelius Pass Road | 14.1 | 14.2 | 0.1 | 1% | 14.5 | 15.6 | 1.1 | 8% |

Similar to the a.m. peak, even though there are increases in travel time along other segments, there is an overall decrease in congestion in the whole system. Congestion in the p.m. decreased from 56% of segments experiencing congestion to around 30% of segments experiencing congestion under Scenario 5. Under Scenario 5 conditions there are also no segments experiencing severe congestion.

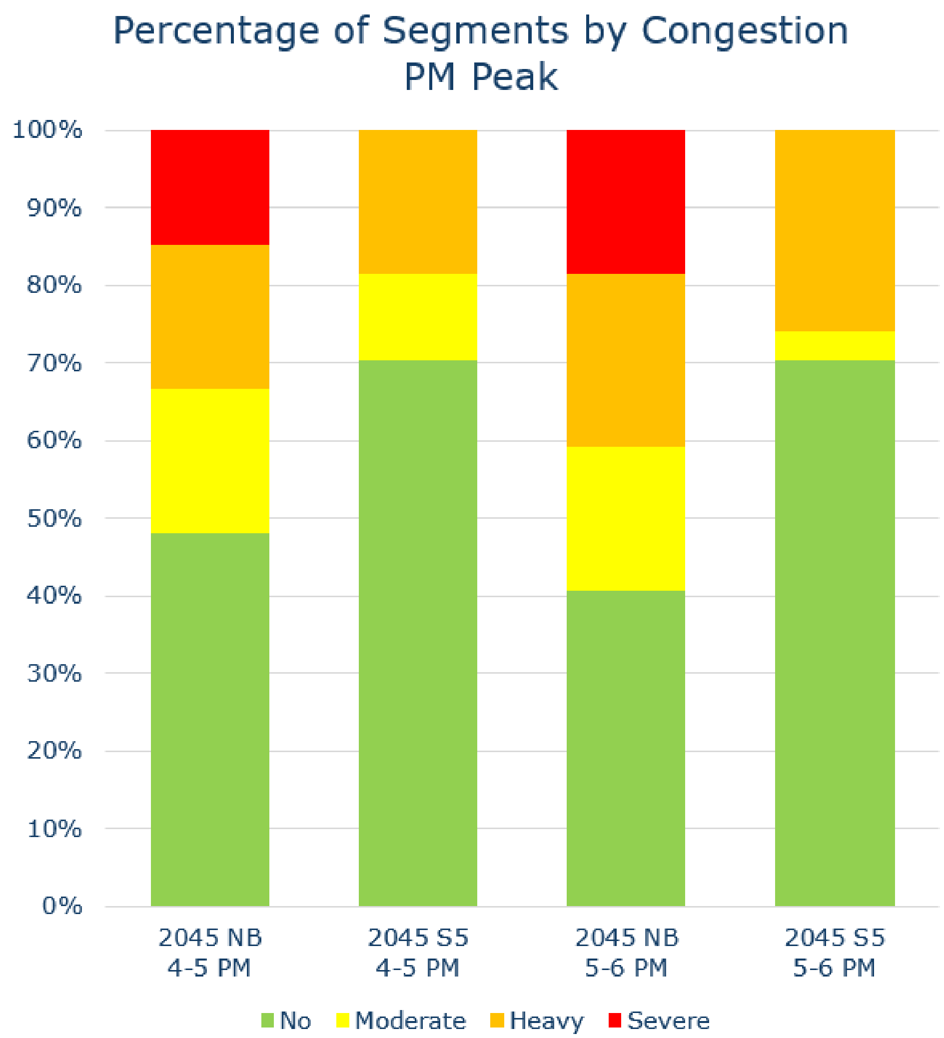
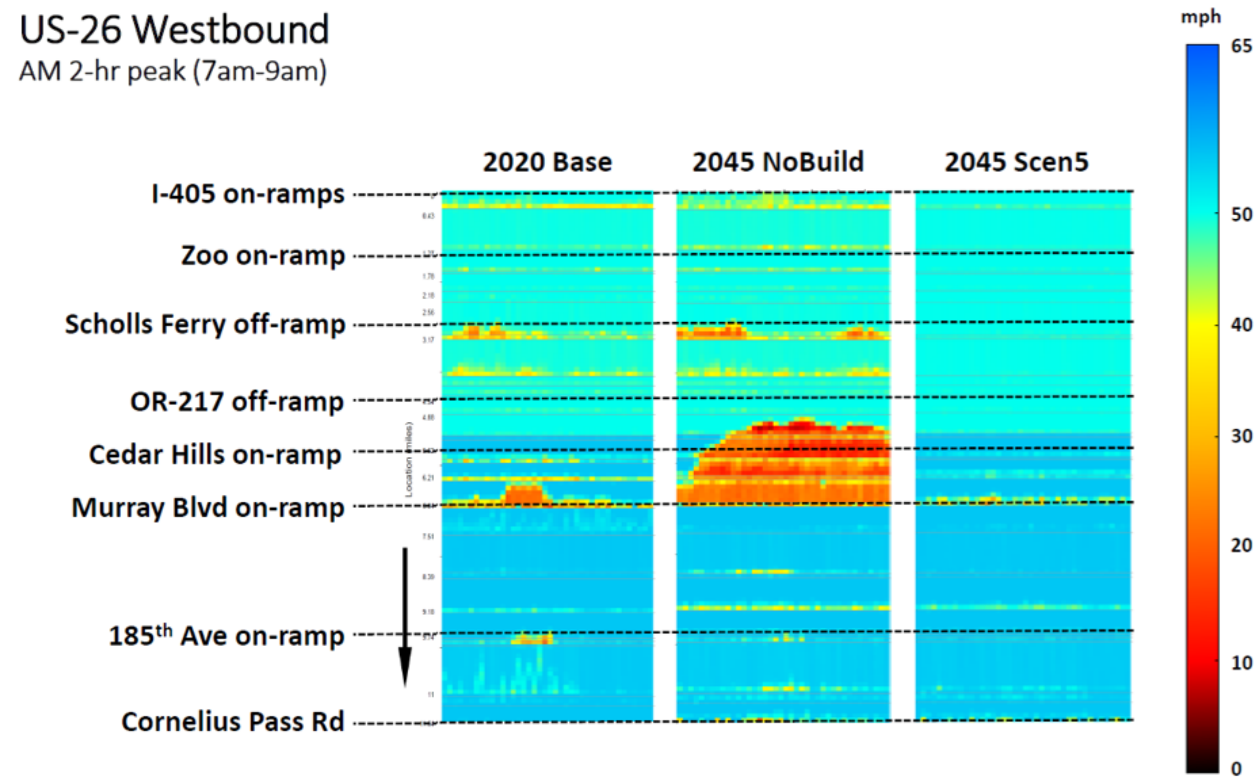



**FIGURE 22: SEGMENTS BY LEVEL OF CONGESTION ACCORDING TO THE ODOT TRAVEL TIME INDEX PM PEAK**

## CONGESTION AND BOTTLENECK LOCATIONS

### Westbound Speeds

Under Scenario 5, there is a significant decrease in congestion compared to the 2045 No Build Scenario in the westbound direction as shown in Figure 22. In addition, speeds along US-26 improve compared to existing conditions as the traffic demand on US-26 is maintained below breakdown capacity.



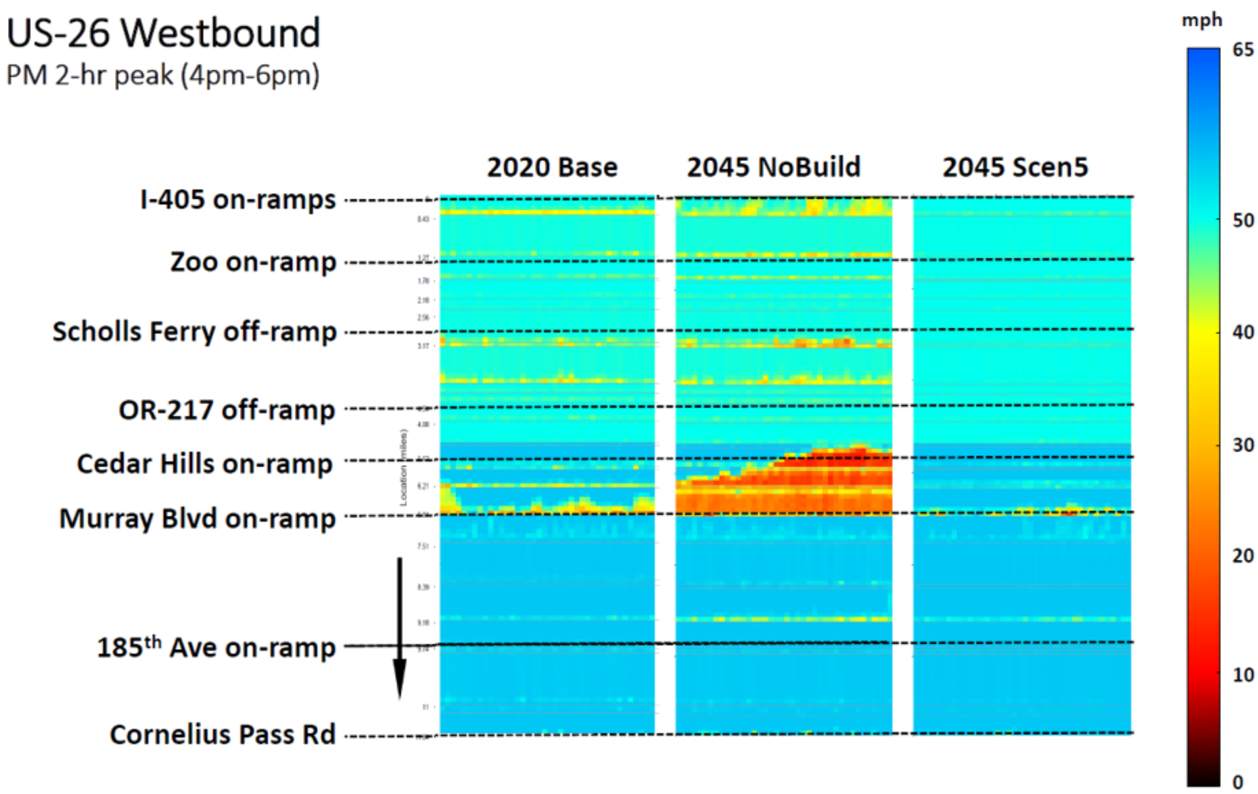
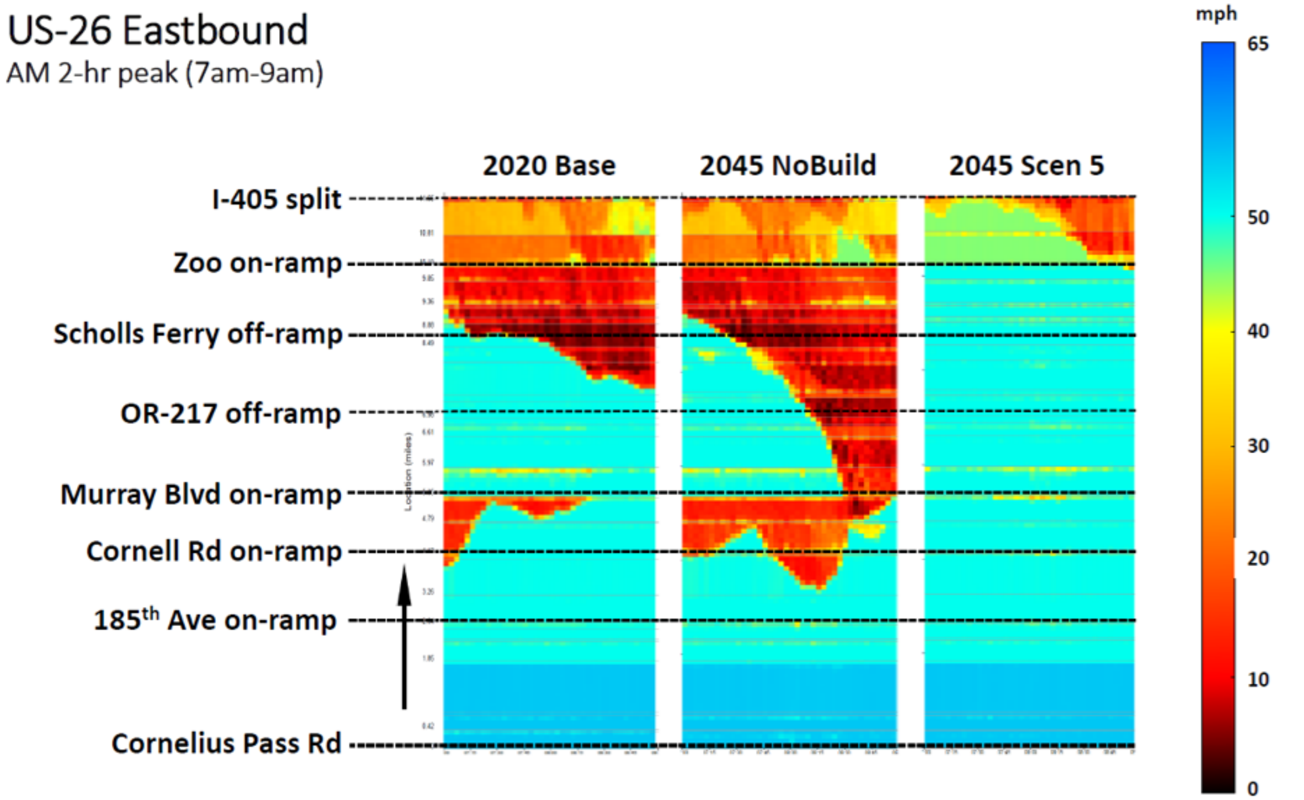




**FIGURE 23: WESTBOUND CONGESTION PLOTS 2045 SCENARIO 5**

### Eastbound Speeds

Under Scenario 5, eastbound congestion is significantly reduced compared to the 2020 Base and 2045 No Build scenario, although there is more congestion in the eastbound direction than there is in the westbound direction in Scenario 5 in both the a.m. and p.m. peak hours. Scenario 5 still shows significant congestion from the I-405 Split to the Zoo Ramp in the a.m. peak hour as well as some congestion over that same stretch in the p.m. peak hour but congestion significantly improvements compared to the 2045 No Build Scenario.



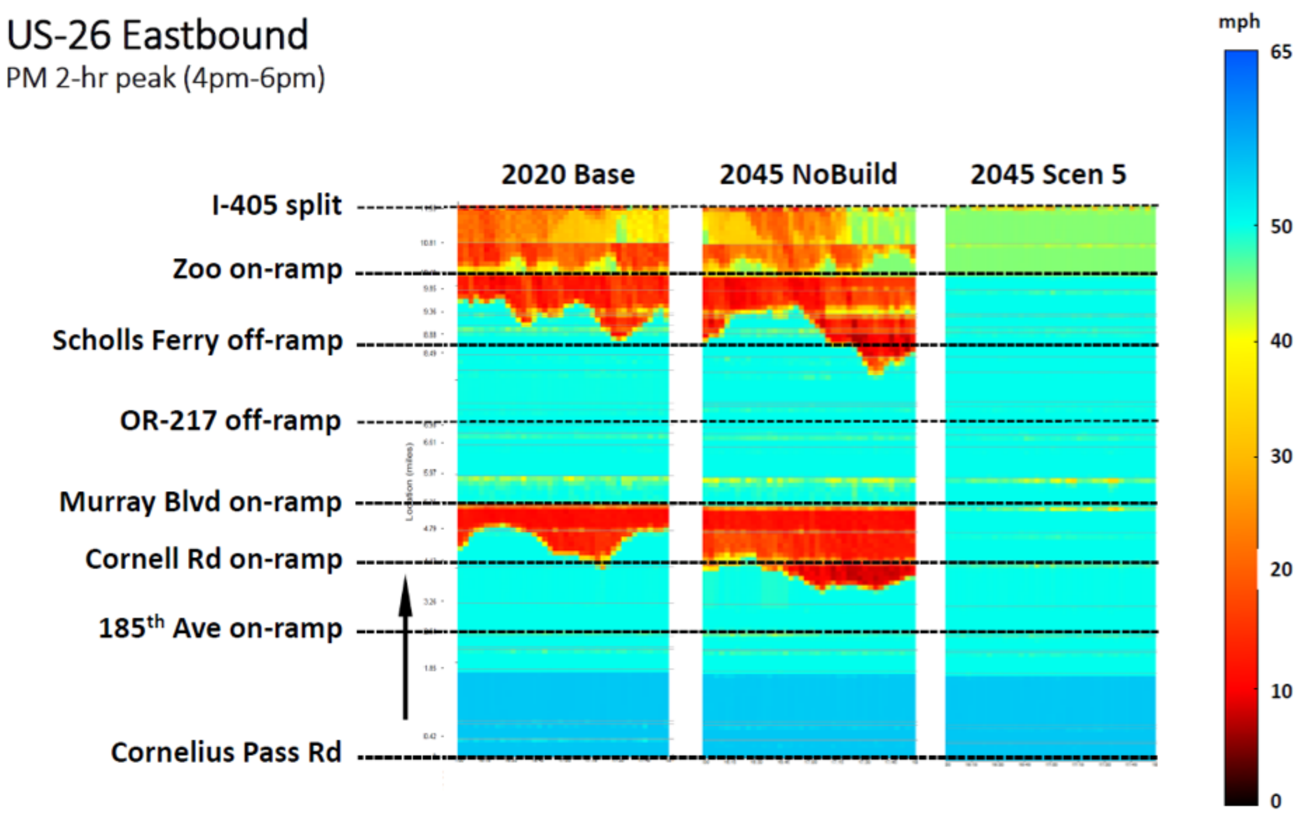




**FIGURE 24: EASTBOUND CONGESTION PLOTS 2045 SCENARIO 5**

## SUMMARY OF FINDINGS

The following summarizes key findings from the DTA analysis for the WMIS:

- Given the limited available data, the DTA model provides a reasonable calibration of the US-26 corridor given the focus of the supplemental DTA analysis:
  - Most hours of analysis show a very high level of fit between model throughput and balanced traffic volumes, with R-squared values > .90 and slopes between 0.94 and 1.00.
    - The exception is the 7-8 a.m. hour, in which the R-squared is a marginal .73 and a slope of 0.90.
  - The large majority (approximately 65-70 percent) of the travel time segments along US-26 and US-30 fall within the ODOT APM criteria for calibration of microsimulation models, which generally require a more stringent calibration than travel demand models.
- Future congestion is expected to significantly increase along the US-26 corridor, with the DTA model showing congestion extending:
  - Westbound from Murray Blvd to Cedar Hills Boulevard (a.m. peak) and OR-217 (p.m. peak)
  - Eastbound in the a.m. peak from I-405 split to Cornell Road.
  - Eastbound in the p.m. peak from I-405 split to Scholls Ferry Road and from Murray Boulevard to beyond Cornell Road.
- Scenario 5 (Tolling Scenario) shows benefits for managing congestion and improving travel times on US-26.
  - Travel times significantly improve on US-26 with tolling:
    - 20-30% more US-26 segments have no congestion in the a.m. and p.m. peak with tolling implemented.
    - Approximately 20% fewer US-26 segments have severe congestion in the a.m. peak and no segments (15-20% fewer) have severe congestion in the p.m. peak with tolling.
  - However, there is more traffic volume and an increase in travel time on parallel facilities to US-26.
  - Significantly more analysis must be done to understand the impact of tolling.
- The DTA model was developed and validated for this project with a focus on the US-26 mainline corridor but can be used as a tool for future analysis needs.
  - Additional calibration/validation would be needed for evaluation of areas outside the US-26 study corridor.
  - Additional calibration/validation would be needed to evaluate detailed or smaller scale project changes (e.g. intersection improvements or changes to on-ramp or off-ramp lane configurations).
  - A larger network could also be added to the model in the future to support additional analysis (e.g., adding more network on the east end to further test improvement options for the I-405 split).

# APPENDIX

1050 SW 6TH AVENUE, SUITE 600 • PORTLAND, OR 97204 • 503.243.3500 • DKSASSOCIATES.COM

# CONTENTS

# APPENDIX A

## TRAFFIC PARAMETER ADJUSTMENTS

**TABLE 1. LIST OF LINKS IN WMIS DTA REQUIRING AN ADJUSTMENT AS PART OF 2020 BASE YEAR NETWORK CALIBRATION.**

| Link ID | Start Node | End Node | Response Time Factor | Length Factor | Free Flow Speed | Link ID | Start Node | End Node | Response Time Factor | Length Factor | Free Flow Speed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 589 | 55845 | -- | 1.3 | 50 | 16826 | 56328 | 54401 | -- | 1.3 | -- |
| 2 | 590 | 10051 | -- | 1.3 | 50 | 16896 | 55951 | 58070 | -- | 1.3 | -- |
| 3 | 591 | 57705 | 1.5 | 1.3 | 50 | 17033 | 60636 | 7894 | 1.2 | 1.3 | 50 |
| 4 | 592 | 593 | -- | 1.3 | 50 | 17293 | 57705 | 59573 | -- | 1.3 | 50 |
| 5 | 593 | 59181 | -- | 1.3 | 50 | 17311 | 59581 | 594 | 1.2 | 1.3 | 50 |
| 6 | 594 | 60636 | -- | 1.1 | 50 | 17315 | 60621 | 59659 | -- | 1.1 | 50 |
| 7 | 56458 | 595 | 1.1 | 1.3 | -- | 17375 | 595 | 55951 | -- | 1.3 | -- |
| 26 | 57091 | 57092 | -- | 1.3 | 50 | 17561 | 52925 | 80020 | -- | 1.3 | 50 |
| 30 | 58070 | 58297 | -- | 1.3 | -- | 17600 | 59427 | 8185 | -- | 1.3 | -- |
| 6472 | 54988 | 589 | 1.2 | 1.3 | 50 | 17738 | 55845 | 59246 | -- | 1.3 | 50 |
| 6638 | 57092 | 58825 | -- | 1.3 | 50 | 17766 | 59498 | 59962 | -- | 1.1 | 50 |
| 9934 | 58163 | 58862 | 2 | -- | -- | 17857 | 54419 | 55892 | -- | 1.1 | 50 |
| 9935 | 58862 | 58163 | 2 | -- | -- | 17860 | 58825 | 80116 | -- | 1.3 | 50 |
| 10329 | 59675 | 56645 | 1.1 | -- | -- | 17996 | 58297 | 8410 | -- | 1.3 | -- |
| 10379 | 59962 | 56439 | 1.1 | 1.3 | 50 | 17998 | 56439 | 54419 | -- | 1.1 | 50 |
| 12114 | 57519 | 9359 | 1.2 | 1.3 | 50 | 18004 | 53265 | 59498 | -- | 1.1 | 50 |
| 12118 | 55105 | 59675 | 1.2 | -- | -- | 18007 | 58404 | 53265 | 1.1 | 1.1 | 50 |
| 12340 | 80078 | 9708 | -- | 1.3 | 50 | 18015 | 59659 | 7708 | 1.2 | 1.3 | 45 |
| 12361 | 56681 | 60648 | 1.1 | -- | 45 | 18018 | 80116 | 57519 | -- | 1.3 | 50 |
| 12389 | 54401 | 9729 | 1.1 | 1.3 | 55 | 18785 | 54578 | 56458 | -- | 1.3 | -- |
| 12760 | 53297 | 9891 | 1.2 | 1.3 | 55 | 23775 | 54516 | 59992 | 2 | -- | 30 |
| 13101 | 56928 | 56927 | 1.1 | 1.3 | 50 | 23776 | 59992 | 54516 | 2 | -- | 30 |
| 13192 | 52992 | 10053 | 1.25 | 1.3 | -- | 26256 | 56567 | 60792 | -- | 1.5 | -- |
| 16412 | 80020 | 591 | 1.5 | 1.3 | 50 | 26257 | 8440 | 56567 | -- | 1.5 | -- |
| 16438 | 59181 | 59581 | -- | 1.1 | 50 | 39795 | 7655 | 54988 | -- | 1.3 | 50 |
| 16476 | 53616 | 592 | 1.2 | 1.3 | 50 | 39848 | 7708 | 54046 | -- | 1.1 | 45 |
| 16489 | 55892 | 80078 | -- | 1.1 | 50 | 39900 | 7760 | 56414 | -- | 1.3 | -- |
| 16493 | 56927 | 53616 | -- | 1.3 | 50 | 40034 | 7894 | 60621 | -- | 1.1 | 50 |
| 16504 | 59573 | 56928 | 1.1 | 1.3 | 50 | 40325 | 8185 | 53297 | -- | 1.3 | -- |
| 16546 | 54317 | 59427 | -- | 1.3 | -- | 40550 | 8410 | 55337 | -- | 1.3 | -- |
| 16613 | 57220 | 7655 | 1.1 | 1.3 | 50 | 40580 | 60792 | 8440 | -- | 1.5 | -- |
| 16651 | 55337 | 56328 | -- | 1.3 | -- | 41499 | 9359 | 56572 | -- | 1.3 | -- |
| 16728 | 56928 | 55105 | 1.2 | -- | 45 | 41848 | 9708 | 57091 | -- | 1.3 | 50 |
| 16760 | 52521 | 57220 | -- | 1.3 | 50 | 42031 | 9891 | 52521 | -- | 1.3 | -- |
| 16783 | 56414 | 52992 | -- | 1.3 | -- | 42191 | 59246 | 590 | 1.2 | 1.3 | 50 |
| 16806 | 56572 | 7760 | 1.1 | 1.3 | -- | 42193 | 10053 | 54578 | -- | 1.3 | -- |

**Note: a value of '--' indicates that no change was made to the default value. These adjustments were reflected in the 2045 model network as well.*

Most of the links within Table 1 above are along US 26 from OR 127 to I 405 shown in Figure 25 below. Links along US 26 were changed in both the eastbound and the westbound directions. In addition to the US 26 link changes, there were four other areas of change:

- The US 26 off ramp onto OR 217
- A portion of Skyline Blvd in Sylvan Heights
- SW Canyon Rd near the Oregon Zoo
- SW Canyon Ct between SW Westgate Drive and SW Canyon Rd

The four areas of change are highlighted within the callouts in the map below.

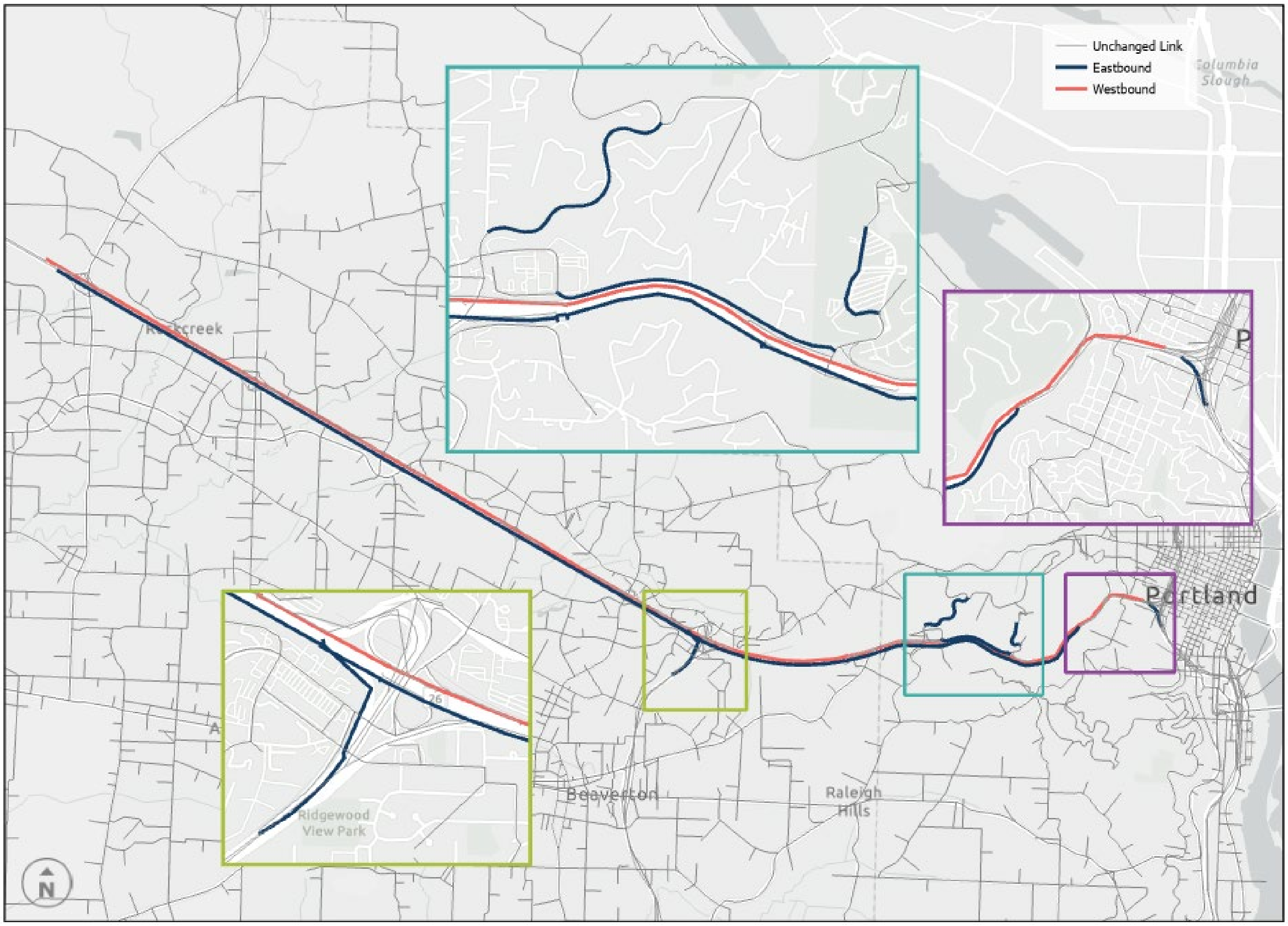



**FIGURE 25. MAP OF ADJUSTED LINKS IN THE DTA MODEL**

# Attachment Y I-205 Toll Project Modeling Methodology and Assumptions for EA

# I-205 Toll Project

| | |
|---|---|
| **Date** | February 3, 2023 |
| **To** | ODOT I-205 Toll Project Team |
| **From** | WSP I-205 Toll Project Team |
| **Subject** | Modeling Methodology and Assumptions for EA |
| **CC** | Portland Metro Modeling Team |

## CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

## ACRONYMS AND ABBREVIATIONS

| Acronym/Abbreviation | Definition |
|---|---|
| API | area of potential impact |
| APM | Analysis Procedure Manual |
| ATR | automatic traffic recorder |
| DTA | dynamic traffic assignment |
| EA | environmental assessment |
| EB | eastbound |
| HCM | Highway Capacity Manual |
| HCS7 | Highway Capacity Software version 7 |
| HDM6 | Highway Design Manual |
| I-205 | Interstate 205 |
| I-5 | Interstate 5 |
| LOS | level of service |
| LTS | level of traffic stress |
| MMLOS | multimodal level of service |
| mph | miles per hour |
| N/A | not applicable |
| NB | northbound |
| NCHRP | National Cooperative Highway Research Program |
| OD | origin-destination |
| ODOT | Oregon Department of Transportation |
| OR | Oregon Route |
| RTDM | regional travel demand model |
| SB | southbound |
| VHT | vehicle-hours traveled |
| VMT | vehicle-miles traveled |

## SUMMARY

### Purpose of Modeling Tools

The Environmental Assessment analysis for the I-205 Toll Project evaluates project alternatives using a variety of models to calculate estimates of measures quantifying potential project impacts. At the outset of this process, evaluation metrics developed to compare conditions within the area of potential impact (API) between the Build Alternative (with the project) and the No Build Alternative (without the project). For the I-205 Toll Project, the primary metrics used to assess project effects are summarized in Table 1. These metrics were developed to evaluate the ability of the project to achieve the goals and objectives that support the project's purpose and need and are discussed in more detail in the *Introduction Section* of this Memo.

**Table 1. Primary Performance Metrics for the I-205 Toll Project**

| Performance Measures | Scenario/Time Periods | Analysis Tool Selected for Assessment of Measure |
|---|---|---|
| Determine Area of Potential Impact (API) | NA | • Regional travel demand model |
| Traffic Analysis Metrics | | |
| • Peak hour change in traffic volumes and diversion to alternative routes | • a.m. and p.m. peak hour | • DTA model |
| • Daily change in traffic volumes and diversion to alternative routes | • Daily | • Regional travel demand model |
| Intersection Operations:<br>• Volume-to-capacity (v/c) ratios<br>• Delay<br>• Level of service (LOS)<br>• Queuing | • a.m. and p.m. peak hour | • Synchro/SimTraffic |
| • Peak Hour API Travel Times | • a.m. and p.m. peak hour | • DTA model |
| • Travel time reliability on I-205 | • a.m. and p.m. peak hour | • Travel time reliability: Regional Integrated Transportation Information System (RITIS) for existing conditions.<br>• DTA model for future conditions |
| • Hours of congestion on I-205 | • Daily | • Regional travel demand model |
| • Vehicle-miles traveled (VMT) within the API for freeway and non-freeway facilities | • Daily | • Regional travel demand model |
| • Vehicle-hours traveled (VHT) within the API for freeway and non-freeway facilities | • Daily | • Regional travel demand model |
| Multimodal Analysis Metrics | | |

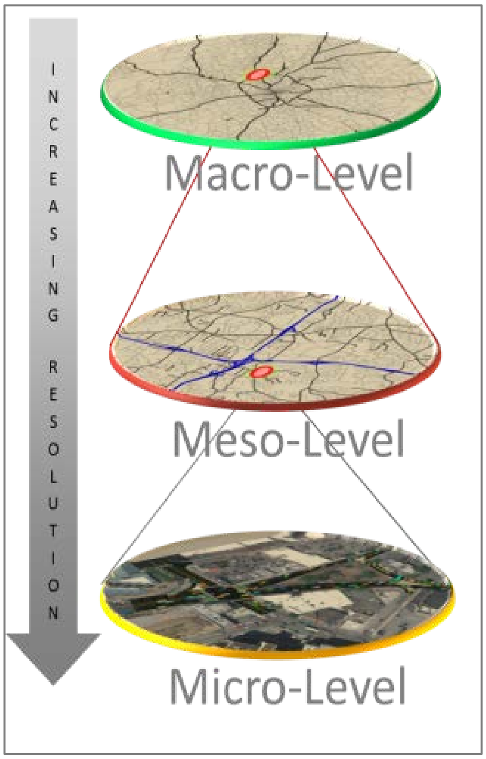
| Performance Measures | Scenario/Time Periods | Analysis Tool Selected for Assessment of Measure |
|---|---|---|
| • Change to travel time on transit-service roadways adjacent to I-205 between Stafford Road and OR 213 | • a.m. and p.m. peak hour | • DTA model |
| • Simplified MMLOS for transit users for study corridors within the API | • Daily | • ODOT's MMLOS calculation tool<br>• Regional travel demand model |
| • Change in level of traffic stress (LTS) for bicycle corridors impacted by traffic volume changes due to the project | • Daily | • ODOT's Bicycle LTS calculations<br>• Regional travel demand model |
| • Change in level of traffic stress (LTS) for pedestrian corridors impacted by traffic volume changes due to the project | • Daily | • ODOT's Pedestrian LTS calculations<br>• Regional travel demand model |
| **Metrics/Transportation Data for Other Environmental Disciplines** | | |
| *Air Quality/Greenhouse Gas Emissions:*<br>• traffic volumes, vehicle mix, length, roadway type and avg. speed on all API links for every hour of an average weekday. | • Daily and hourly | • Regional travel demand model |
| *Noise Analysis:*<br>• Traffic volumes for automobiles, medium trucks, heavy trucks, buses, and motorcycles. | • Peak truck hour and commuter peak hour | • Regional travel demand model<br>• DTA model (commuter peak volumes)<br>• Vehicle traffic count data (for vehicle mix) |
| *Economic Analysis:*<br>• VMT, VHT, average speed and percent trucks by hour and link for the economic analysis API. | • Daily and hourly | • Regional travel demand model |
| *Social Analysis:*<br>• Travel-time changes to representative destinations for those living within and outside the API, including equity framework communities (EFCs), comparing tolled and non-tolled paths<br>• Rerouted traffic volumes to local streets<br>• Differences in local intersection operations along access routes to social resources located in EFCs within the API | • Peak hour and off-peak | • Regional travel demand model (for travel times, since some locations are outside the DTA modeling area, and off-peak travel times are also required)<br>• DTA model for rerouted peak hour volumes within the API<br>• Synchro and Sidra for intersection operations |

A central goal of the traffic modeling was to assess traffic diversion impacts to adjacent roads and neighborhoods and associated impacts to quality of life.

### Modeling Approach Overview

The modeling sequence summarized below is in chronological order of how the modeling tools were applied. The main body of the memo explains the technical details of how the final traffic analysis results in the EA were developed. To support the calculation of the primary metrics identified above, the key data to be estimated include volumes (peak hour and daily) and speeds (peak hour and off-peak*). Peak hour volumes are the key input to intersection operations analysis and speeds (which directly affect travel times) are the primary factor in the decisions drivers will make for their travel route. This is especially critical when assessing the potential impact of toll projects on the system because it estimates traveler decisions and traffic volumes based on a more complete set of factors that influence the choice a driver would need to make between paying the toll or incurring additional travel time on an alternate route through a congested system.*

**Figure 1. Multi-resolution Modeling Approach**




Project-level transportation analysis involves using implied growth from a *macro-level* regional travel demand model and applying it to observed traffic count data to develop future traffic volumes for use in a micro-level or location-specific deterministic (e.g., Synchro or Highway Capacity Software (HCS)) traffic analysis model. The process described here adds an additional step between the macro-level (regional) and micro-level (location-specific) applications—a "meso-level" subarea model (see Figure 1). Introducing a meso-level subarea model enhances the typical process because meso-level models consider more elements of the roadway system than regional models do (e.g., more roadway characteristics, traffic signals, vehicle flows and queues) and provide a more detailed representation of what choices drivers make during congested times. This is especially important when considering travel choices made in a congested network when a roadway is tolled. Drivers need to weigh the trade-offs between paying a toll to use a free-flowing facility or rerouting to alternative roadways that may or may not be congested. Use of a subarea DTA model as an interim step between the RTDM and the site-specific analysis enhances traffic assignment as it provides a more complete consideration of the operational factors that affect traffic conditions and travel times, particularly during congested peak travel times. This results in better peak hour volume estimates for use in the micro-level/site specific analysis tools. In comparison to the macro-level model, the meso-level subarea model provides a more complete estimation of the traffic operations in the project area and thus the travel time incurred when choosing an alternative route.

### Macro-Level – Metro Regional Travel Demand Model

The Metro regional travel demand model (RTDM) is the primary tool used to estimate regional multi-modal demand. It is the foundation for all the subsequent traffic projections used in the EA. The RTDM is a macroscopic trip-based travel demand model. It estimates person trips for all modes and roadway network vehicle demand by hour for all 24 hours for an average weekday. It is important to utilize the adopted and maintained regional model for these efforts because it contains the approved projected land use forecasts and transportation system changes for the region and provides a consistent estimate of regional travel demand to assess all regional projects.

Output from the RTDM was used to develop:

- Area of potential impact (API) based on level of volume differences between Build and No Build conditions (see *Traffic Volume Development* section of this memo for more details).
- Average weekday traffic volumes,
- Travel times for representative equity framework community (EFC) trips that include ODs outside the transportation API, as well as travel times for off-peak time periods,
- Regional VMT and VHT estimates by vehicle type as needed

#### Meso-Level – Dynamic Traffic Assignment Model

To better estimate travel times under congested conditions, which is especially important when determining the trade-off between paying a toll and using an alternative route, additional refinements to the modeling process were applied in the meso-scale subarea dynamic traffic assignment (DTA) model.

To develop future volume forecasts, model outputs for the base year were aligned with observed traffic counts using standard procedures, and factors were developed to relate future model estimates to future traffic conditions. Introducing a meso-level model into the process allows the study to consider more elements of the roadway system than regional models do (e.g., more detailed roadway characteristics, traffic signals, vehicle flows and queues) and provide a better estimate of traffic volumes during congested periods The more detailed features of the project area represented in the DTA model have important consequences for key performance measures (including queuing effects, delay and travel time estimation) and the subsequent assignment of traffic volumes in the project study area. Using the DTA brings the modeled traffic estimates closer to the ground counts in the base year and reduce reliance on model-to-count adjustment factors in both base and future years. Other projects that have used DTA models on tolling analyses for this same reason include WSDOT's SR 99 Tunnel Project, SR 509 Extension Project, and the SR 167 Completion Project.

Future weekday AM and PM peak-hour traffic volume forecasts were developed for the future years for the No Build Alternative and Build Alternative based on future year model results from the I 205 DTA model. Standardized methods described in the ODOT Analysis Procedures Manual (APM) and the National Cooperative Highway Research Program Report 765 (NCHRP 765) were used to post-process raw DTA model link volumes. The difference or growth between the model base year (2015) and future year model output was calculated and compared on a relative percentage or increment basis. The difference in volume was then applied to the existing year (2021) volumes to develop No Build future year post-processed volumes, and the difference between the future Build and No Build model volumes was applied to the post-processed No Build volumes to develop the post-processed Build volumes.

Output from the DTA model was used to develop:

- Peak hour volumes
- Peak hour speeds and travel times
- Assessment of peak hour traffic diversion (volume changes)

### Micro-Level/Location-Specific Traffic Operations Analysis

The identification of transportation impacts in the EA are based primarily on weekday peak hour operations analysis. The weekday peak-hour intersection traffic operations analysis for study intersections was performed using Synchro (version 10) software, with results reflecting the Highway Capacity Manual Version 6 (HCM6) reporting methodology (TRB 2016). Where queuing impacts were likely, SimTraffic was used to estimate approach queues at intersections. Roundabout intersections were analyzed with the Sidra software. Volume-to-capacity ratios for signalized intersections were calculated using a method developed by ODOT and outlined in their Analysis Procedure Manual (APM).

The Vissim micro-simulation model was used for the Stafford Road corridor that experienced congestion to the level that impacts on adjacent intersections were not captured using Synchro.

To assess corridor operations on I 205 mainline highway segments, including weave, merge, and diverge geometry, Highway Capacity Software version 7 (HCS7) highway facilities modeling tools were used.

Output from the location-specific models included the following:

- Peak hour v/c ratios for intersections and I-205 mainline segments
- Intersection and freeway level-of-service (based on average vehicle delay at intersections, and density for freeway segments)
- Peak hour queuing for key intersection approaches

The remainder of this memo describes the development, calibration and use of these modeling tools for the I-205 Toll Project EA.

## INTRODUCTION

This memorandum describes the approach for conducting the traffic analysis and transportation modeling supporting the Environmental Assessment (EA) comparison of alternatives for the I-205 Toll Project. At the outset of the EA process, a list of evaluation metrics was developed based on the project's purpose and need and associated goals and objectives. These metrics were used to compare conditions within the area of potential impact (API) between the Build Alternative (with the project) and the No Build Alternative (without the project) were made. The primary metrics used to assess project effects are summarized below.

### Traffic Analysis Metrics

A range of performance measures was used to assess the potential impacts of the Project on motor vehicle travel. Impacts were assessed by comparing the traffic analysis results for the No Build and Build Alternatives with respect to vehicular movements and congestion. These performance measures are described in the following subsections.

- **Traffic Volume Shifts**

  How the project affects changes in travel behavior is especially important for this project because it includes a tolling component. Due to this, there is a focused interest and concern about how traffic may shift to avoid the tolls, and hence impact operations along those potential alternative routes. Projected traffic shifts were estimated for peak hour and average weekday traffic conditions.

- **Volume-to-Capacity Ratios**

  The principal performance measure ODOT uses when evaluating motor vehicle operating characteristics on the state highway system is v/c ratio. The ODOT Analysis Procedures Manual (APM)1, states that a v/c ratio reflects the ability of a facility to serve motorized vehicle traffic volume over a given time period under ideal conditions such as good weather, no incidents, no heavy vehicles, and no geometric deficiencies. The v/c ratio is the degree of utilization of the capacity of a segment, intersection, or approach and was calculated for all intersections per guidance using the ODOT APM critical v/c calculation method.

- **Average Vehicle Delay**

  Average vehicle delay represents the average wait times in seconds per vehicle, specifically at intersection locations. Vehicular delays were used to gauge overall intersection congestion levels based on predefined ranges and thresholds used to determine LOS (described in the next section).

- **Level of Service**

  LOS is a performance measure or index, defined in the HCM6, that is commonly used in transportation studies to represent congestion levels for vehicles on arterials, rural highways, limited-access roadways[2], and intersections. LOS for intersections is based on average vehicle control delay (seconds per vehicle), with letter "grades" of A through F representing little to no delay through very high delays, respectively.

- **Queuing**

  Queuing was estimated for critical approaches at key study intersections, including all I-205 off-ramp termini intersections. Queues were estimated and compared to the safe storage capacity of each facility in question. The definition of safe storage capacity incorporates specific features of the roadway environment, including length of turn lanes, sight distance concerns, proximity of other intersections, and potential to back up onto highway ramps and affect mainline operations. Queues exceeding the safe storage capacity were identified as unacceptable, and strategies for addressing the issues were developed.

---

[1] Oregon Department of Transportation (ODOT). 2020a. *Transportation Planning and Analysis Unit Analysis Procedures Manual.* https://www.oregon.gov/odot/Planning/Documents/APMv2.pdf.

[2] Limited-access roadways generally refer to roads designed for high-speed traffic that have limited or no access to adjacent property and few or no intersecting cross streets.

- **Travel Time**

  Travel time is a measure of the length of time a segment, facility, or route can be traversed in a given time period. Travel time is most often reported for a given direction during the peak period and expressed as the average travel time of all vehicles.

- **Travel Time Reliability**

  Travel time reliability considers the range of potential travel times roadway users may experience, the consistency of travel times, and the ability of roadway conditions to provide a desired travel time. Travel time reliability for existing year (2021) Conditions was measured using a travel time index (TTI). A TTI is calculated as actual travel time divided by the expected free-flow travel time or posted-speed travel time.

- **Hours of Congestion on I-205**

  Hours of congestion is an estimate of how many hours of a typical weekday I-205 within the project area would operate under congested conditions. This measure is calculated based on v/c ratios from RTDM. Heavy congestion includes any hour of the day where the v/c ratio would be greater than 0.90, while moderate congestion is indicated where the v/c ratio would be between 0.80 and 0.90.

- **Vehicle-Miles Traveled**

  Vehicle-miles traveled (VMT) is the amount of vehicle travel on a system in terms of vehicle volume and distance. VMT is the relationship of the total vehicle volume on the specified links multiplied by the total link lengths.

- **Vehicle-Hours Traveled**

  Vehicle-hours traveled (VHT) is calculated from speed and miles traveled data to measure overall vehicle travel time in a given roadway or study area (i.e., the API) (U.S. Department of Transportation Volpe Center). VHT depends both on demand (VMT) and delay (travel time).

#### Metrics for Other Modes of Travel

### Transit

Performance metrics for transit included the following:

- Multimodal level of service (LOS) for transit using ODOT APM methodto quantify user perception of quality of transit service based on inputs including transit speed, frequency, estimated ridership, and on-time performance.
- Change to travel time on transit-service roadways adjacent to I-205 between Stafford Road and OR 213

### Active Transportation

Performance metrics for active transportation modes included the following:

- Multimodal level of service (LOS) for pedestrians using ODOT APM method
- Level of traffic stress (LTS) for bicycles and pedestrians based on functional classification, roadway configuration, speed limit, average daily traffic, and other roadway characteristics

#### Metrics/Data for Other Environmental Disciplines

### Air Quality/Greenhouse Gas Emissions

Data provided from the transportation modeling tools as input to the air quality/greenhouse gas analysis included:

- Average weekday traffic volumes for all links within the air quality API, including link length and roadway type, and average modeled speed data for every hour of an average weekday. These average weekday values were applied to all days throughout the analysis year. Volumes were provided by vehicle type and accounted for expected changes to the vehicle mix in the future with or without the Project.
- VMT for each hour by three vehicle: passenger vehicle, medium truck, and heavy truck.

### Noise Analysis

Data provided from the transportation modeling tools as input to the noise analysis included:

- Peak truck hour and peak vehicle hour traffic volumes for automobiles, medium trucks, heavy trucks, buses, and motorcycles for the identified noise analysis API

### Economic Impacts

Data provided from the transportation modeling tools as input to the economic impact analysis included:

- VMT, VHT, average speed and percent trucks by hour and link for the economic analysis API

### Social Impacts

Data provided from the transportation modeling tools as input to the social impact analysis included:

- Changes in travel-times to representative destinations for people who live within and outside the API, including equity framework communities (EFCs), comparing paths that would be tolled and paths that would not be tolled.
- Rerouted traffic volumes to local streets, and differences in local intersection operations, that could affect access to social resources located in specific geographic communities within the API.

## DEVELOPMENT OF MODELING TOOLS

The following narrative lays out the primary evaluation tools, general assumptions, and procedures used for conducting the transportation analysis for the EA, including the development of travel demand forecasts and the daily and peak hour volumes used in the traffic analysis. The modeling tools were used to develop future year forecasts and provide performance measures to evaluate alternatives and estimate Project impacts. Modeled performance measures are a subset of the quantitative and qualitative measures established for the Project. These tools are described below beginning with the tools that support the critical analysis results contained in the EA, the micro-level traffic or location-specific operations analysis, and then follow with the tools that supported the development of the traffic volumes used in that analysis—the meso- and macro-level models.

The primary evaluation models used to assess performance metrics for the project include the following:

- Location-specific *micro-level* traffic operations analysis models (e.g., Synchro)
- I-205 subarea *meso-level* dynamic traffic assignment (DTA) model
- Metro *macro-level* regional travel demand model (RTDM)

Location-specific micro-level traffic operations analysis was performed for weekday peak hour conditions at study intersections and corridors using standard traffic engineering methodologies. These tools include deterministic Highway Capacity Manual capacity analysis software (e.g., HCS, Synchro, Sidra). The analysis was performed for existing conditions as well as future years based on traffic volume forecasts developed using post-processing methodology consistent with standard procedures identified in NCHRP Report 765. The future year analysis considers base-year traffic count data, with travel demand/traffic models being used as inputs to identify forecasted growth in traffic volume in future years. Future year volume forecasts for peak hour analyses were developed using the I-205 subarea DTA model results as inputs.

The I-205 subarea DTA model is a project-specific meso-level traffic model that refines the RTDM outputs for a specific area and time periods. The model utilizes origin-destination trip tables from the RTDM as inputs and uses dynamic traffic assignment procedures to model traffic conditions during peak demand periods (7 to 9 a.m. and 4 to 6 p.m.) on the southern end of the I-205 corridor. The subarea DTA model results were the primary source for evaluating changes in traffic patterns and volumes during peak periods, while the RTDM is used for daily and off-peak analysis.

The Metro RTDM is the primary tool used to estimate regional multi-modal demand. The RTDM is a macroscopic trip-based travel demand model. It estimates person trips for all modes and roadway network vehicle demand by hour for all 24 hours for an average weekday. The model version developed for the 2018 Regional Transportation Plan (RTP) is called "Kate" and represents model years for 2015, 2027, and 2040. An updated 2045 scenario was developed for this project.[3] The future model years include adopted projections of regional land use growth and changes to the regional transportation network including anticipated projects, as appropriate to the project analysis needs.

## LOCATION SPECIFIC TRAFFIC OPERATIONS ANALYSIS

The identification of transportation impacts in the EA are based primarily on weekday peak hour operations analysis. The weekday peak-hour intersection traffic operations analysis for study intersections was performed using Synchro (version 10) software, with results reflecting the Highway Capacity Manual

---

3 The 2018 RTP used a 2040 horizon year while this Project uses a 2045 horizon year. The 2045 model scenario uses the most recent land use assumptions developed in 2021 by Metro in conjunction with partner agencies, consistent with growth patterns identified in the RTP.

Version 6 (HCM6) reporting methodology (TRB 2016). Synchro is a deterministic analysis software package developed by Trafficware that is widely used for evaluating intersection operational performance and supporting design decisions. For this analysis, Synchro required key data input items such as traffic volumes, vehicle composition, traffic control, signal timing and phasing, lane geometry, transit stops, and non-motorized volumes (i.e., bicycle movements and pedestrian volumes). Typical performance measures and outputs generated by Synchro include average vehicle delays, volume-to-capacity (v/c) ratios, queues, and level of service (LOS). Where v/c ratios exceed 0.90, SimTraffic was used to report queues.

To assess corridor operations on I 205 mainline highway segments, including weave, merge, and diverge geometry, Highway Capacity Software version 7 (HCS7) highway facilities modeling tools were used.

Performance measures that were developed using peak hour traffic operations analysis include the following:

Volume-to-Capacity Ratios. The principal performance measure ODOT uses when evaluating motor vehicle operating characteristics on the state highway system is v/c ratio. The Synchro model produces a v/c ratio calculation that was used in the EA for unsignalized intersections. For signalized intersections, ODOT requires use of methods outlined in the ODOT Analysis Procedures Manual (APM) (ODOT 2020a). The Synchro v/c results were used to inform the analysts where v/c may be an issue, and then the v/c ratios used to identify impacts were then calculated based on the ODOT APM method. The APM states that a v/c ratio reflects the ability of a facility to serve motorized vehicle traffic volume over a given time period under ideal conditions such as good weather, no incidents, no heavy vehicles, and no geometric deficiencies. The v/c ratio is the degree of utilization of the capacity of a segment, intersection, or approach. Under the future conditions, the measure may be considered to be a demand to capacity ratio. In general, a lower v/c ratio indicates smooth operations and minimal delays. As the ratio approaches 1.0, congestion increases, and operational performance is reduced. At 1.0, the capacity is fully utilized (ODOT 2020a). Volume-to-capacity output from the Sidra modeling software was used for the EA for roundabouts.

Average Vehicle Delay. Average vehicle delay represents the average wait times in seconds per vehicle, specifically at intersection locations. Vehicular delays were used to gauge overall intersection congestion levels based on predefined ranges and thresholds used to determine LOS (described in the next section). Delays were provided from the Synchro analysis and reflect standard HCM reporting methodologies.

Level of Service. LOS is a performance measure or index, defined in the HCM6, that is commonly used in transportation studies to represent congestion levels for vehicles on arterials, rural highways, limited-access roadways, and intersections. LOS for intersections is based on average vehicle control delay (seconds per vehicle), with letter "grades" of A through F representing little to no delay through very high delays, respectively. Intersection LOS was provided from the Synchro analysis and reflects HCM6 reporting methodologies. LOS for limited-access roadway mainline segments and ramp merge and diverge segments is based on density, expressed in terms of passenger cars per mile per lane (pc/mi/ln). HCS7 was used to evaluate the traffic operations along I-205.

Queuing. Queuing was estimated for all relevant approaches at each of the study intersections. Queues were based on 95th percentile queue lengths reported in Synchro/SimTraffic and were compared to the safe storage capacity available on each facility in question. The definition of safe storage capacity incorporates specific features of the roadway environment, including length of turn lanes, sight distance concerns, proximity of other intersections, and potential to back up onto highway ramps and affect mainline operations. Queues exceeding the safe storage capacity were identified as unacceptable, and strategies for addressing the issues were developed.

## Traffic Volume Development

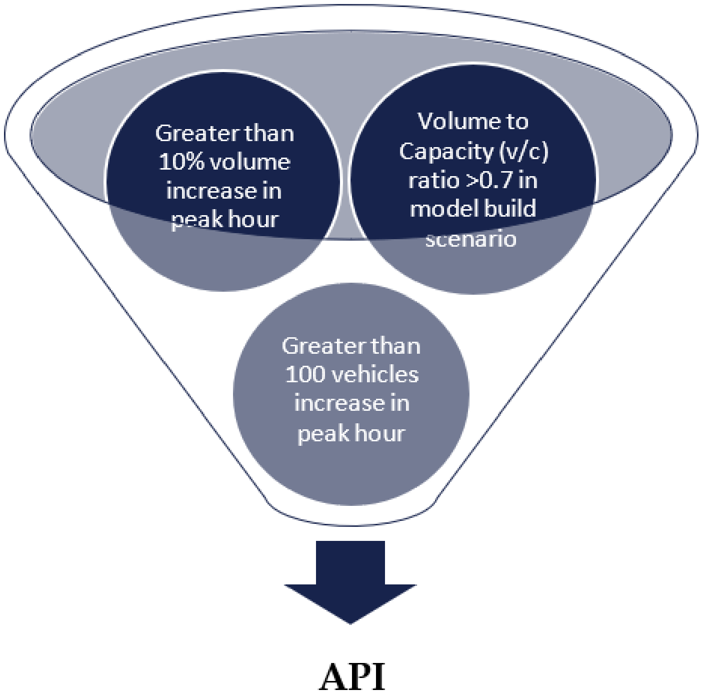
### Area of Potential Impact

The transportation area of potential impact (API) of the Project was identified by examining the anticipated volume changes for daily, AM peak-hour, and PM peak-hour traffic from Metro regional travel demand model (RTDM) results for 2045 under the No Build and Build Alternatives. The projected change in volumes identifies where traffic diversion, or rerouting, off I-205 may occur to avoid congestion, in the case of the No Build Alternative, or tolls, in the case of the Build Alternative. The conclusions from the RTDM results were subsequently confirmed with results from a dynamic traffic assignment (DTA) model. The DTA model was developed and used on this effort for the AM and PM peak periods because it better reflects potential diversion related to tolls under congested conditions. As shown in Figure 2, intersection locations were selected for inclusion in the API if the change in AM or PM peak-hour volumes between the No Build and Build Alternatives met all three of the following criteria:

- Greater than 10% volume increase
- Greater than 100 vehicles increase total
- Volume-to-capacity (v/c) ratio is greater than 0.7 in the Build Alternative model

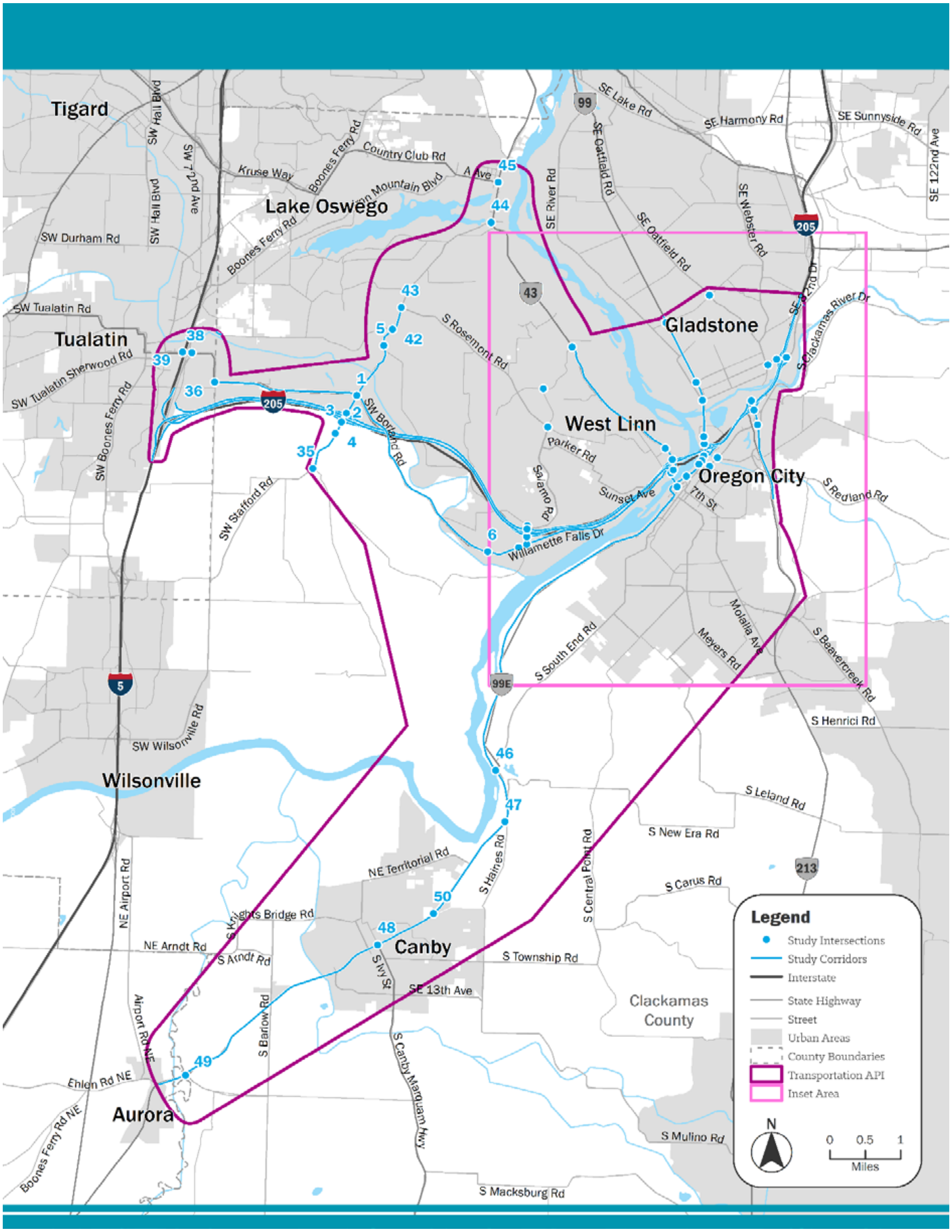
Input from local jurisdictions on specific intersections of concern was also considered in developing the API.

**Figure 2. Criteria for Determining Transportation Area of Potential Impact**




To capture the potential impacts of rerouting due to tolling on I-205, key intersections identified by communities that may experience changes in traffic volumes are included within the API, including intersections in unincorporated Clackamas County, Oregon City, West Linn, and Gladstone. The API boundary and the 50 study intersections within it are illustrated in Figure 3.

**Figure 3. Transportation Area of Potential Impact**



#### Existing Peak Hour Traffic Volumes

For existing year (2021), traffic volume information was compiled using existing resources in accordance with the ODOT APM. After the Area of Potential Impact (API) and study intersections were finalized, data sources and post-processing methodology for each study corridor and intersection were coordinated with ODOT.

The API for the Project includes 50 study intersections. Two-hour morning and afternoon peak-period turning movement counts were collected in June 2021 at 34 study intersections, and in October 2021 for the remaining 16 study intersections because they were added later to the API. See the EA *Transportation Technical Report* for existing year (2021) traffic counts. Seven of the intersections counted in October 2021 were also counted in June 2021 to gain an understanding of whether and how the travel patterns might have changed. Intersection volumes were similar for the intersections counted for both months, except for the intersections at 7th Street and Main Street, OR 99E and I-205 southbound ramps, and OR 99E and Jennings Avenue during the AM peak. The higher October 2021 volumes were used for the AM peak-period analysis because they were considered to be a more appropriate starting point for evaluation of potential project impacts.

The 2021 two-hour peak-period counts for the 50 intersections were adjusted to a single system peak hour, which is the peak single hour of the day that has the highest hourly volume across the API. The system peak hour was determined by identifying the time frame with the highest count of intersection peak hours. Based on this examination, the appropriate AM peak hour for analysis is 7:45 a.m. to 8:45 a.m. and PM peak hour is 5:00 p.m. to 6:00 p.m. See the EA *Transportation Technical Report* for system peak-hour details. Heavy vehicle percentages, as well as bicycle and pedestrian volumes, at each study intersection were obtained from the turn movement counts during the system peak hour.

To assess whether the traffic counts collected in June 2021 are representative of normal pre-pandemic traffic conditions, recent historical data available within the API was reviewed for years 2017, 2018, and 2019 (pre-pandemic). Based on the historical data review, June 2021 counts were adjusted as appropriate to represent normal pre-pandemic traffic conditions. See the EA *Transportation Technical Report* for details on this adjustment approach.

#### Future Peak Hour Traffic Volume Development

Future weekday AM and PM peak-hour traffic volume forecasts were developed for the future years (2027 year of opening and 2045 future horizon year) for the No Build Alternative and Build Alternative based on future year model results from the I 205 Subarea DTA model. Standardized methods described in the APM and the National Cooperative Highway Research Program Report 765 (NCHRP 765) were used to post-process raw model link volumes. The difference or growth between the model base year (2015) and future year (2027 and 2045) model output was calculated and compared on a relative percentage or increment basis. The difference in volume was then applied to the existing year (2021) volumes to develop No Build Year (2027 and 2045) post-processed volumes. This approach ensures that forecasts from the models are consistent with real-world data (i.e., traffic counts). In some locations the DTA model constrained demand so that a notable amount of unserved demand resulted. In these cases, the post-processed volumes when input to the Synchro or Vissim models did not reflect the expected level of constrained congestion. In these cases, unserved demand as captured by the DTA model was included in the DTA model volumes prior to post-processing. More details on this approach are contained in Appendix A.

After the forecasting step, the turning movement volumes were balanced between the intersections as appropriate. The future year (2027 and 2045) No Build turning movement forecast volumes were used as the base and the future year (2027 and 2045) No Build and Build DTA model volumes were used following the APM and the NCHRP 765 method to develop future year (2045) Build turning movement forecasts. In situations where the future year (2027 and 2045) No Build and Build Alternative link volumes were lower, as a result of constrained flow due to congestion, the link volumes were adjusted as appropriate based on demand and observed queuing in the DTA model. Detailed steps related to the post-processing methodology used to develop the No Build (year 2027 and 2045) and Build (year 2027 and 2045) turning movement forecast volumes are included in in the EA *Transportation Technical Report*. Where analyses dependent on traffic volumes required vehicle classification breakdowns, such as the percentage of trucks, vehicle mixes were based on existing traffic count data. Observed data is used where available given limitations in the RTDM in representing different vehicle classes. This is the case for all the traffic analysis work conducted. For region-wide analyses, such as emissions and greenhouse gas, vehicle classification data was obtained from the RTDM because it was not feasible to obtain observed count data on all facilities systemwide.

## Summary

Traffic analysis for the EA was conducted using state-of-the-practice methods as outlined in the ODOT Analysis Procedure Manual (APM). The analysis considers detailed location-specific characteristics of transportation facilities and peak hour traffic count data collected in 2021. Existing traffic volumes were adjusted to reflect potential COVID pandemic effects, and future peak hour traffic volume forecasts were developed using standardized procedures for post-processing. The forecasts use existing data and combine them with expected changes identified in the subarea DTA model to help estimate future volumes that account for expected growth in the area and the effects of the project.

Additional details for the traffic operations analysis methodologies are documented in the EA *Transportation Technical Report.*

## I-205 SUBAREA DTA MODEL

### Why use a DTA model?

To develop future year traffic forecasts, the industry-standard approach involves using the adopted and maintained regional travel demand model to develop growth factors between the base year and future No Build scenarios and apply these factors to observed traffic counts to develop “post-processed” future baseline traffic forecasts. The proposed project is then coded into the model to represent the “Build” network and the model is run. Differences between the future No Build and Build scenarios are then applied to the post-processed future baseline forecasts to determine post-processed future Build traffic forecasts. These post-processed volumes are then used in more detailed micro-level traffic analysis models to assess traffic operations for the No Build and Build scenarios and evaluate the differences in order to determine the expected effects of the project on performance measures of interest at key locations within the project API. It is important to utilize the adopted and maintained regional model for these efforts because it contains the approved projected land use forecasts and transportation system changes for the region and provides a consistent estimate of regional travel demand to assess all regional projects.

This analysis adds the use of a subarea DTA model as an interim step between the RTDM and the site-specific analysis because it enhances traffic assignment by providing a more complete consideration of the operational factors that affect traffic conditions and travel times, particularly during congested peak travel times. To develop future traffic volumes for this EA, traffic volume changes as reflected in the meso-level subarea DTA model rather than the RTDM are applied to actual traffic counts to generate future volumes. Introducing a meso-level model into the process allows the analysis to consider more elements of the roadway system than regional models do (e.g., more detailed roadway characteristics, traffic signals, vehicle flows and queues) and provide a more nuanced estimation of traffic volumes during congested periods [5]. The more detailed features of the project API represented in the subarea DTA model may have important consequences for key performance measures (including queuing effects, delay, and travel time estimation) and the subsequent assignment of traffic volumes in the project API. Using the subarea DTA brings the modeled traffic estimates closer to the ground counts in the base year and reduce reliance on model-to-count adjustment factors in both base and future years.

In comparison to a static model, a DTA model will generate traffic and speed estimates that more closely align with observed traffic during congested times. Table 2 shows how the DTA model improves the match of modeled results with observed peak period volumes along I-205. The results show that the subarea DTA model estimates more closely align with observed volumes at these locations, and that the RTDM tends to over-assign volumes along I-205 during the peak periods.

**Table 2. RTDM and DTA Model Peak Period Base Year Volumes on I-205 Compared to Observed Volumes**

| **RTDM Results** | **Bi-Directional** | | | | **Northbound** | | | | **Southbound** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AM Peak Period - 7-9 AM** | **2015 2-Hr Peak RTDM Volumes** | **2015 2-Hr Peak Counts** | **Difference RTDM - Counts** | **% Δ from Counts** | **2015 2-Hr Peak RTDM Volumes** | **2015 2-Hr Peak Counts** | **Difference RTDM - Counts** | **% Δ from Counts** | **2015 2-Hr Peak RTDM Volumes** | **2015 2-Hr Peak Counts** | **Difference RTDM - Counts** | **% Δ from Counts** |
| **I-205 Mainline** | | | | | | | | | | | | |
| Between I-5 and Stafford Rd | 13,327 | 11,931 | 1,396 | 12% | 5,728 | 5,500 | 229 | 4% | 7,599 | 6,431 | 1,167 | 18% |
| Abernethy Bridge | 17,547 | 14,713 | 2,834 | 19% | 8,607 | 7,455 | 1,152 | 15% | 8,940 | 7,258 | 1,682 | 23% |
| Between OR 213 and SE 82nd Dr | 22,441 | 18,744 | 3,697 | 20% | 12,011 | 11,148 | 863 | 8% | 10,430 | 7,596 | 2,834 | 37% |
| **Group Summary:** | **53,315** | **45,388** | **7,927** | **17%** | **26,346** | **24,103** | **2,243** | **9%** | **26,969** | **21,285** | **5,683** | **27%** |
| **PM Peak Period - 4-6 PM** | | | | | | | | | | | | |
| **I-205 Mainline** | | | | | | | | | | | | |
| Between I-5 and Stafford Rd | 13,474 | 11,918 | 1,557 | 13% | 7,193 | 5,984 | 1,209 | 20% | 6,282 | 5,934 | 348 | 6% |
| Abernethy Bridge | 18,310 | 14,976 | 3,334 | 22% | 9,315 | 7,671 | 1,644 | 21% | 8,995 | 7,305 | 1,690 | 23% |
| Between OR 213 and SE 82nd Dr | 22,987 | 21,858 | 1,129 | 5% | 10,836 | 10,468 | 368 | 4% | 12,151 | 11,390 | 761 | 7% |
| **Group Summary:** | **54,771** | **48,752** | **6,020** | **12%** | **27,344** | **24,123** | **3,221** | **13%** | **27,428** | **24,629** | **2,799** | **11%** |

| **DTA Model Results** | **Bi-Directional** | | | | **Northbound** | | | | **Southbound** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AM Peak Period - 7-9 AM** | **2015 2-Hr Peak DTA Volumes** | **2015 2-Hr Peak Counts** | **Difference DTA - Counts** | **% Δ from Counts** | **2015 2-Hr Peak DTA Volumes** | **2015 2-Hr Peak Counts** | **Difference DTA - Counts** | **% Δ from Counts** | **2015 2-Hr Peak DTA Volumes** | **2015 2-Hr Peak Counts** | **Difference DTA - Counts** | **% Δ from Counts** |
| **I-205 Mainline** | | | | | | | | | | | | |
| Between I-5 and Stafford Rd | 12,931 | 12,248 | 683 | 6% | 5,957 | 5,591 | 366 | 7% | 6,974 | 6,657 | 317 | 5% |
| Abernethy Bridge | 15,517 | 14,713 | 804 | 5% | 8,009 | 7,455 | 554 | 7% | 7,508 | 7,258 | 250 | 3% |
| Between OR 213 and SE 82nd Dr | 19,148 | 18,744 | 404 | 2% | 11,438 | 11,148 | 290 | 3% | 7,710 | 7,596 | 114 | 2% |
| **Group Summary:** | **47,596** | **45,705** | **1,891** | **4%** | **25,404** | **24,194** | **1,210** | **5%** | **22,192** | **21,511** | **681** | **3%** |
| **PM Peak Period - 4-6** | | | | | | | | | | | | |
| **I-205 Mainline** | | | | | | | | | | | | |
| Between I-5 and Stafford Rd | 11,321 | 11,792 | -471 | -4% | 5,269 | 5,872 | -603 | -10% | 6,052 | 5,920 | 132 | 2% |
| Abernethy Bridge | 15,440 | 14,976 | 464 | 3% | 8,167 | 7,671 | 496 | 6% | 7,273 | 7,305 | -32 | 0% |
| Between OR 213 and SE 82nd Dr | 21,355 | 21,858 | -503 | -2% | 10,510 | 10,468 | 42 | 0% | 10,845 | 11,390 | -545 | -5% |
| **Group Summary:** | **48,116** | **48,626** | **-510** | **-1%** | **23,946** | **24,011** | **-65** | **0%** | **24,170** | **24,615** | **-445** | **-2%** |

Use of the subarea DTA model is also expected to provide enhanced results when assessing the potential impact of toll projects on the transportation system. This is because it estimates traffic based on a more complete set of factors that influence the choice a driver would need to make between paying the toll or incurring the additional travel time on an alternate route through a congested system. Reflecting these trade-offs in time and cost are critical to assessing transportation impacts, in particular by improving estimates of traffic on adjacent routes and crossings due to potential toll diversion. For the I-205 Toll Project, drivers will need to weigh the trade-offs between paying a toll to use a free-flowing facility versus rerouting to alternative roadways that may or may not be congested. In comparison to the macro-level RTDM, the meso-level DTA model takes into account more factors that affect the cost and travel time incurred when choosing an alternative route and thus improves the alignment between model results and ground counts, while ensuring that future forecasts are also sensitive to those factors.

In summary, in comparison to the RTDM, the subarea DTA model is able to better reflect congested operational conditions within a constrained network, which occurs during the peak periods across many portions of the API in the base year and will be even more constrained in future years. As such, the subarea DTA model provides a much more sensitive estimate of travel time and cost for the traveler deciding on which routes to choose.

## Subarea DTA Model Development

A sub-area Dynamic Traffic Assignment (DTA) model based on Portland Metro's Regional DTA model was developed and refined for this project. Metro maintains a regional DTA model which utilizes the Dynameq software package and is validated well comparing hourly volumes against observed counts at a screenline level. Regional traffic volume results of static assignments and mesoscopic simulations are not substantially different with the Base Year demand. However, when future year scenarios are modelled (e.g., 2045), the regional trip-based model produces traffic volume forecasts that unrealistically exceeds network capacity in many locations. This is a result of the RTDM not taking into account the more detailed factors represented in the DTA model. Using demand directly from the RTDM as input into a subarea DTA model would undoubtedly result in a substantial number of trips unable to be served on the firmly constrained DTA networks due to the excess demand. This condition would require substantial demand adjustments within the subarea DTA model to calibrate the model. By utilizing the regional DTA model to create capacity-constrained OD demand for use in the DTA subarea, we ensure that the demand entering the subarea is better aligned with congestion and toll outcomes due to project features not represented in the RTDM.

A subarea DTA model was used instead of the Regional DTA model for project impact analysis because it could be feasibly developed and calibrated to sufficient accuracy for use on the project. Calibrating the full Regional DTA model to the same level of detail and accuracy was not necessary because this level of detail was not needed outside of the API.

The subarea DTA model was developed as a collaborative effort between the project team including staff from ODOT, Metro Modeling, and the consultant team. The process for developing the subarea DTA model is a relatively standard process for Metro and includes the following general steps:

1. The RTDM is run to full convergence to produce a full set of hourly trip tables (24 per mode—sov, hov, medium truck, heavy truck)
2. RTDM travel demand output (trip tables) is exported for the appropriate DTA time-period. (Example, an AM/PM Peak 2-hour analysis period requires 4 hours of trip tables: 1 hour of warm up time, 2 hours of analysis time, 1 hour of cool down time)
3. Exported RTDM trip tables input to the regional DTA model network and an initial DTA model run is made, which includes actual ramp meter rates and ALL GREEN timing plans for all other signalized intersections
4. Using Dynameq's signal optimization module, results from this first regional DTA model run in initial set of signal phasings and timings for all non-ramp meter signalized intersections based on best accommodation of traffic at each intersection. The regional DTA model is then rerun using these initial timing plans
5. A subarea cut of the regional DTA model is made to get the project-specific subarea DTA model. The subarea is determined by evaluating difference plots from RTDM of Build and No Build scenarios to identify likely alternative routes and facilities that will be impacted by project (a process similar to how the project API was developed). The subarea DTA model will utilize capacity constrained trip tables created by the regional DTA model
6. Initial assignments on the subarea DTA model are run, which includes actual ramp meter rates and ALL GREEN timing plans for all other signalized intersections
7. Use the signal optimization module again in the initial subarea DTA model run to develop an initial set of signal phasings and timings for all non-ramp meter signalized. Rerun the subarea DTA model using the model-developed timing plans
8. Use the optimized subarea DTA model assignments as the starting point for model calibration. Calibration focuses on network updates (free flow speeds, response time factors (Dynameq), and specific signal timing plans at key intersections impacted by project).

More detail on the subarea DTA model calibration adjustments is included below and in the appendices.

The subarea DTA network was extracted from the regional DTA model network and further refined with enhanced details near the project corridor. As indicated above, the trip tables defining origin-destination vehicle demand come from the RTDM and are run through the regional DTA model to create the capacity-constrained demand matrices used as inputs into the subarea DTA model.

Several datasets were assembled to calibrate and validate the DTA model, including a consolidated-count database of traffic volume counts from Metro, ODOT, and partner agencies participating in the Project's Regional Model Group (RMG). Travel time data from mobility analytics company INRIX was also applied to calibrate and validate the DTA model. The methodology and results of the model calibration and validation are summarized in this section.

The subarea DTA model was developed to model the peak periods of the I-205 Toll Project area of potential impact (API) because it provides a better representation of traffic operations and understanding of vehicle routing patterns on and near I-205 during congested peak period traffic conditions. For estimated off-peak and daily volume projections the RTDM was used. A map of the I-205 subarea covered by the DTA model is shown in Figure 4 side by side with a map depicting the API. The subarea DTA model network encompasses more than the entire area of the API to allow for possible traffic shifts outside of the API that could affect API facilities.

This model was used to gauge segment-level travel time and volume changes for the AM and PM peak periods under future project alternatives and was relied on as a decision-making tool for identifying potential short term and long-range changes in peak period traffic volumes in response to tolls and I-205 roadway capacity and tolling infrastructure included in the project.

#### Study Area

The study area of the subarea DTA model (Figure 4) includes an approximately 17-mile section of the I-205 corridor extending from I-5 in the west to SE Foster Rd in the east. It also includes I-5 from Ehlen Rd in the south to OR 10 in the north. The model area includes all freeway interchanges along this section as well as the signalized intersections within the model boundary. These intersections are included to evaluate path choice (or vehicle routing) to and from I-205 and I-5, as well as travel patterns parallel to these freeways.

#### Time Horizon

The DTA model was developed and calibrated for a base year of 2015 and updated to represent future 2027 and 2045 horizon years under various scenarios (baseline conditions and with testing strategies). The 2015 base year aligns with the Metro RTDM base year.

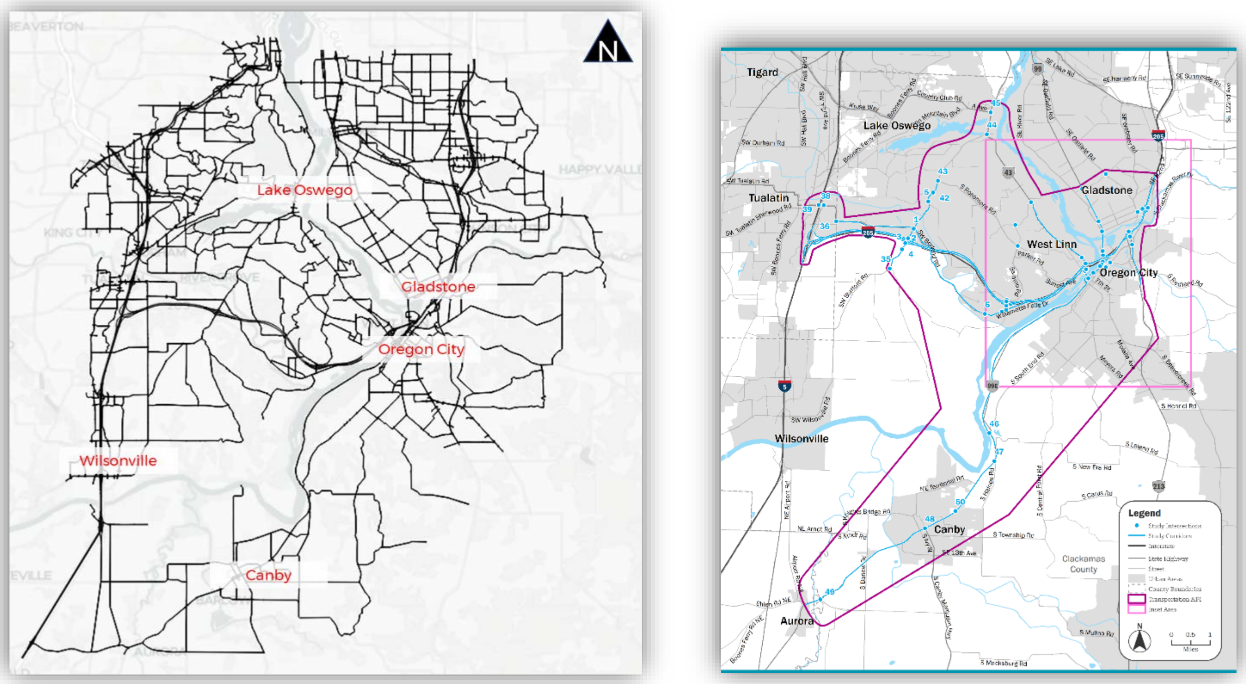
#### Time of Day

The DTA model was developed to analyze two average weekday periods: an AM peak period from 07:00 to 9:00 and a PM peak period from 16:00 to 18:00. Warm up and cool down periods of 60 minutes each were incorporated before and after each modeling period.  The warm-up period is standard practice to “pre-load” the network in order to have the 2-hour evaluation period reflect realistic traffic conditions.

#### Vehicle Classes

The sub-area DTA model includes the following vehicle classes: single occupancy vehicles (SOV), high occupancy vehicles (HOV), Medium Trucks and Heavy Trucks, and Transit. Origin/Destination demand matrices for each class (except Transit) and day period were provided by the regional travel demand model in a resolution of 15-minutes.  Each auto vehicle class (SOV and HOV) was further broken out into three sub-classes segmented to represent a range of potential responses to tolls.  These were used to represent expected differences in willingness to pay the monetary toll cost, consistent with the vehicle travel demand estimation process in the Metro RTDM and Regional DTA model.

**Figure 4. DTA Subarea Model Area**




Source: Dynameq software. Map tiles ©MapTiler ©OpenstreetMap contributors

#### Value of Travel Time

Monetary toll costs are represented as equivalent time penalties in the traffic models, based on estimated values of travel time. These values of time represent willingness to pay and differ depending on the modeled vehicle class. These "toll in minutes" were defined in such a way as to reflect a range of willingness to pay a toll for the different auto and truck vehicle classes. For the DTA model, the perceived time to cross a toll link or segment depended on the simulated travel time plus the value of time and toll cost in minutes for the specific vehicle class.

There are no tolled facilities in the base year (2015) so a value-of-time assumption was not needed for initial calibration. For the future horizon DTA models, segmented demand matrices were used, as described above. These assumptions are consistent between the Metro RTDM, Regional DTA, and subarea DTA models.

#### Data Collected

### Volumes

Traffic counts for model comparison and calibration were primarily extracted from ODOT's Regional Integrated Transportation Information System (RITIS) database. Major road corridors in this study area for which detailed segment volume counts were extracted and summarized included the following:

- I-205
- I-5
- US-99E
- OR-43
- Willamette Falls Dr
- Borland Rd
- OR-213
- Stafford Rd/ Elligsen Rd

Intersection turning movement traffic counts were also collected for AM peak period (7-9 AM) and PM peak period (4-6 PM) at a variety of locations within the study area.

### Speeds

Speed data for I-205 was provided by INRIX and Metro. Data was provided in tabular format as well as "contour" maps depicting average corridor speeds by time and location.

### Travel Times

Point-to-point travel times along key road sections were also obtained from INRIX. Table 3 below shows the complete list of road segments that were used for travel time comparison between the model and observed data.

### Signals

Base year signal timing and phasing data for ramp termini intersections and arterial intersections were synthesized by the Dynameq software for the study area. For the critical (to the DTA model) intersection of 7th Street and Main Street in downtown Oregon City, field observation yielded the existing signal timing plan. Signal timing representations in the model were reviewed and checked for reasonableness as part of the model calibration process.

### Ramp Meter Rates

Metering rates for signalized on-ramps were specified by ODOT and were coded by Metro into the regional Dynameq model, and subsequently passed through to the DTA subarea model. When Dynameq signal generation was run for the subarea model, ramp meter controls were excluded and their original coding preserved.

**Table 3. List of segments for travel time measurements**

| Road | Direction | From | To |
|---|---|---|---|
| I-205 | NB | I-5 ramps | Stafford Rd |
| I-205 | NB | Stafford Rd | 10th St |
| I-205 | NB | 10th St | OR-43 NB |
| I-205 | NB | OR-43 NB | US-99E |
| I-205 | NB | US-99E | OR-213 |
| I-205 | NB | OR-213 | Gladstone |
| I-205 | NB | Gladstone | OR-212 |
| I-205 | SB | OR-212 | Gladstone |
| I-205 | SB | Gladstone | OR-213 |
| I-205 | SB | OR-213 | US-99E |
| I-205 | SB | US-99E | OR-43 |
| I-205 | SB | OR-43 | 10th St |
| I-205 | SB | 10th St | Stafford Rd |
| I-205 | SB | Stafford Rd | I-5 split |
| I-5 | NB | Elligsen Rd | I-205 |
| I-5 | NB | I-205 | Nyberg Rd |
| I-5 | NB | Nyberg Rd | Lower Boones Ferry |
| I-5 | NB | Lower Boones Ferry | Upper Boones Ferry |
| I-5 | NB | Upper Boones Ferry | Kruse Way |
| I-5 | SB | OR-217 | Upper Boones Ferry |
| I-5 | SB | Upper Boones Ferry | Lower Boones Ferry |
| I-5 | SB | Lower Boones Ferry | Nyberg Rd |
| I-5 | SB | Nyberg Rd | I-205 |
| I-5 | SB | I-205 | Elligsen Rd |
| I-205 | NB | I-5 ramps | OR-212 |
| I-205 | SB | OR-212 | I-5 ramps |
| I-5 | NB | Elligsen Rd | Kruse Way |
| I-5 | SB | OR-217 | Elligsen Rd |
| US-99E | SB | Tacoma | OR-224 |
| US-99E | SB | OR-224 | River Rd |
| US-99E | SB | River Rd | Concord Rd |
| US-99E | SB | Concord Rd | 15th St (OC) |
| US-99E | SB | 15th St (OC) | Railroad Ave |
| US-99E | SB | Main St | South End |
| US-99E | SB | South End | Grant St (Canby) |
| US-99E | NB | Grant St (Canby) | South End |
| US-99E | NB | South End | Main St |
| US-99E | NB | Main St | I-205 SB |

| Road | Direction | From | To |
|---|---|---|---|
| US-99E | NB | I-205 SB | Concord Rd |
| US-99E | NB | Concord Rd | River Rd |
| US-99E | NB | River Rd | OR-224 |
| US-99E | NB | OR-224 | Tacoma |
| OR-43 | SB | Sellwood Br | A Ave |
| OR-43 | SB | A Ave | Hidden Springs |
| OR-43 | SB | Hidden Springs | I-205 NB off-ramp |
| OR-43 | SB | I-205 NB off-ramp | Main St (OC) |
| OR-43 | NB | Main St (OC) | I-205 SB off-ramp |
| OR-43 | NB | I-205 SB off-ramp | Hidden Springs |
| OR-43 | NB | Hidden Springs | A Ave |
| OR-43 | NB | A Ave | Sellwood Br |
| Willamette Falls Dr | WB | OR-43 | 10th St |
| Willamette Falls Dr | WB | 10th St | Stafford Rd |
| Willamette Falls Dr | EB | Stafford Rd | 10th St |
| Willamette Falls Dr | EB | 10th St | OR-43 |
| Borland Rd | EB | SW 65th Ave | Stafford Rd |
| Borland Rd | WB | Stafford Rd | SW 65th Ave |
| OR-213 | NB | Mollala Ave | I-205 |
| OR-213 | SB | I-205 | Mollala Ave |
| Stafford / Elligsen | NB | I-5 (Elligsen) | I-205 |
| Stafford / Elligsen | NB | I-205 | OR-43 |
| Stafford / Elligsen | SB | OR-43 | I-205 |
| Stafford / Elligsen | SB | I-205 | I-5 (Elligsen) |
| US-99E | SB | Tacoma | 15th St (OC) |
| US-99E | SB | Main St | Grant St (Canby) |
| US-99E | NB | Grant St (Canby) | Main St |
| US-99E | NB | Main St | Tacoma |
| OR-43 | SB | Sellwood Br | Main St |
| OR-43 | NB | Main St | Sellwood Br |

## Calibration Procedure Outline

Figure 5 outlines the process used to develop and establish the calibrated Dynameq model.

**Figure 5 Calibration Procedure**

A) Develop and Implement calibration documentation procedure

B) Checking network coding details – number of lanes, speeds, intersection coding

C) Condensing observed data for analysis, for example importing into Dynameq and spreadsheet

D) AM and PM periods to be calibrated separately, focusing on one, followed by the other

E) Identify model result discrepancies with observed conditions (e.g., volumes, speeds, queues) and adjust model/network parameters, for example response time factors, free speeds, link/intersection delay outliers to address discrepancies

F) Calibrate demand through the I-205 corridor as necessary, using demand adjustments at targeted locations as determined by the model (see example in next section)

G) Monitor aggregate goodness of fit measures for corridor and individual link level calibration criteria

H) Return to step E) if required

### Demand Adjustments

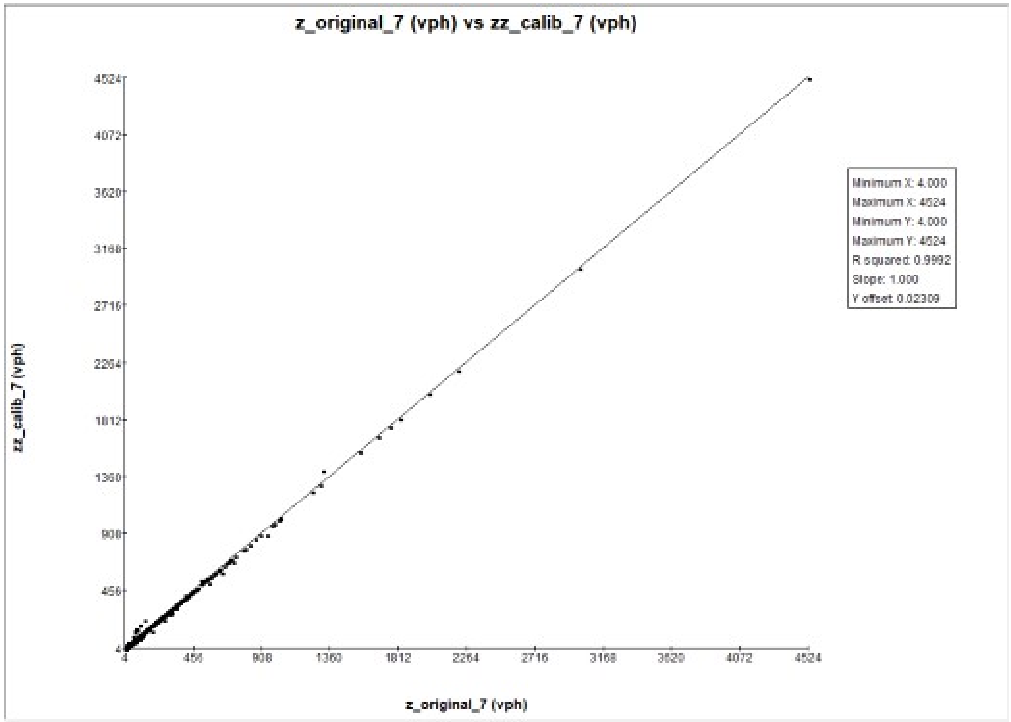
Demand adjustments were made during calibration of the I-205 subarea DTA AM and PM models by taking the approach and departure volumes and producing adjustment factors to better align the model results with observed counts. Using a select link analysis-based adjustment procedure.. The procedure for this project used hourly observed traffic counts for selected links (7-8 am, 8-9 am, 4-5 pm, 5-6 pm) and an equilibrated DTA solution as inputs. Then the following steps were taken:

- Select link demand matrices for demand crossing the specified links each hour were calculated
- The ratios of assigned flows on the selected links relative to their observed counts were calculated
- Approach and departure volumes in the select link demand matrices were increased or decreased as indicated by the flow/count ratios

The following four figures (Figure 6 through Figure 9) show comparisons of calibrated demand to original subarea demand resulting from the demand adjustments for the two AM and PM peak hours respectively. Each figure shows the comparison for each 1-hour interval including a scatter plot for the individual approaches, comparing original volumes estimates to calibrated estimates. The figures also include maps showing centroid locations where either total originating demand or total destined demand changed by +/- 20 trips.

Overall, the comparisons show very little change to the AM demand, limited to only the 7 and 8 AM hours. The PM comparisons show somewhat larger differences due to demand calibration.

**Figure 6 Comparison of Calibrated to Original Subarea Demand: 7:00-8:00 AM**



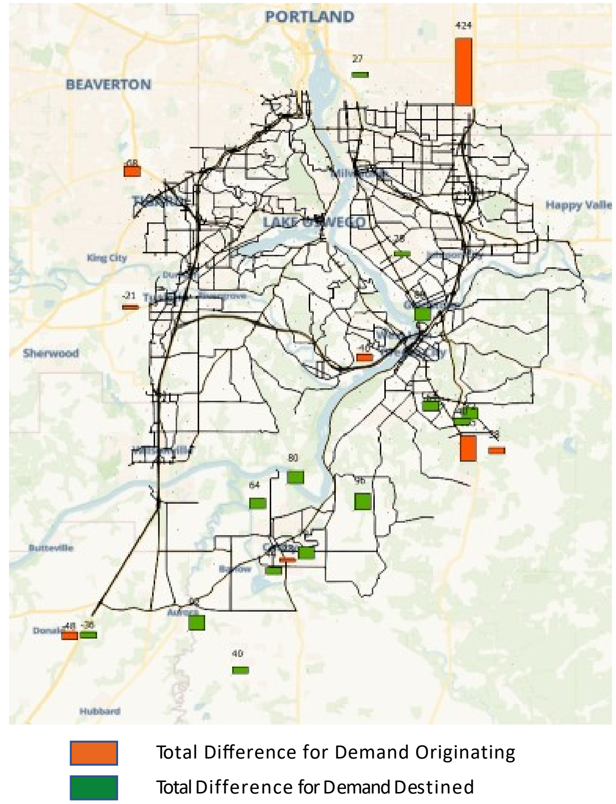
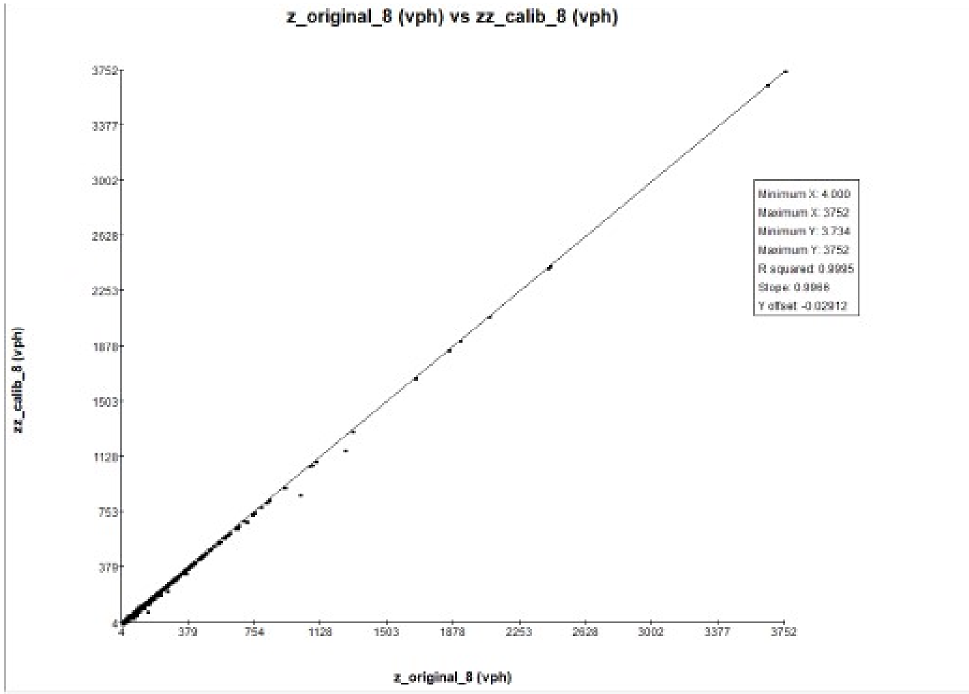
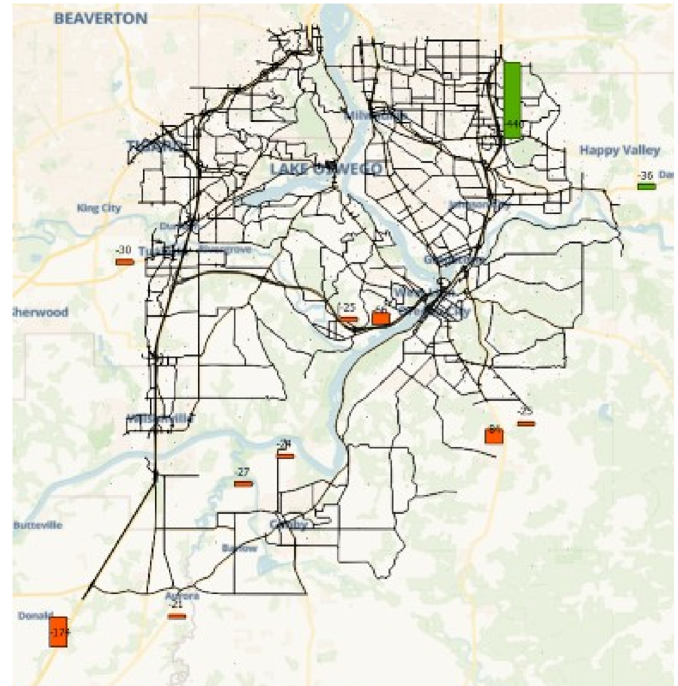



**Figure 7 Comparison of Calibrated to Original Subarea Demand: 8:00-9:00 AM**




Total Difference for Demand Originating
Total Difference for Demand Destined

**Figure 8 Comparison of Calibrated to Original Subarea Demand: 4:00-5:00 PM**

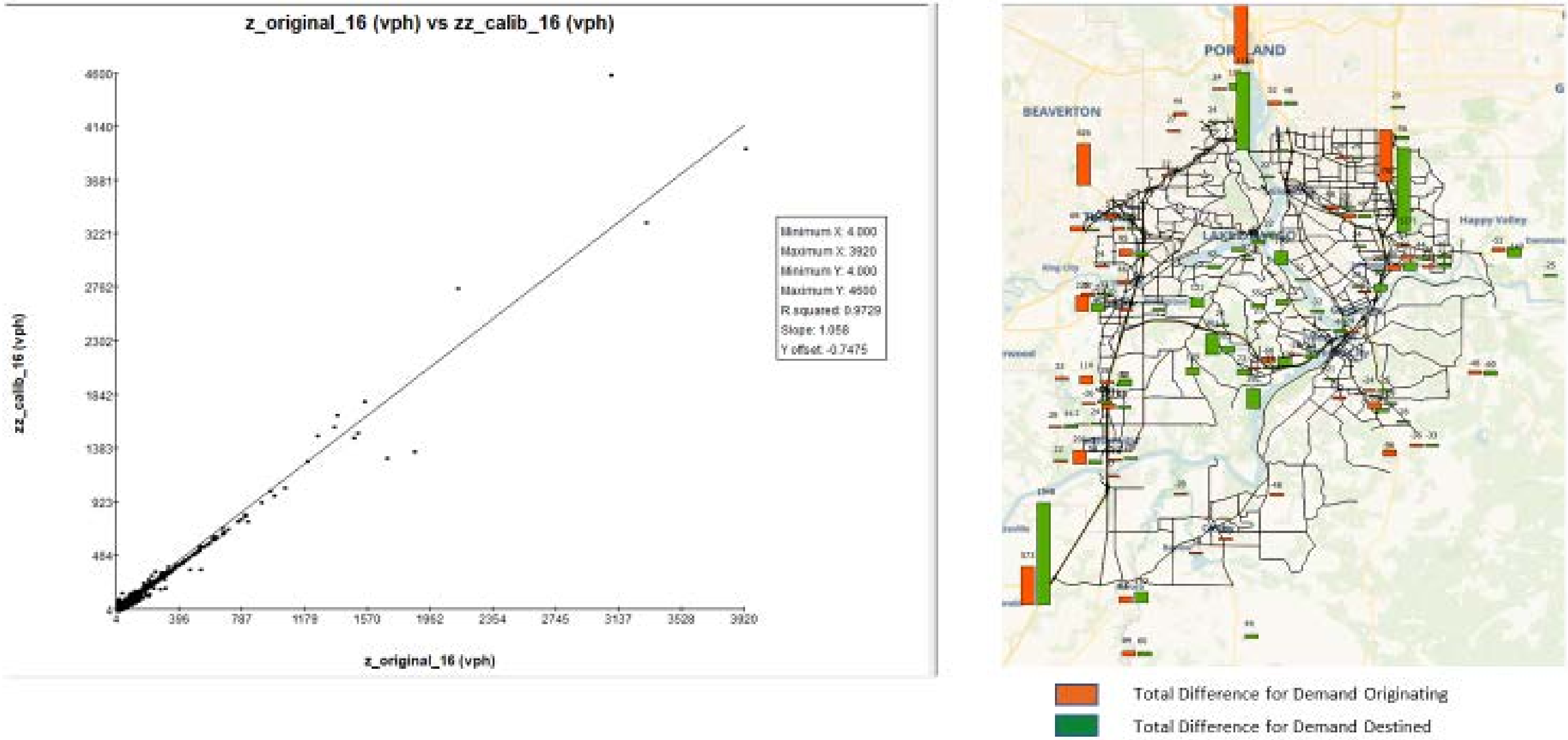
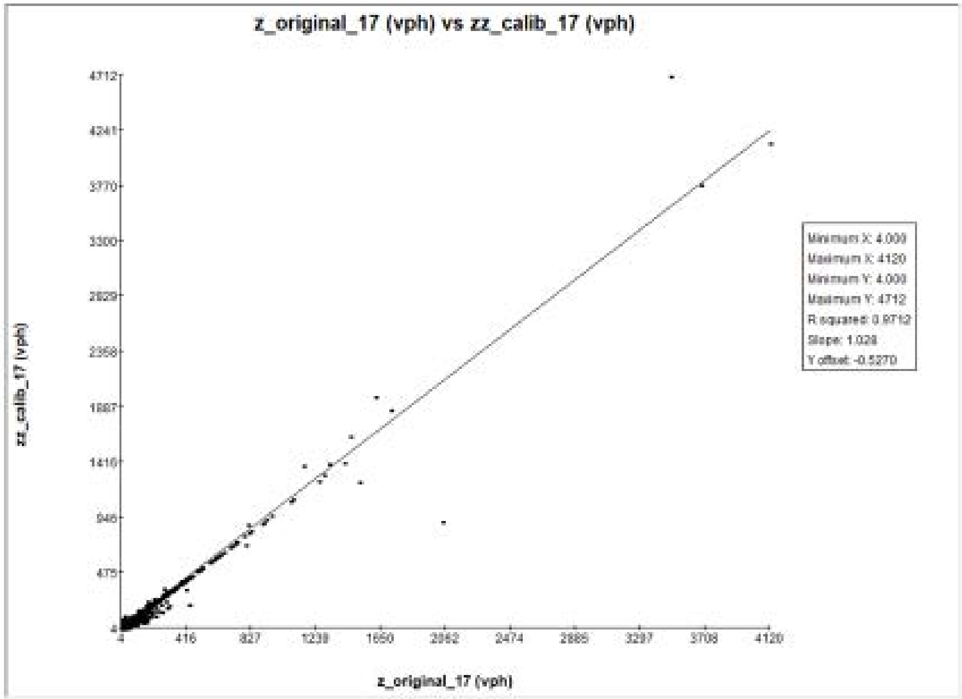
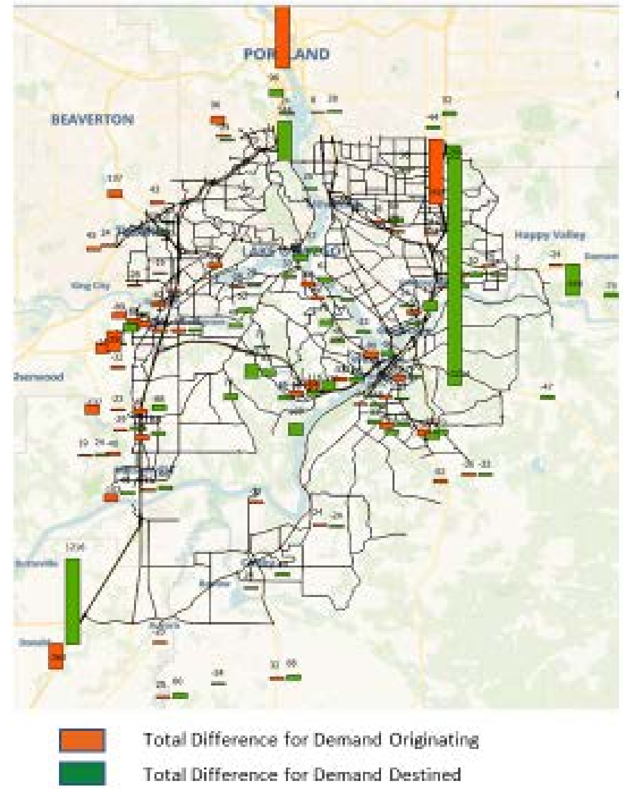


**Figure 9 Comparison of Calibrated to Original Subarea Demand: 5:00-6:00 PM**



#### Subarea DTA Model Validation Targets

While both macroscopic traffic assignment models used in regional travel demand models and microscopic traffic simulation models have well established validation guidelines, currently mesoscopic DTA models do not. The limited guidelines for DTA model validation that do exist are rather general, so this project developed a set of DTA model validation criteria based on a review of validation guidance for both microscopic simulation and macroscopic models.

Federal and State publications of model development guidelines, listed in Appendix B, were reviewed to guide specification of criteria for the I-205 DTA model. While specific validation criteria are not specified in these documents reviewed, there are concepts and examples included that provide some guidance in developing our process. The validation criteria for the base model development are explained in detail in Appendix B.

To guide the validation process, traffic volume and travel time calibration targets were developed as shown in Table 4 and Table 5 for portions of the network considered to be in the model focus area. Measures and values in these tables were developed by the project team and derived from various sources as detailed in Appendix B. Note that because there is no standard calibration metrics for DTA models at this point, the criteria outlined here are considered only to be targets, not hard requirements to be met for calibration

Additionally, for speeds, the ODOT VISSIM Protocol states that "if detailed networkwide travel speeds are available from sources such as the PORTAL database, then speeds in the model shall be within 10 mph of observed real-world spot speed data on at least 85 percent of all freeway links where real-world speed is available for comparison." This target was also assessed for the subarea DTA model validation.

**Table 4. Aggregate Volume Validation Targets**

| Scatter Plot Goodness-of-fit | | DTA Model Area |
|---|---|---|
| Freeways | Trendline Slope | 1.0 +/- 0.04 |
| | Trendline y-intercept | +/- 5% maximum link Count |
| | Trendline $R^2$ | 0.95 |
| Arterials | Trendline Slope | 1.0 +/- 0.08 |
| | Trendline y-intercept | +/- 10% maximum link Count |
| | Trendline $R^2$ | 0.9 |

**Table 5. Corridor Travel Time Validation Targets**

| Corridor Travel Time Comparison Range | | Criteria* | Target Percent for DTA Subarea |
|---|---|---|---|
| Freeways | Observed path time <= 7 minutes | +/- 1 minute | 80% |
| | Observed path time > 7 minutes | +/- 15% of path time | 80% |
| Arterials | Observed path time <= 7 minutes | +/- 1 minute | 75% |
| | Observed path time > 7 minutes | +/- 15% of path time | 75% |

**Criteria based on ODOT VISSIM Protocol*

## Subarea DTA Model Validation and Calibration

#### AM Base Year 2015 DTA Model

### Volume

A common validation measure for volumes involves an aggregate measure of modeled flow compared to observed counts. This is a typical scatter plot where we consider individual link hourly flows/counts with data points for all links where we have counts.  Validation criteria based on the slope of the trend lines of the scatter plots and $R^2$ values are specified.  Figure 10 and Figure 11 show scatter plots and R-squared correlation between I-5 DTA subarea model freeway volumes and traffic counts for the two AM peak hours. The results show a strong correlation between modeled and observed volumes, with R-squared values slightly higher than 0.98 for both hours, which meets and exceeds the target of 0.95 for freeways. Additionally, the y-intercept ranges from -120 to -99. The maximum count volume in both peak hours is approximately 7,200 vph, and the target for freeways is to be within 5% of that—which is 360. Hence, the y-intercept is well within the target for freeways. The target for the trendline slope is 1 +/- 0.04 for freeways. The 7-8 AM hour is close to this value, while the slope for the 8-9 AM hour is 1.14, which exceeds the target value for freeways. Based on this information, the model meets the calibration targets overall, though slightly more closely at 7-8 AM than at 8-9 AM for freeways.

**Figure 10. Scatter Plot – Observed vs DTA Model Freeway Volumes – 7:00 – 8:00 a.m.**

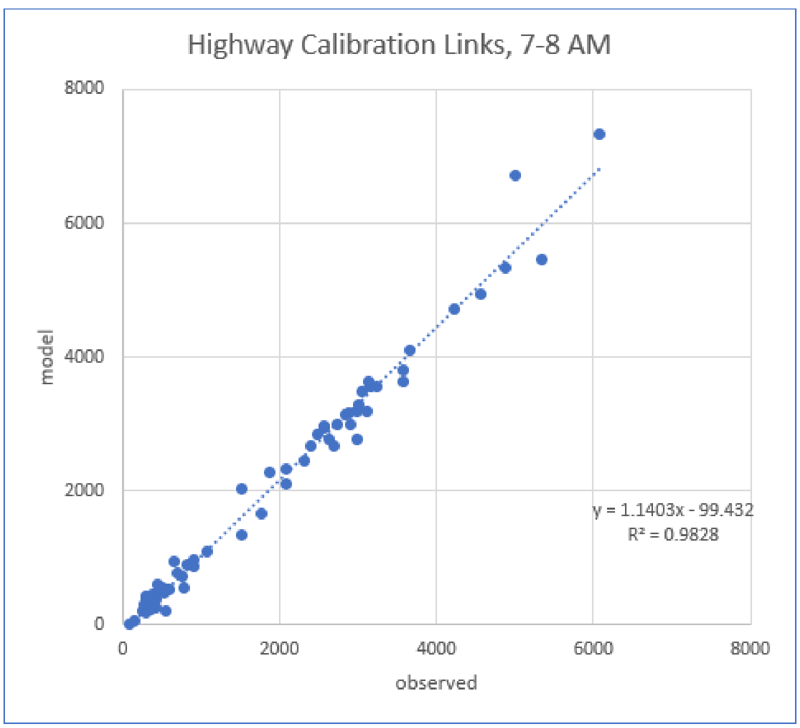


**Figure 11. Scatter Plot – Observed vs DTA Model Freeway Volumes – 8:00 – 9:00 a.m.**

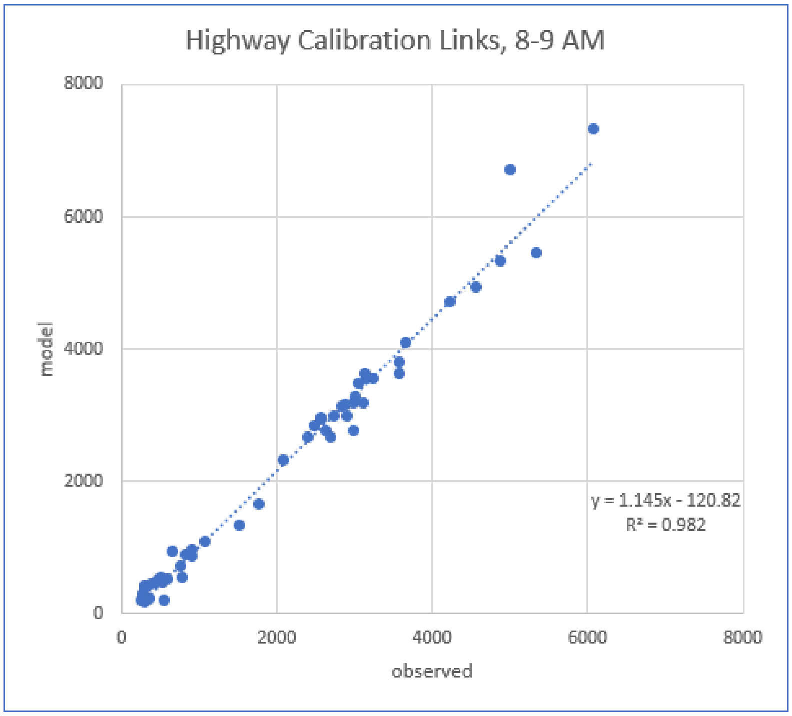



Figure 12 and Figure 13 show scatter plots and R-squared correlation between I-5 DTA subarea model arterial volumes and traffic counts for the two AM peak hours. Although there were fewer data points available on arterials compared to the highway mainline, the results show a relatively strong correlation between modeled and observed volumes, with R-squared values ranging from 0.91 to just under 0.97 for each hour, which meets the project team's target of 0.90 for arterials. Additionally, the y-intercept ranges from -67 to +15. The maximum count volume in both peak hours is approximately 2,500 vph, and the target for arterials is to be within +/-10% of that—which is +/-250. Hence, the y-intercept is well within the targets for arterials. The target for the trendline slope is 1 +/- 0.08 for arterials. The 7-8 AM hour, at 1.0049 is well within this value, while the slope for the 8-9 AM hour is 1.1566, which exceeds the value for arterials. Based on this information, similar as with freeway volumes, the model meets the calibration targets, although slightly more closely at 7-8 AM than at 8-9 AM for arterial volumes.

**Figure 12. Scatter Plot – Observed vs DTA Model Arterial Volumes – 7:00 – 8:00 a.m.**

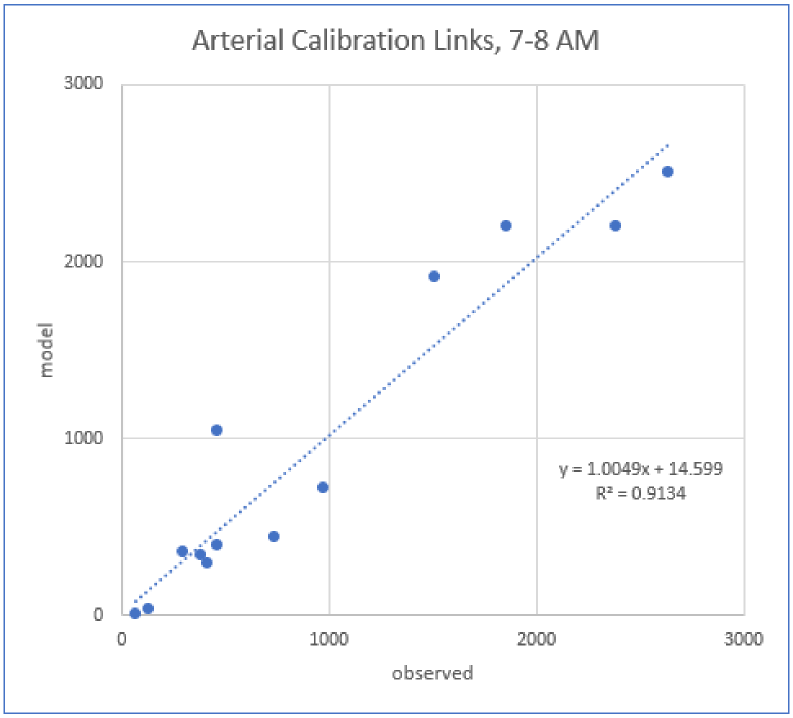
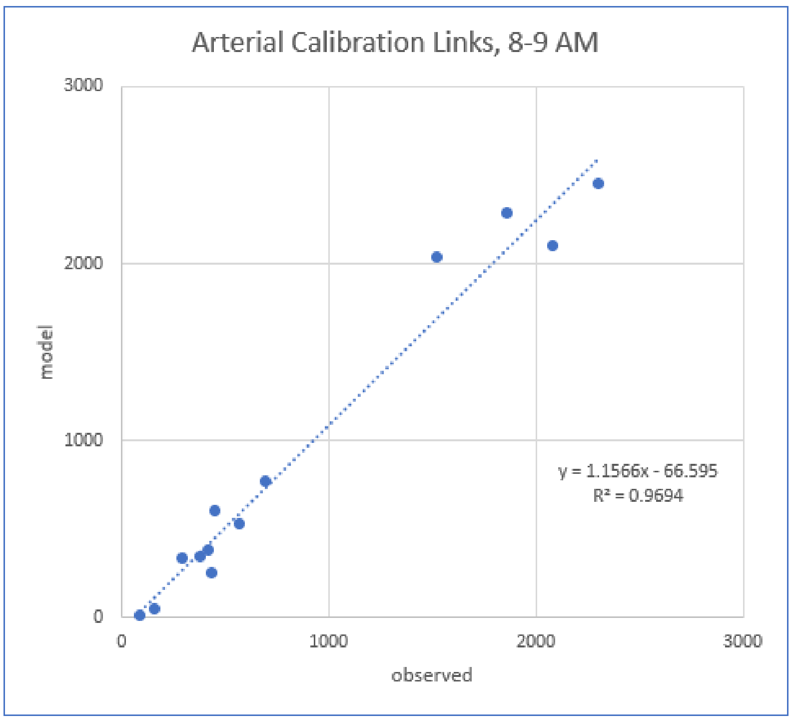



**Figure 13. Scatter Plot – Observed vs DTA Model Arterial Volumes – 8:00 – 9:00 a.m.**



## Travel Time

The list of travel time segments used for calibration is shown in Table 3. Table 6 shows the number and percentage of segments that satisfy the calibration criteria for less than 7 minutes and greater than 7 minutes respectively for Freeways and Arterials in the 2015 base year AM peak period. Results show that for trips under 7 minutes, the model matches observed travel times 92 percent of the time for Freeways and 81 percent of the time for Arterials—both of which are within the targets set for model calibration. In Table 7, results indicate that for trips of 7 minutes or greater, freeway trips are within the target range for 66% of the time, and 75% of the time for arterial trips. The smaller sample size for trips of 7 minutes or longer contributes to the lower percentage of trips within the target range. Figure 14 and Figure 15 show the percentage of travel time segments that are within the calibration range for every 15-minute time interval on Freeways and Arterials, respectively for trips of less than 7 minutes. Every 15-minute interval falls within the percent targets identified for freeways (80% target) and arterials (75% target). Figure 16 and Figure 17 show the percentage of travel time segments that are within the calibration range for every 15-minute time interval on Freeways and Arterials, respectively for trips of 7 minutes or greater. Each 15-minute interval has only 4 observed trips, and 5 of the 8 intervals have 3 out of 4 (75%) trips within the target travel time range. There are 7 arterial segments of 7 minutes or greater, and 4 of the 8 intervals have 86% or more within the target range. The other 4 intervals range from 57% to 71% of trips within the target range. The smaller sample size of observed trips longer than 7 minutes in length contributes to the relatively wide variation between the percentage of time intervals meeting the target range.

**Table 6. 2015 Base Year AM Travel Time Comparison for Trips less than 7 Minutes**

| % of Freeway Routes | | | | Freeway Routes | | | |
|---|---|---|---|---|---|---|---|
| | Slower | Within | Faster | | Slower | Within | Faster |
| 7-9 AM | 4% | 92% | 4% | 7-9 AM | 7 | 162 | 7 |
| **% of Arterial Routes** | | | | **Arterial Routes** | | | |
| | Slower | Within | Faster | | Slower | Within | Faster |
| 7-9 AM | 13% | 81% | 6% | 7-9 AM | 33 | 200 | 15 |

**Table 7. 2015 Base Year AM Travel Time Comparison for Trips of 7 Minutes or Greater**

| % of Freeway Routes | | | | Freeway Routes | | | |
|---|---|---|---|---|---|---|---|
| | Slower | Within | Faster | | Slower | Within | Faster |
| 7-9 AM | 19% | 66% | 16% | 7-9 AM | 6 | 21 | 5 |
| **% of Arterial Routes** | | | | **Arterial Routes** | | | |
| | Slower | Within | Faster | | Slower | Within | Faster |
| 7-9 AM | 16% | 75% | 9% | 7-9 AM | 9 | 42 | 5 |

**Figure 14. 2015 Base Year AM Travel Time Comparison for Freeway Trips Less than 7 Minutes**

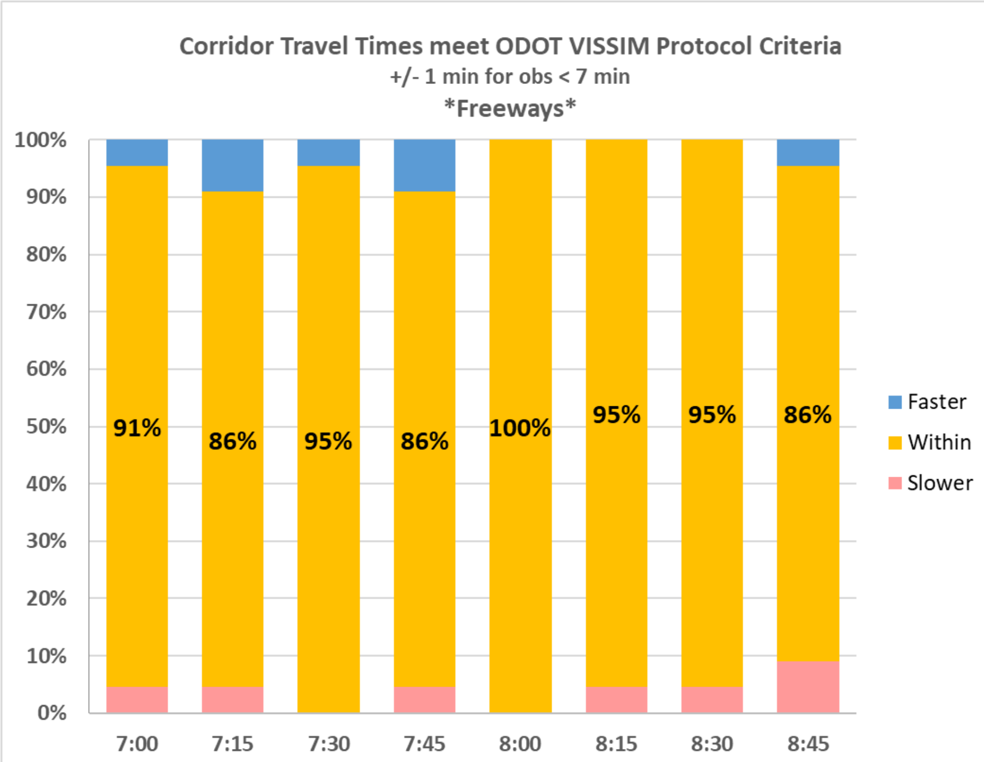



**Figure 15. 2015 Base Year AM Travel Time Comparison for Arterial Trips Less than 7 Minutes**

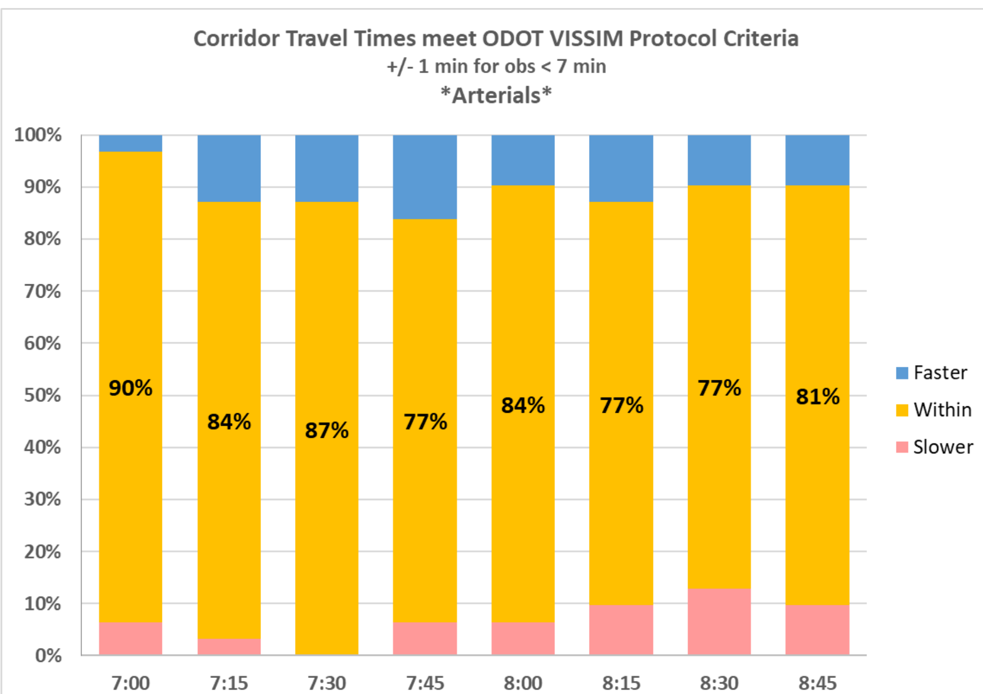


**Figure 16. 2015 Base Year AM Travel Time Comparison for Freeway Trips of 7 Minutes or Greater**

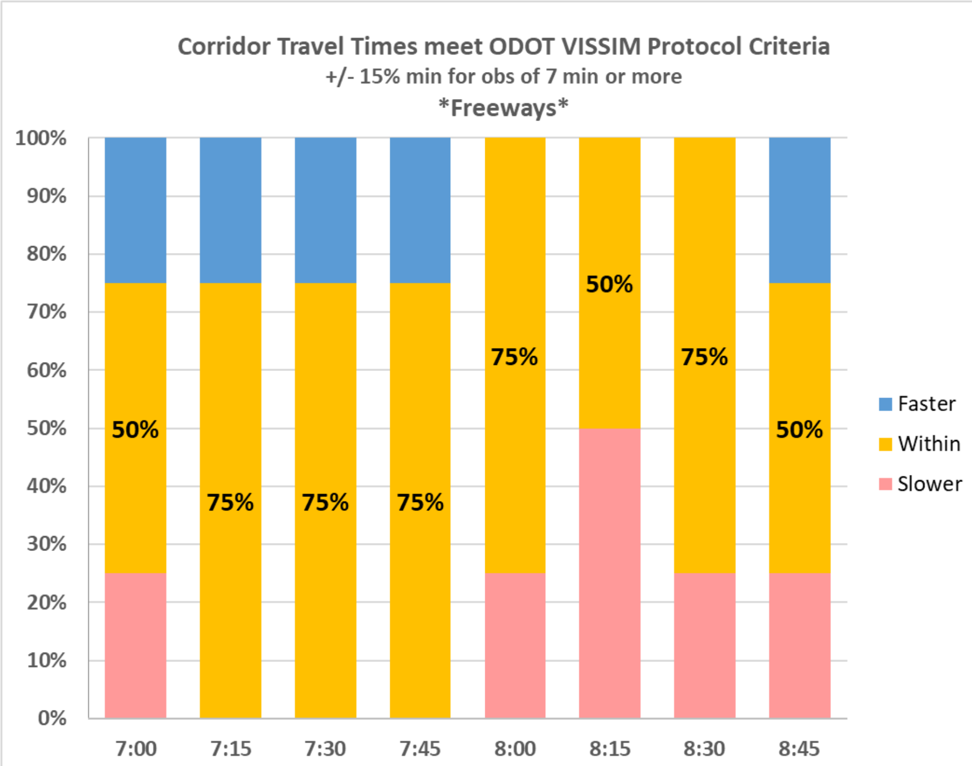



**Figure 17. 2015 Base Year AM Travel Time Comparison for Arterial Trips of 7 Minutes or Greater**

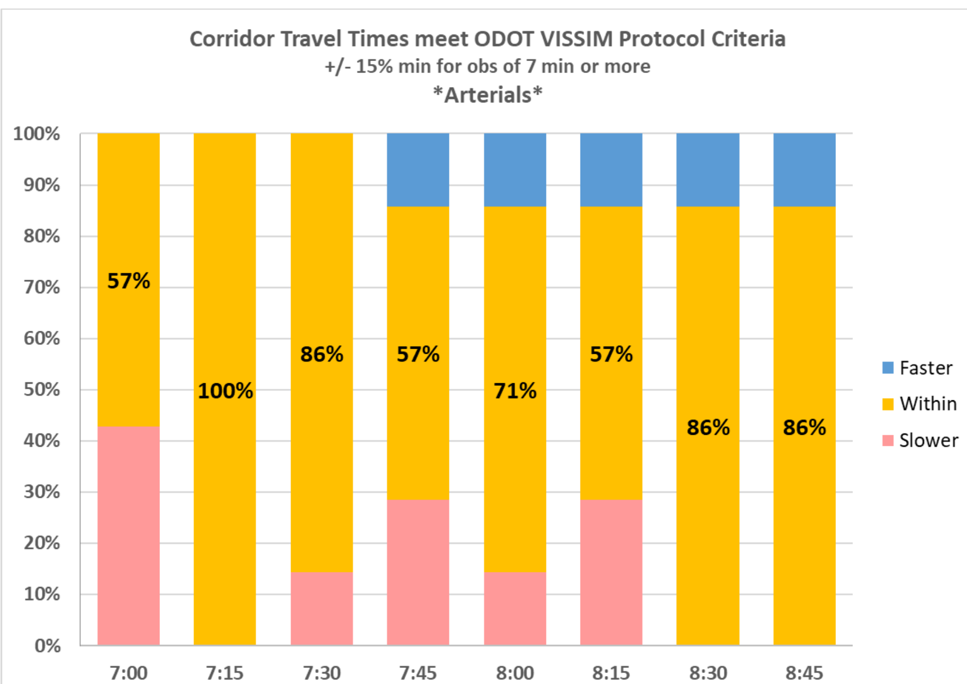



Figure 18 and Figure 19 show the percentage of travel time segments that are within the calibration range for every 15-minute time interval for all trips on Freeways and Arterials, respectively. Every 15-minute interval falls within the percent targets identified for freeways (80% target) and all but one for arterials (75% target).

**Figure 18. 2015 Base Year AM Travel Time Comparison for all Freeways Trips**

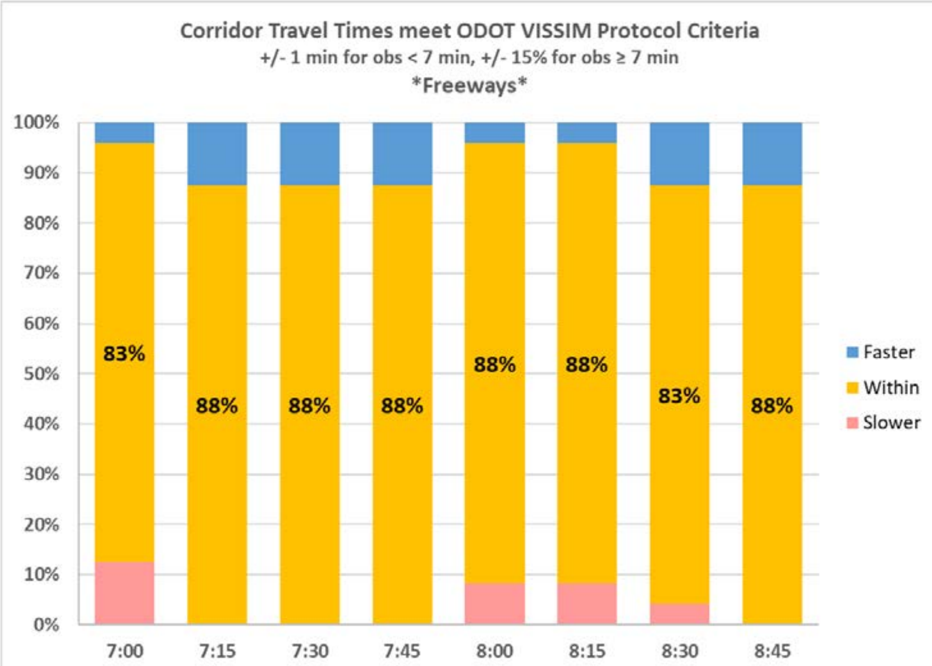
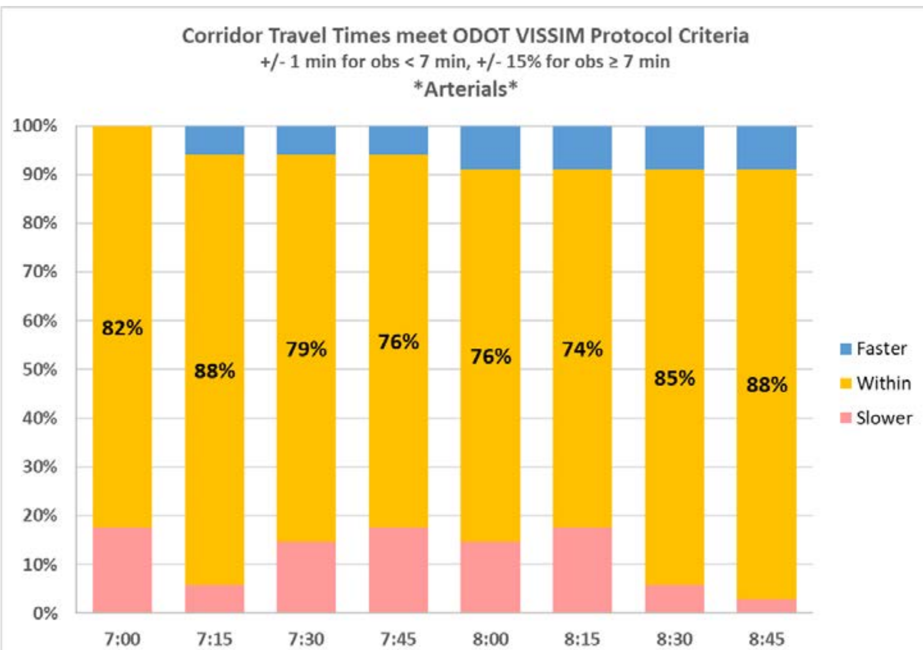



**Figure 19. 2015 Base Year AM Travel Time Comparison for all Arterial Trips**



## Speeds

### Freeway Speeds

Table 8 and Table 9 show comparisons of the 2015 base year hourly speeds from INRIX (observed data) and from Dynameq (modeled data) along I-205 in the AM peak period for the southbound and northbound directions, respectively. These hourly comparisons are important because data from the model will feed into analyses conducted on hourly increments. To see a finer level of detail for calibration purposes, Table 10 and Table 11 show similar comparisons for 15-minute increments of time for the AM southbound and northbound directions respectively.

For the southbound direction (Table 8), the hourly INRIX data reflects slow speeds from Gladstone across the Abernethy Bridge (OR 99E to OR 43). The Dynameq DTA model shows a similar pattern as well, though speeds are estimated to be a little bit faster in the model across the bridge. Between the bridge and I-5, speeds increase notably with the observed data, and the modeled speeds show a similar increase. Overall, the average speed between Gladstone and I-5 is very similar between the observed and modeled data for southbound I-205 in the AM peak period. Looking at the 15-minute comparisons in Table 10, the trend is similar to the hourly comparison; however, observed speeds match the DTA model speeds better during the middle of the 2-hour peak period, and diverge more at the beginning and the end of the period. As stated previously, the ODOT VISSIM Protocol indicates that speeds can be considered reasonably calibrated when the model speeds are within +/- 10 mph of observed for at least 85% of the time. Of the 48 speed comparisons for I-205 southbound the AM peak period, 40, or 83% were within the desired measure—which is very close to meeting the target of 85%.

For the northbound direction (Table 9) the observed hourly data reflects relatively good speeds ranging from 54 to 61 mph through the corridor. The modeled data also reflect relatively high speeds, though a bit slower than observed, ranging between 50 and 54 mph. The average speed for the overall corridor reflects a similar pattern, with both observed and modeled speeds being relatively high, but the modeled speeds are somewhat lower. Looking at the 15-minute comparisons in Table 11, the trend is similar to the hourly comparison, with DTA model speeds being consistently slightly lower than observed. Of the 48 speed comparisons for I-205 northbound in the AM peak period, 45, or 94% were within the desired measure of being within +/- 10 mph of observed.

Figure 20 and Figure 21 show plots comparing average speeds across the project corridor between observed and modeled data for the AM peak period for southbound and northbound I-205 respectively. Averaged across the corridor, the DTA model is within +/- 10 mph of the observed speeds for all 15-minute intervals in both directions.

**Table 8. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, Hourly Increments, I-205 Southbound Direction**

| From | To | INRIX Average Speed | | Dynameq Average Speed | |
|---|---|---|---|---|---|
| | | 7:00 -8:00 AM | 8:00 - 9:00 AM | 7:00 -8:00 AM | 8:00 - 9:00 AM |
| Gladstone | OR 213 | 15 | 15 | 13 | 18 |
| OR 213 | OR 99E | 20 | 20 | 19 | 19 |
| OR 99E | OR 43 | 28 | 28 | 34 | 42 |
| OR 43 | 10th St | 45 | 45 | 53 | 54 |
| 10th St | Stafford Rd | 55 | 57 | 59 | 59 |
| Stafford Rd | I-5 split | 63 | 63 | 59 | 55 |
| **Full Corridor** | | | | | |
| Gladstone | I-5 split | 38 | 39 | 39 | 42 |

**Table 9. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, Hourly Increments, I-205 Northbound Direction**

| From | To | INRIX Average Speed | | Dynameq Average Speed | |
|---|---|---|---|---|---|
| | | 7:00 -8:00 AM | 8:00 - 9:00 AM | 7:00 -8:00 AM | 8:00 - 9:00 AM |
| I-5 ramps | Stafford Rd | 61 | 61 | 54 | 54 |
| Stafford Rd | 10th St | 60 | 59 | 54 | 51 |
| 10th St | OR 43 | 58 | 58 | 53 | 51 |
| OR 43 | OR 99E | 54 | 55 | 52 | 53 |
| OR 99E | OR 213 | 58 | 58 | 52 | 53 |
| OR 213 | Gladstone | 55 | 58 | 50 | 51 |
| **Full Corridor** | | | | | |
| I-5 ramps | Gladstone | 59 | 59 | 53 | 52 |

**Table 10. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, 15-Minute Increments, I-205 Southbound Direction**

| From | To | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | |
| | | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 |
| Gladstone | OR 213 | 18 | 16 | 14 | 13 | 15 | 15 | 15 | 15 | 10 | 11 | 14 | 19 | 16 | 12 | 21 | 26 |
| OR 213 | OR 99E | 23 | 20 | 19 | 17 | 18 | 21 | 20 | 21 | 16 | 19 | 21 | 20 | 17 | 18 | 19 | 26 |
| OR 99E | OR 43 | 32 | 27 | 26 | 26 | 28 | 30 | 26 | 29 | 31 | 34 | 39 | 34 | 36 | 40 | 45 | 48 |
| OR 43 | 10th St | 45 | 45 | 46 | 43 | 45 | 46 | 44 | 47 | 53 | 54 | 53 | 53 | 54 | 54 | 54 | 54 |
| 10th St | Stafford Rd | 55 | 56 | 55 | 54 | 55 | 57 | 59 | 58 | 59 | 59 | 59 | 59 | 59 | 60 | 60 | 60 |
| Stafford Rd | I-5 split | 64 | 63 | 62 | 63 | 63 | 64 | 63 | 63 | 59 | 59 | 59 | 59 | 59 | 49 | 52 | 59 |

**Table 11. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, 15-Minute Increments, I-205 Northbound Direction**

| From | To | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | |
| | | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 |
| I-5 ramps | Stafford Rd | 62 | 61 | 61 | 61 | 61 | 61 | 62 | 61 | 54 | 55 | 54 | 52 | 53 | 54 | 55 | 55 |
| Stafford Rd | 10th St | 61 | 60 | 59 | 59 | 59 | 60 | 60 | 59 | 55 | 55 | 54 | 54 | 47 | 47 | 55 | 55 |
| 10th St | OR 43 | 59 | 59 | 57 | 57 | 58 | 58 | 59 | 57 | 53 | 55 | 53 | 50 | 45 | 49 | 55 | 55 |
| OR 43 | OR 99E | 55 | 55 | 53 | 53 | 55 | 55 | 54 | 54 | 53 | 54 | 53 | 49 | 52 | 52 | 54 | 54 |
| OR 99E | OR 213 | 58 | 58 | 57 | 57 | 58 | 58 | 59 | 58 | 51 | 54 | 52 | 50 | 51 | 52 | 54 | 54 |
| Stafford Rd | Gladstone | 58 | 57 | 49 | 54 | 57 | 57 | 57 | 59 | 49 | 52 | 50 | 50 | 50 | 51 | 52 | 53 |

**Figure 20. 2015 Base Observed vs Modeled Speeds across Project Corridor: AM 2-hr Peak, 15-Minute Increments, I-205 Southbound Direction**

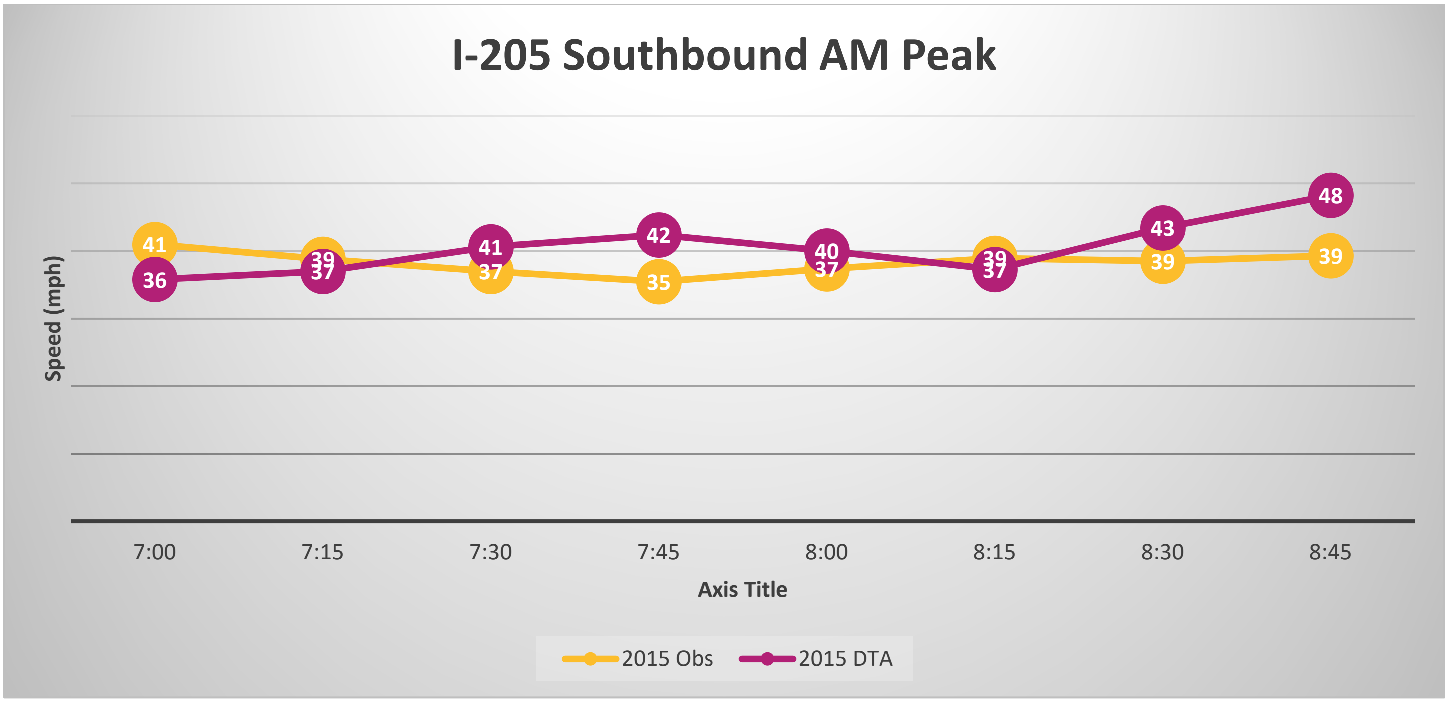
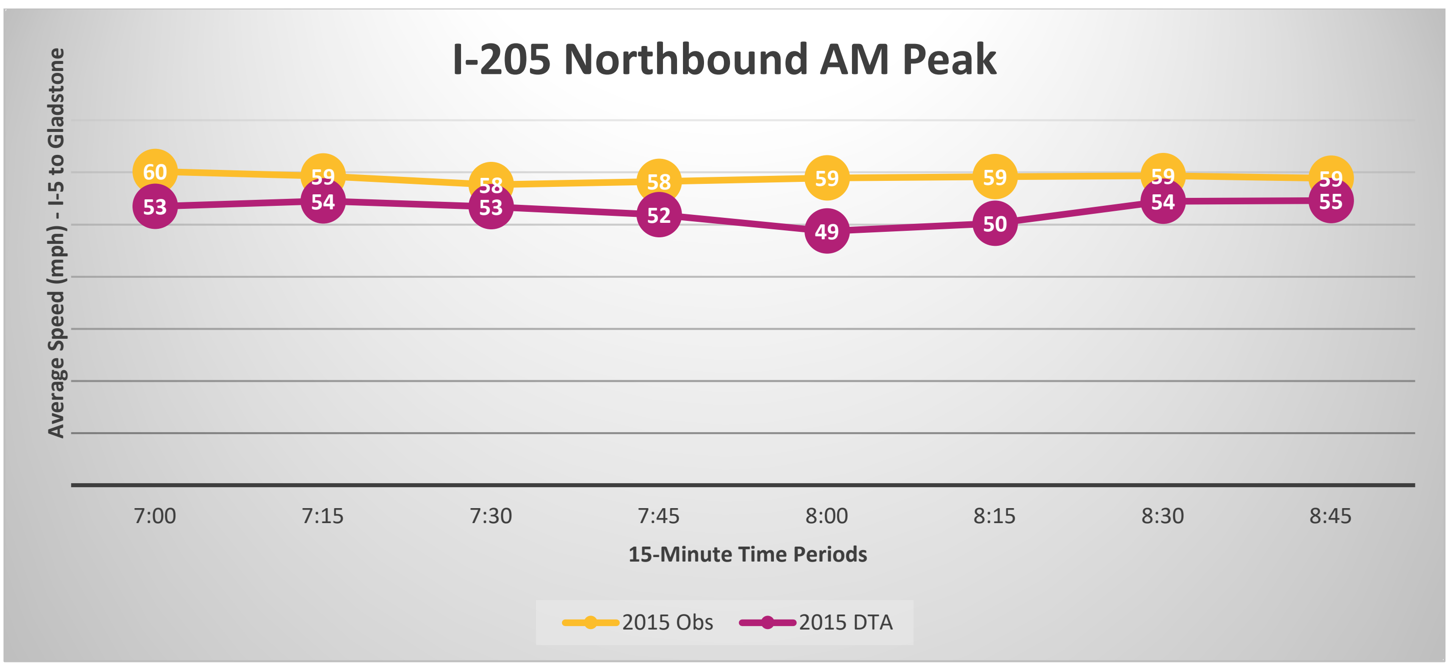



**Figure 21. 2015 Base Observed vs Modeled Speeds across Project Corridor: AM 2-hr Peak, 15-Minute Increments, I-205 Northbound Direction**




### Arterial Speeds

Table 12 and Table 13 show comparisons of the 2015 base year 15-minute increment speeds from INRIX (observed data) and from Dynameq (modeled data) along OR 99E between Gladstone (River Road) and Canby (Grant Road) in the AM peak period for the southbound and northbound directions, respectively. This section of OR 99E was chosen to assess calibration performance more closely because it would be a likely diversion route once tolls are implemented on I-205.

For the southbound direction (Table 12), the Dynameq speeds fall within +/- 10 mph of the INRIX for all except the first 15-minute interval through the I-205 interchange and downtown Oregon City (between Concord Road and Railroad Avenue), where the Dynameq DTA model shows considerably slower speeds. This shows that the model matches the desired speed range for 95% of the segments and intervals analyzed. For the northbound direction (Table 13) the Dynameq speeds fall within +/- 10 mph of the INRIX speeds for all segments and time periods, indicating a high level of calibration.

Figure 22 and Figure 23 show plots comparing average observed versus modeled speeds across the OR 99E corridor between Oregon City (15th Street) and Canby (Grant Street) for the AM peak period for the southbound and northbound directions respectively. Averaged across the corridor, the DTA model is within +/- 10 mph of the observed speeds for all 15-minute time periods, indicating that this corridor is relatively well calibrated for the AM peak period in both directions.

Table 14 and Table 15 show comparisons of the 2015 base year 15-minute increment speeds from INRIX (observed data) and from Dynameq (modeled data) along Willamette Falls Drive/Borland Road between OR 43 and Stafford Road in the AM peak period for the westbound and eastbound directions, respectively. This section of roadway was also chosen to assess calibration performance more closely because it would be a likely diversion route once tolls are implemented on I-205.

For the westbound direction (Table 14), the Dynameq speeds fall within +/- 3 mph of the INRIX speeds for all 15-minute intervals, easily meeting the criteria of +/- 10 mph. For the eastbound direction (Table 15) the Dynameq speeds fall within +/- 10 mph of the INRIX speeds for all segments and time periods except for the three intervals between 7:45 and 8:30 a.m., where the Dynameq model speeds are notably lower than observed. This may be an indication that the model projects more congestion on WFD for the segment approaching the unsignalized intersection with OR 43 than was observed, hence overestimating congestion at this location. Despite this difference, the model meets the desired criteria across all segments and time periods 81% of the time.

Figure 24 and Figure 25 show plots comparing average observed versus modeled speeds across the Willamette Falls Drive/Borland Road corridor between OR 43 and Stafford Road for the AM peak period for the westbound and eastbound directions respectively. Averaged across the corridor, the DTA model is within +/- 10 mph of the observed speeds for all 15-minute time periods, indicating that this corridor is relatively well calibrated for the AM peak period in both directions. However, it is noted that the largest differences between the speeds occurs on eastbound WFD approaching OR 43, where modeled speeds are lower than observed.

**Table 12. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, 15-Minute Increments, OR 99E Southbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | |
| From | To | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 |
| River Rd | Concord Rd | 33 | 34 | 33 | 33 | 33 | 32 | 33 | 34 | 33 | 33 | 33 | 33 | 33 | 33 | 34 | 33 |
| Concord Rd | 15th St (OC) | 32 | 29 | 30 | 27 | 27 | 28 | 31 | 31 | 19 | 30 | 23 | 22 | 19 | 19 | 29 | 31 |
| 15th St (OC) | Railroad Ave | 26 | 26 | 26 | 25 | 25 | 25 | 25 | 25 | 12 | 21 | 21 | 20 | 19 | 23 | 21 | 22 |
| Main St | South End | 49 | 49 | 49 | 49 | 50 | 49 | 48 | 49 | 48 | 48 | 48 | 47 | 48 | 48 | 48 | 48 |
| South End | Grant St (Canby) | 40 | 41 | 37 | 38 | 38 | 39 | 38 | 39 | 36 | 35 | 34 | 35 | 35 | 35 | 35 | 35 |

**Table 13. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, 15-Minute Increments, OR 99E Northbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | |
| From | To | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 |
| Grant St (Canby) | South End | 42 | 41 | 37 | 40 | 40 | 39 | 39 | 39 | 35 | 35 | 35 | 36 | 36 | 37 | 36 | 36 |
| South End | Main St | 48 | 47 | 46 | 47 | 47 | 47 | 49 | 48 | 43 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| Main St | I-205 SB | 17 | 16 | 14 | 12 | 11 | 15 | 15 | 15 | 9 | 13 | 13 | 10 | 14 | 18 | 21 | 20 |
| I-205 SB | Concord Rd | 35 | 35 | 34 | 32 | 31 | 33 | 33 | 33 | 33 | 32 | 33 | 32 | 32 | 33 | 32 | 33 |
| Concord Rd | River Rd | 33 | 33 | 32 | 31 | 33 | 30 | 34 | 33 | 31 | 31 | 30 | 31 | 32 | 33 | 32 | 33 |

**Figure 22. 2015 Base Observed vs Modeled Speeds across Project Corridor: AM 15-Minute Increments, OR 99E Southbound Direction Oregon City to Canby**

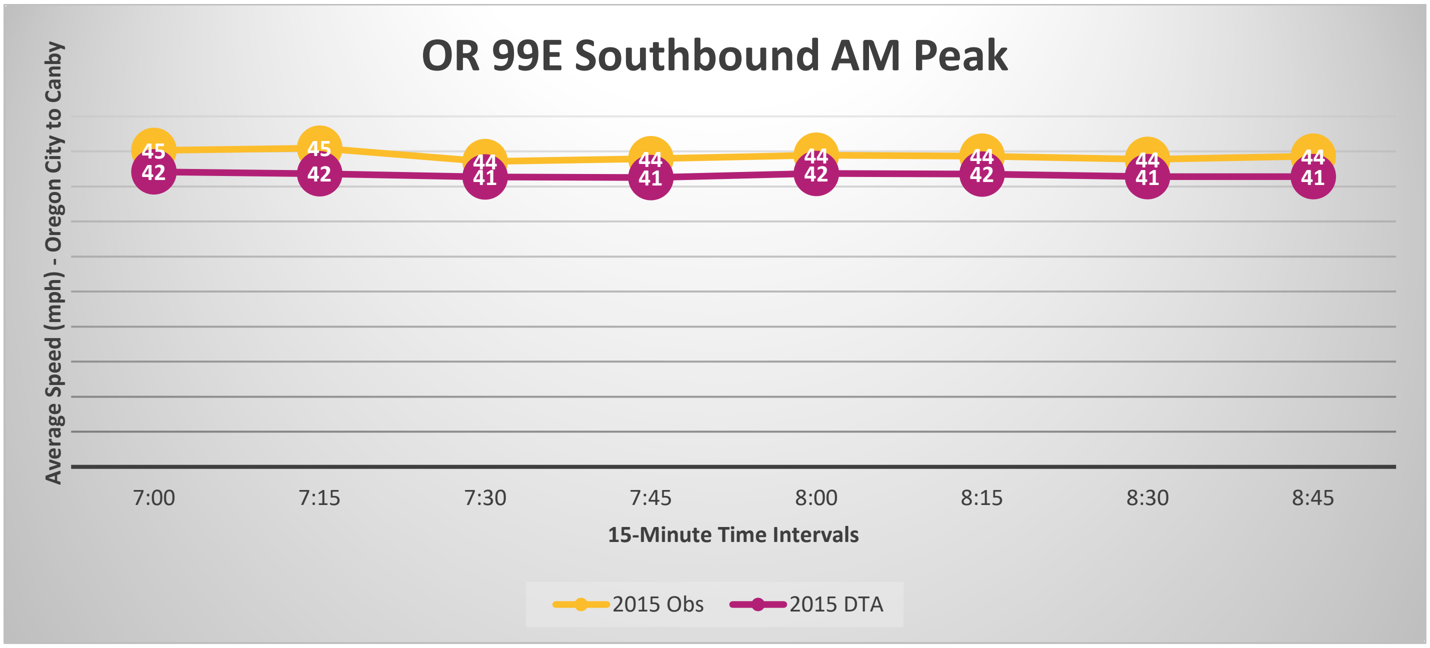



**Figure 23. 2015 Base Observed vs Modeled Speeds across Project Corridor: AM 15-Minute Increments, OR 99E Northbound Direction Canby to Oregon City**

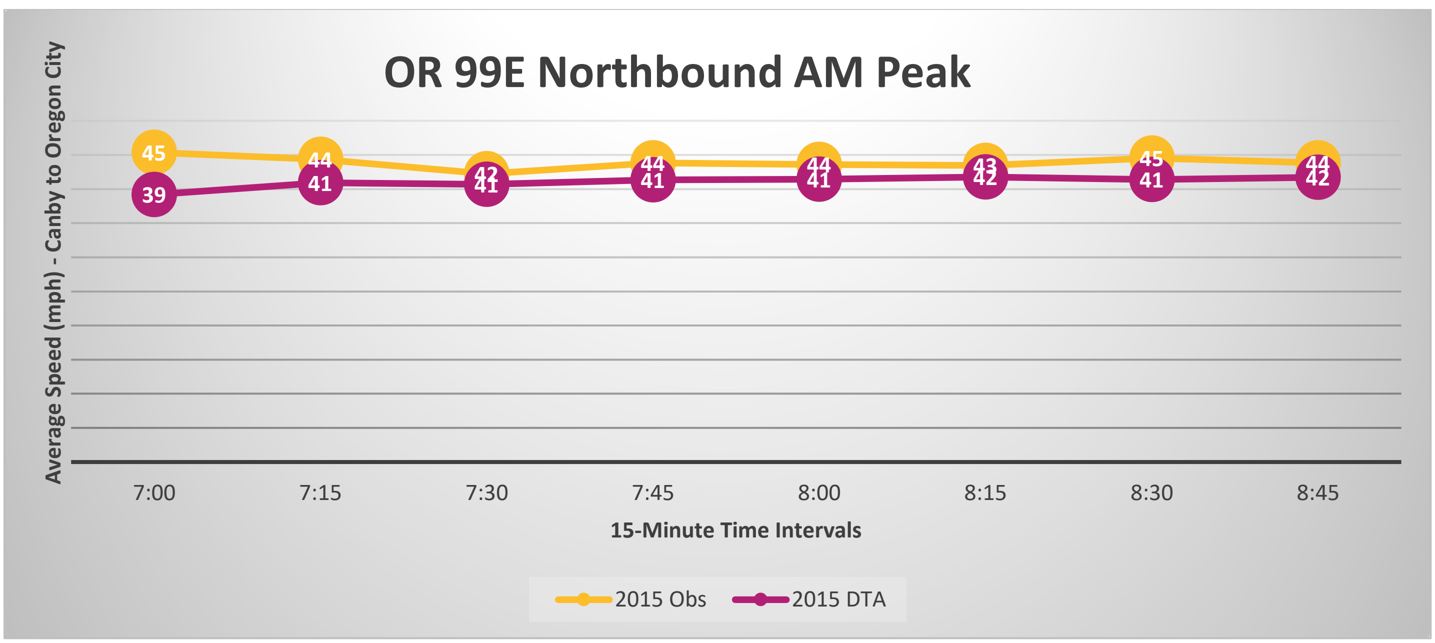


**Table 14. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, 15-Minute Increments, WFD/Borland Rd Westbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | |
| From | To | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 |
| OR-43 | 10th St | 37 | 37 | 37 | 36 | 36 | 37 | 36 | 37 | 38 | 38 | 38 | 38 | 37 | 38 | 38 | 38 |
| 10th St | Stafford Rd | 35 | 34 | 34 | 34 | 34 | 34 | 34 | 34 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |

**Table 15. 2015 Base Observed vs Modeled Speeds: AM 2-hr Peak, 15-Minute Increments, WFD/Borland Rd Eastbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | | 7:00 - 8:00 AM | | | | 8:00 - 9:00 AM | | | |
| From | To | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 | 7:00 | 7:15 | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 |
| Stafford Rd | 10th St | 33 | 33 | 33 | 33 | 32 | 33 | 33 | 33 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| 10th St | OR-43 | 36 | 35 | 35 | 35 | 34 | 35 | 34 | 33 | 29 | 35 | 26 | 24 | 18 | 21 | 37 | 35 |

**Figure 24. 2015 Base Observed vs Modeled Speeds across Project Corridor: AM 15-Minute Increments, Willamette Falls Drive/Borland Road Westbound Direction**

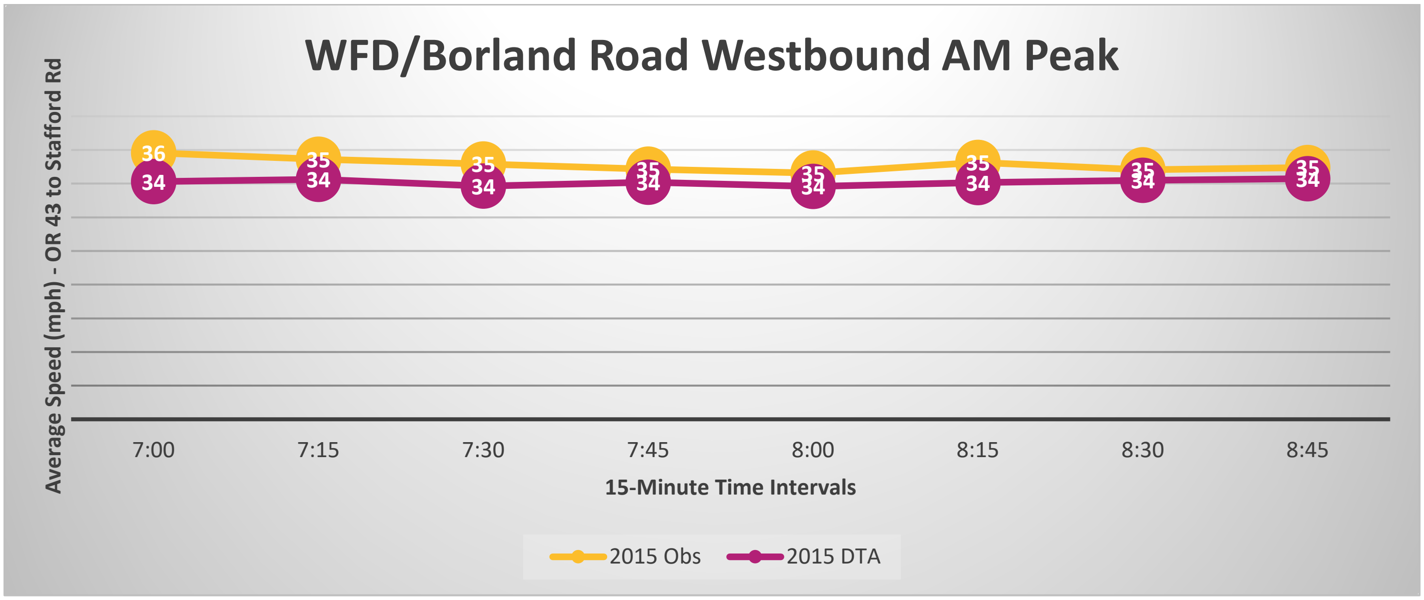
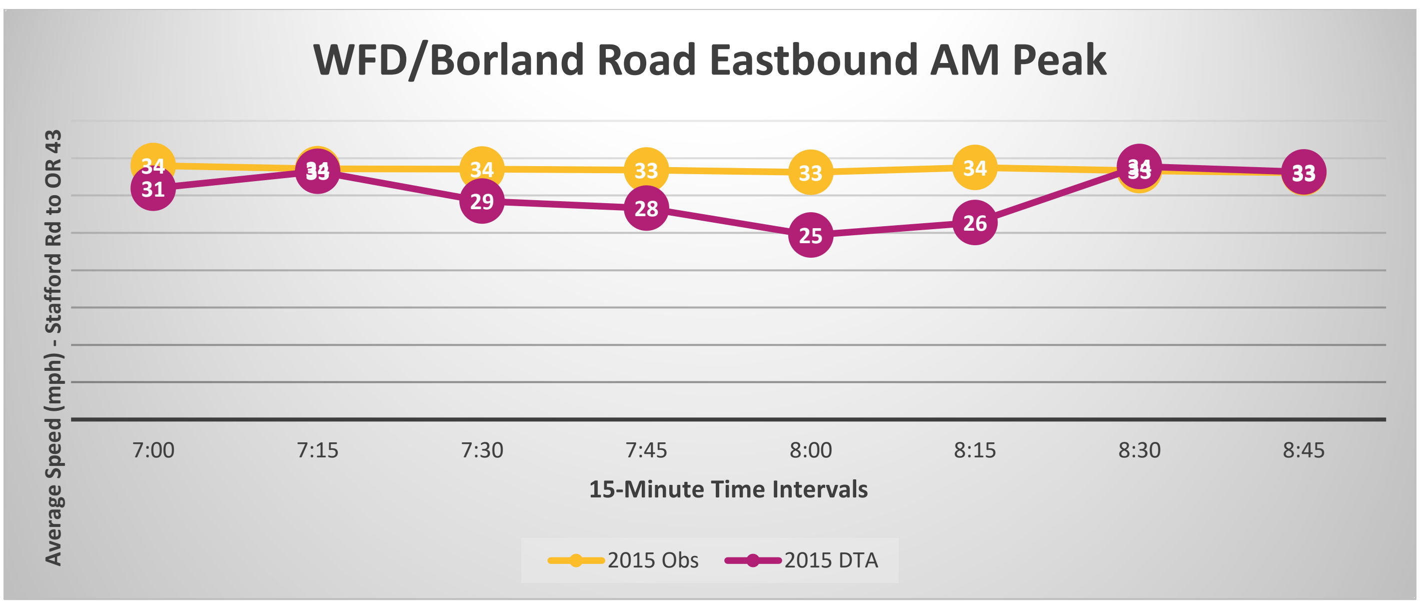



**Figure 25. 2015 Base Observed vs Modeled Speeds across Project Corridor: AM 15-Minute Increments, Willamette Falls Drive/Borland Road Eastbound Direction**




### PM Base Year 2015 DTA Model

## Volume

Figure 26 and Figure 27 show scatter plots and R-squared correlation between I-5 DTA subarea model freeway volumes and traffic counts for the two PM peak hours. Similar to the AM peak hours, the results show a relatively strong correlation between modeled and observed volumes, with R-squared values ranging between

0.976 and 0.982 across both hours, which surpasses the target of 0.95 for freeways. Additionally, the y-intercept ranges from -73 to -50. The maximum count volume in both peak hours is approximately 7,000 vph, and the target for freeways is to be within 5% of that—which is 350. Hence, the y-intercept is well within the target for freeways. The target for the trendline slope is 1 +/- 0.04 for freeways. The 4-5 PM hour slope at 1.057 is slightly higher than the target, while the slope for the 5-6 PM hour is 1.02, which is within the target range for freeways. Based on this information, the model meets the calibration targets for both the PM peak hours.

**Figure 26. Scatter Plot – Observed vs DTA Model Freeway Volumes – 4:00 – 5:00 p.m.**

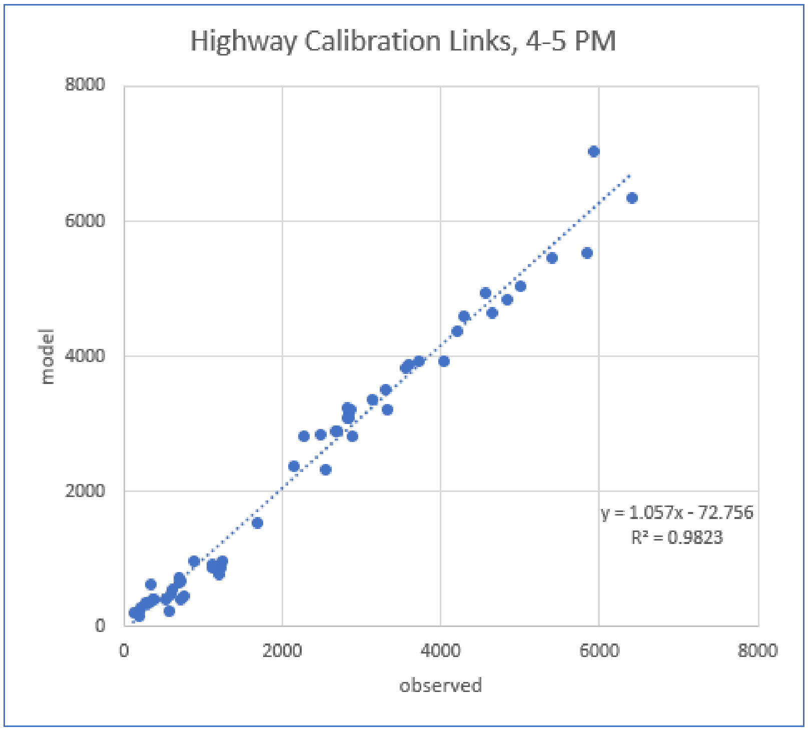


**Figure 27. Scatter Plot – Observed vs DTA Model Freeway Volumes – 5:00 – 6:00 p.m.**

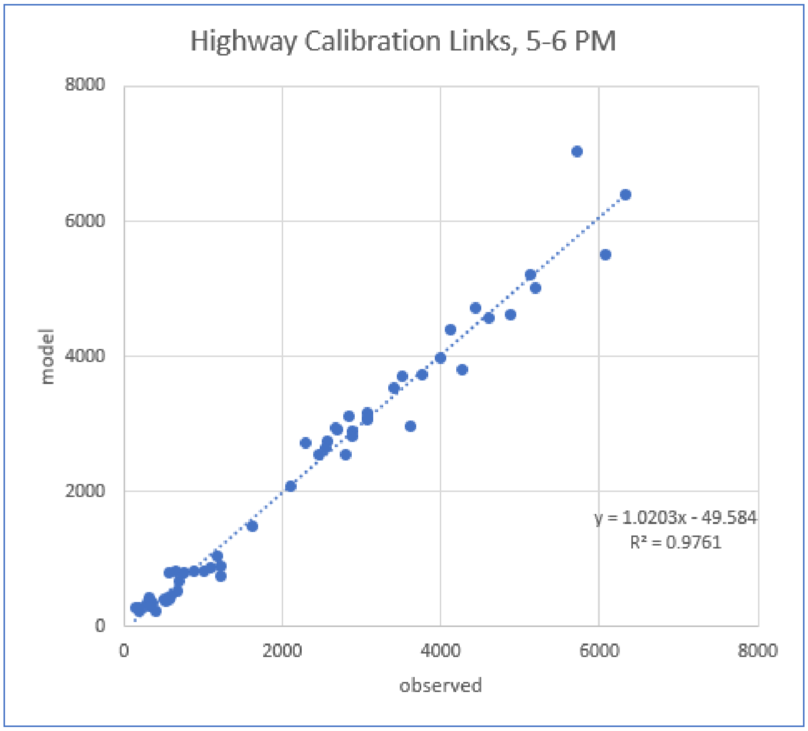



Figure 28 and Figure 29 show scatter plots and R-squared correlation between I-5 DTA subarea model arterial volumes and traffic counts for the two PM peak hours. The results show a strong correlation between modeled and observed volumes, with R-squared values ranging from just under 0.98 to 0.99 for each hour, which well exceeds our target of 0.90 for arterials. Additionally, the y-intercept ranges from -142 to -100. The maximum count volume in the 4-5 PM hour is approximately 3,000 vph and for the 5-6 PM hour 2,300 vph. The target for arterials is to be within +/-10% of the maximum count—which is +/-350 and 230 respectively. Hence, the y-intercept for both hours is well within the targets for arterials. The target for the trendline slope is 1 +/- 0.08 for arterials. The trendline slope ranges from 1.10 to 1.14 for the two hours, which are not within the target value for arterials. Based on this information, the model meets the calibration targets, though more closely for freeways than for arterials in the PM peak period.

**Figure 28. Scatter Plot – Observed vs DTA Model Arterial Volumes – 4:00 – 5:00 p.m.**

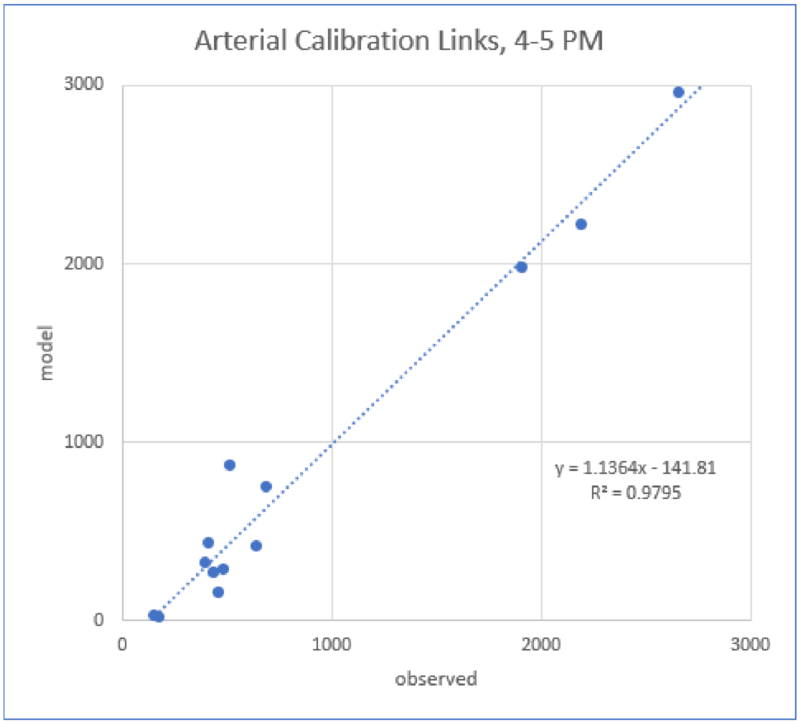
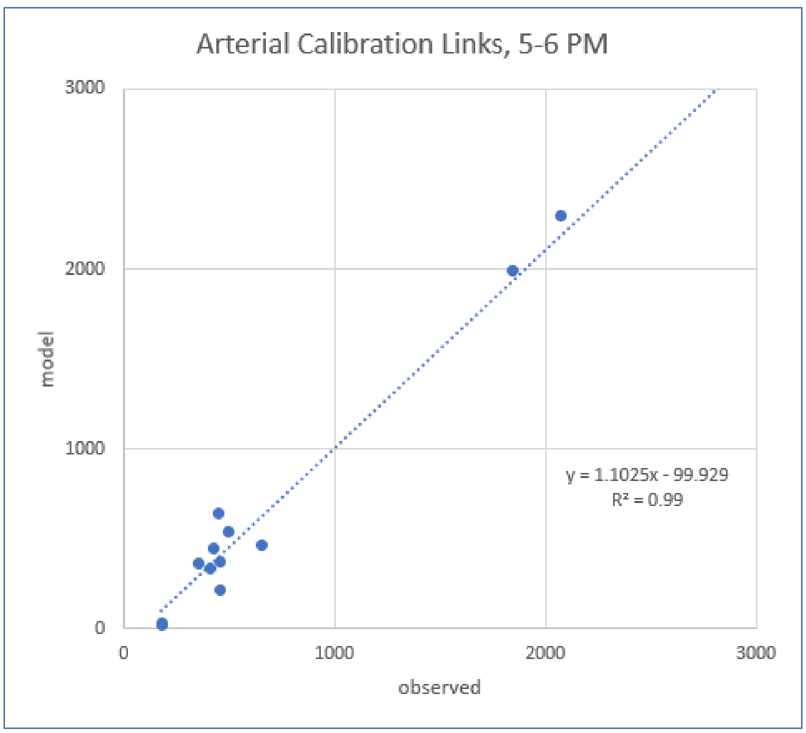



**Figure 29. Scatter Plot – Observed vs DTA Model Arterial Volumes – 5:00 – 6:00 p.m.**



### Travel Time

The list of travel time segments is shown in Table 3. Table 16 and Table 17 show the number and percentage of segments that satisfy the calibration criteria for less than 7 minutes and greater than 7 minutes respectively for Freeways and Arterials in the 2015 base year PM peak period. Results show that for trips under 7 minutes, the model matches observed travel times 80 percent of the time for Freeways and 82 percent of the time for Arterials—both of which are within the targets set for model calibration. In Table 17, results indicate that for trips of 7 minutes or greater, freeway trips are within the target range for 66% of the time, and 75% of the time for arterial trips. The smaller sample size for trips of 7 minutes or longer contributes to the lower percentage of trips within the target range.

Figure 30 and Figure 31 show the percentage of PM peak period travel time segments that are within the calibration range for every 15-minute time interval on Freeways and Arterials, respectively for trips of less than 7 minutes. Four of the eight 15-minute intervals fall within the percent targets identified for freeways (80% target), and the other four are close at 77%. All of the time intervals fall within the identified target range for arterials (75% target). Figure 32 and Figure 33 show the percentage of travel time segments that are within the calibration range for every 15-minute time interval on Freeways and Arterials, respectively for trips of 7 minutes or greater. Each 15-minute interval for freeways has only 4 observed trips, and 5 of the 8 intervals have 3 out of 4 (75%) trips within the target travel time range, one has 100% within the range, and the remaining two are at 50%. The smaller sample size of observed trips longer than 7 minutes in length contributes to the relatively wide variation between the percentage of time intervals meeting the target range. There are 7 arterial segments reflecting travel times of 7 minutes or greater, and all of the intervals have 86% or more within the target range.

**Table 16. 2015 Base Year PM Travel Time comparison for Trips less than 7 Minutes**

| Freeways | | | | Freeways | | | |
|---|---|---|---|---|---|---|---|
| | Slower | Within | Faster | | Slower | Within | Faster |
| **4-6 PM** | 9% | 80% | 11% | **4-6 PM** | 15 | 141 | 20 |
| **Arterials** | | | | **Arterials** | | | |
| | Slower | Within | Faster | | Slower | Within | Faster |
| **4-6 PM** | 7% | 82% | 11% | **4-6 PM** | 17 | 204 | 27 |

**Table 17. 2015 Base Year PM Travel Time comparison for Trips of 7 Minutes or Greater**

| Freeways | | | | Freeways | | | |
|---|---|---|---|---|---|---|---|
| | Slower | Within | Faster | | Slower | Within | Faster |
| **4-6 PM** | 12% | 72% | 16% | **4-6 PM** | 4 | 23 | 5 |
| **Arterials** | | | | **Arterials** | | | |
| | Slower | Within | Faster | | Slower | Within | Faster |
| **4-6 PM** | 7% | 89% | 4% | **4-6 PM** | 4 | 50 | 2 |

**Figure 30. 2015 Base Year PM Travel Time comparison for Freeway Trips Less than 7 Minutes**

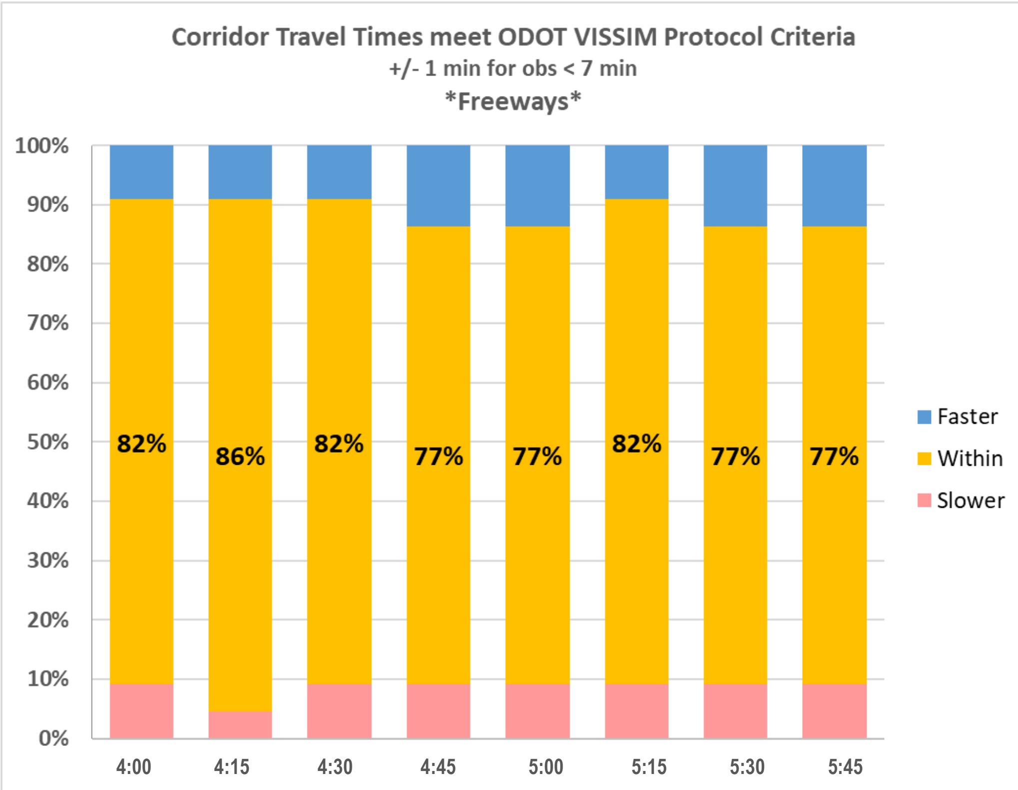



**Figure 31. 2015 Base Year PM Travel Time comparison for Arterial Trips Less than 7 Minutes**

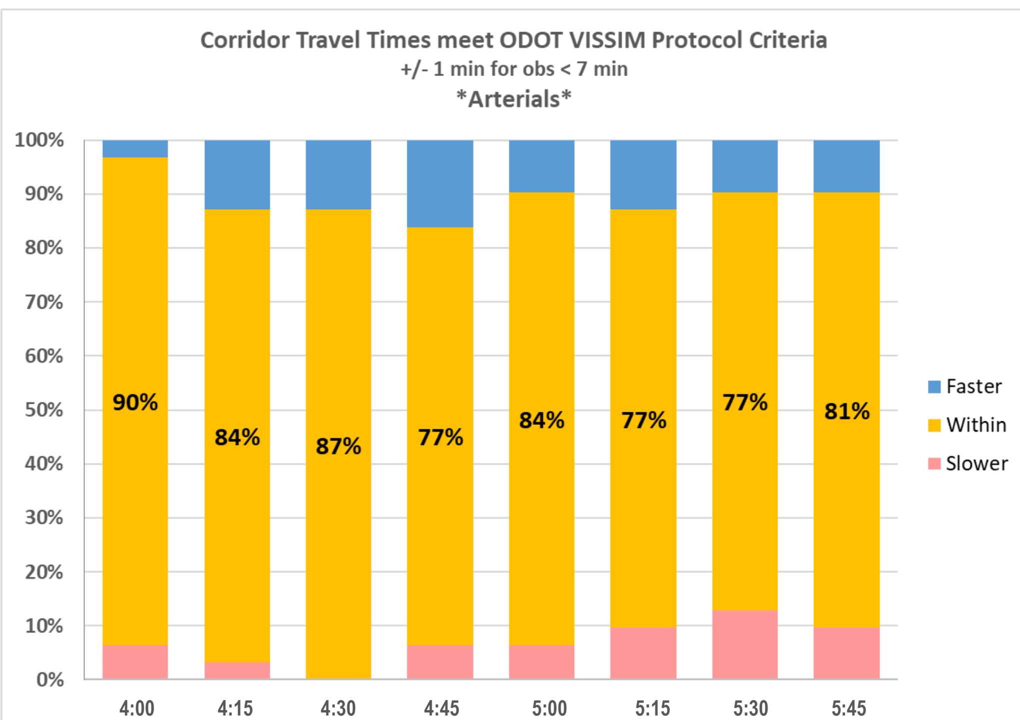


**Figure 32. 2015 Base Year PM Travel Time comparison for Freeway Trips of 7 Minutes or Greater**

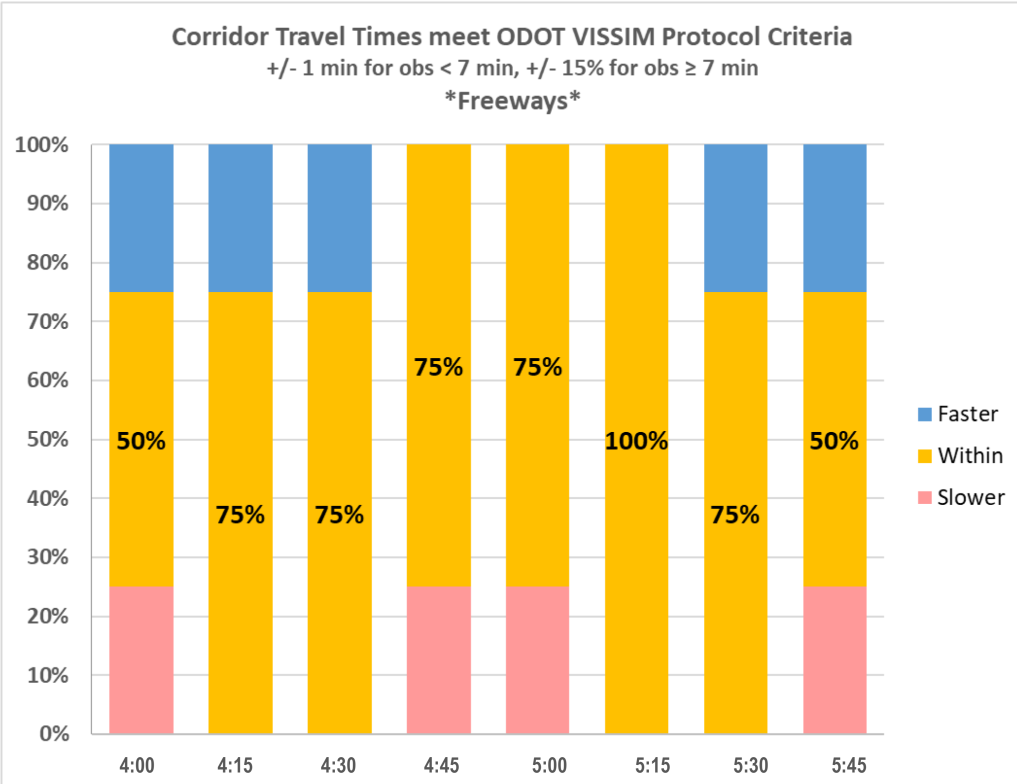



**Figure 33. 2015 Base Year PM Travel Time comparison for Arterial Trips of 7 Minutes or Greater**

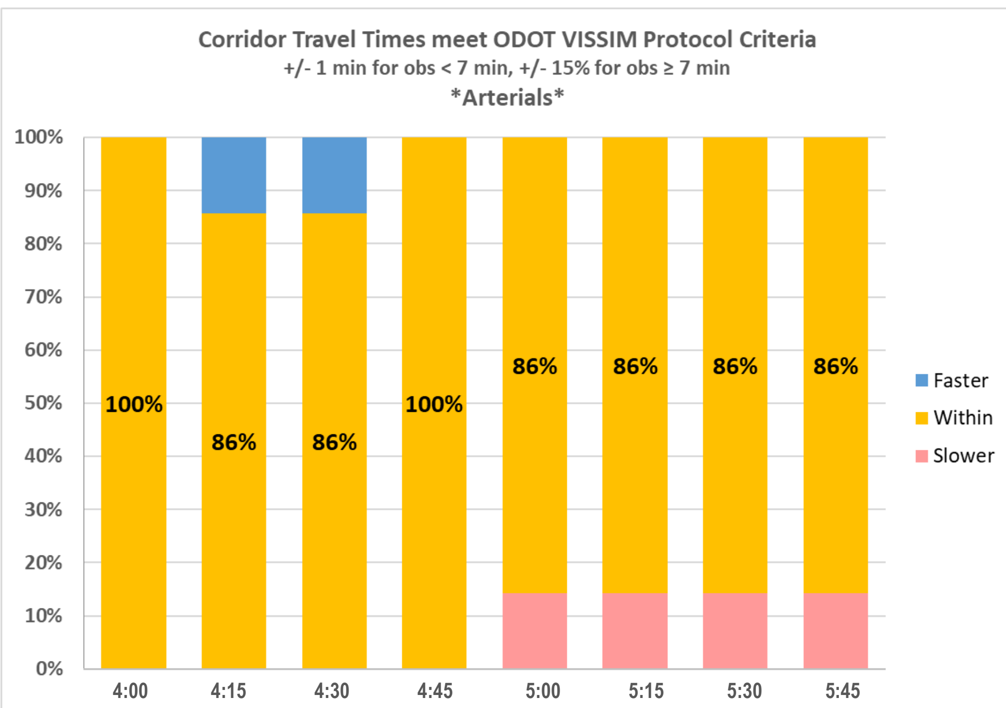


Figure 34 and Figure 35 show the percentage of travel time segments that are within the calibration range for every 15-minute PM peak period time interval for all trips on Freeways and Arterials, respectively. For freeways, four of the eight 15-minute intervals fall within the percent targets identified for freeways (80% target), while three of the four others are just under the target at 79%. For arterials, all but two of the time-intervals exceed the 75% target.

**Figure 34. 2015 Base Year PM Travel Time comparison for all Freeway Trips**

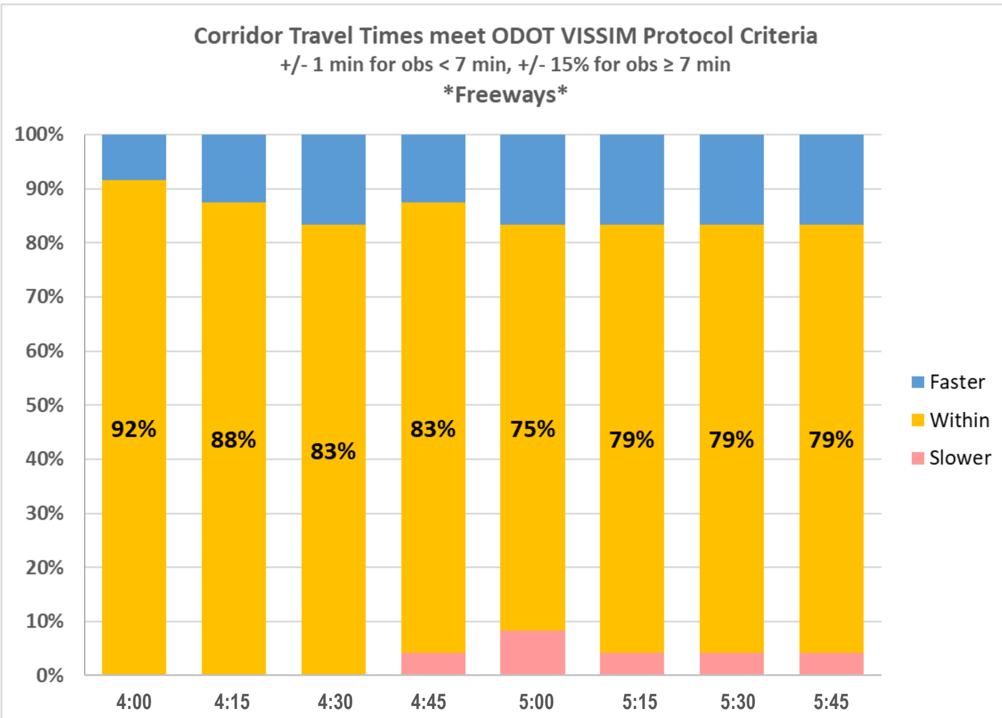
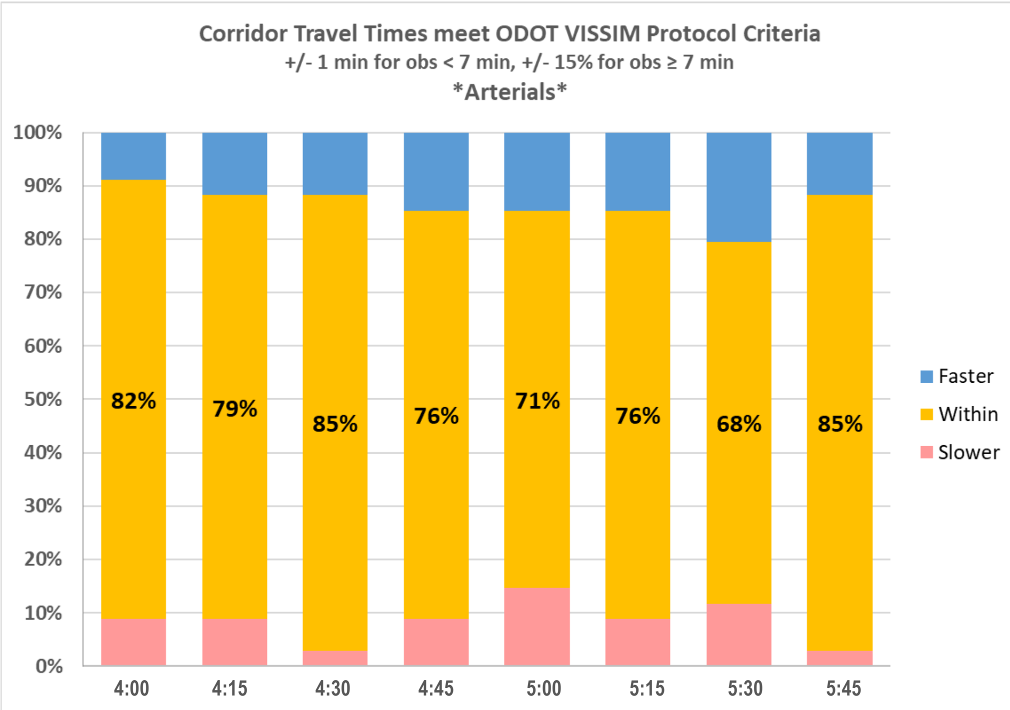


**Figure 35. 2015 Base Year PM Travel Time comparison for all Arterial Trips**




## Speeds

### Freeway Speeds

Table 18 and Table 19 show comparisons of the 2015 base year speeds from INRIX (observed data) with Dynameq (modeled data) along I-205 in the PM peak period for the southbound and northbound directions, respectively. As for the AM peak period, these PM peak hourly comparisons are important because data from the model will feed into analyses conducted on hourly increments. To see a finer level of detail for calibration purposes, Table 20 and Table 21 show similar comparisons for 15-minute increments of time for the PM southbound and northbound directions respectively.

For the southbound direction, the observed data reflects relatively good speeds ranging from 53 to 64 mph through the corridor. The modeled data also reflect relatively high speeds, though as with the AM northbound speeds, a bit slower than observed, ranging between 51 and 60 mph. The average speed for the overall corridor reflects a similar pattern, with both observed and modeled speeds being relatively high, with the modeled speeds somewhat lower. Looking at the 15-minute comparisons in Table 20, the trend is similar to the hourly comparison; however, observed speeds match the DTA model speeds better through the middle of the corridor (between OR 99E and Stafford Road), than at the end segments. Speeds can be considered reasonably calibrated when the model speeds are within +/- 10 mph of observed. Of the 48 speed comparisons for I-205 southbound the PM peak period, 48, or 100% are within the desired measure.

For the northbound direction (Table 19) the INRIX data reflects slow speeds from I-5 through the Stafford Road and 10th Street interchanges (20 to 26 mph) and moderately slow speeds between 10th Street and OR 43

(35-36 mph). The Dynameq model shows somewhat higher speeds between I-5 and 10th Street interchange (31 to 44 mph) but slower speeds between 10th Street and OR 43 (25-26 mph). North of OR 43, speeds increase in both the observed and modeled data, though the observed speeds are generally higher than the modeled speeds. Overall, the average speed between I-5 and Gladstone is similar between the observed and modeled data for northbound I-205 in the PM peak period, particularly for the 4-5 PM peak hour. Looking at the 15-minute comparisons in Table 21, the trend resembles the hourly comparison, with DTA model speeds being higher than observed from I-5 to 10th Street, and lower than observed from OR 99E to Gladstone. Of the 48 speed comparisons for I-205 northbound in the AM peak period, 34, or 71% were within the desired measure of being within +/- 10 mph of observed, which is less than the desired target of 85%. Compared to observed volumes, the DTA model tends to overestimate speeds on the south end of the corridor and underestimate them on the north end. This will be considered during post-processing of volumes and subsequent analysis.

Figure 36 and Figure 37 show plots comparing average speeds across the project corridor between observed and modeled data for the PM peak period for southbound and northbound I-205 respectively. Averaged across the corridor, the DTA model is within +/- 10 mph of the observed speeds for all but one 15-minute time period—the 5:45 to 6:00 p.m. interval in the northbound direction.

**Table 18. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, I-205 Southbound Direction**

| | | INRIX Average Speed | | Dynameq Average Speed | |
|---|---|---|---|---|---|
| **From** | **To** | **4:00 - 5:00 PM** | **5:00 - 6:00 PM** | **4:00 - 5:00 PM** | **5:00 - 6:00 PM** |
| Gladstone | OR 213 | 58 | 58 | 51 | 51 |
| OR 213 | OR 99E | 58 | 58 | 53 | 53 |
| OR 99E | OR 43 | 53 | 55 | 53 | 53 |
| OR 43 | 10th St | 57 | 59 | 54 | 54 |
| 10th St | Stafford Rd | 61 | 61 | 59 | 60 |
| Stafford Rd | I-5 split | 64 | 64 | 59 | 59 |
| **Full Corridor** | | | | | |
| Gladstone | I-5 split | 59 | 60 | 56 | 56 |

**Table 19. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, I-205 Northbound Direction**

| | | INRIX Average Speed | | Dynameq Average Speed | |
|---|---|---|---|---|---|
| **From** | **To** | **4:00 - 5:00 PM** | **5:00 - 6:00 PM** | **4:00 - 5:00 PM** | **5:00 - 6:00 PM** |
| I-5 ramps | Stafford Rd | 23 | 20 | 31 | 44 |
| Stafford Rd | 10th St | 26 | 24 | 31 | 34 |
| 10th St | OR 43 | 36 | 35 | 26 | 25 |
| OR 43 | OR 99E | 49 | 49 | 51 | 52 |
| OR 99E | OR 213 | 58 | 59 | 53 | 53 |
| OR 213 | Gladstone | 59 | 59 | 51 | 51 |
| **Full Corridor** | | | | | |
| I-5 ramps | Gladstone | 30 | 28 | 32 | 36 |

**Table 20. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, 15-Minute Increments, I-205 Southbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | |
| From | To | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 |
| Gladstone | OR 213 | 58 | 58 | 58 | 58 | 58 | 58 | 58 | 57 | 50 | 53 | 50 | 51 | 50 | 50 | 52 | 53 |
| OR 213 | OR 99E | 59 | 57 | 57 | 57 | 58 | 58 | 58 | 58 | 50 | 54 | 53 | 53 | 53 | 53 | 54 | 54 |
| OR 99E | OR 43 | 53 | 53 | 52 | 54 | 55 | 55 | 55 | 55 | 52 | 54 | 53 | 53 | 53 | 52 | 53 | 52 |
| OR 43 | 10th St | 58 | 57 | 57 | 58 | 58 | 59 | 58 | 59 | 54 | 55 | 55 | 54 | 54 | 54 | 55 | 55 |
| 10th St | Stafford Rd | 61 | 60 | 61 | 61 | 61 | 61 | 60 | 62 | 58 | 60 | 59 | 59 | 60 | 59 | 60 | 60 |
| Stafford Rd | I-5 split | 64 | 63 | 64 | 65 | 64 | 65 | 64 | 64 | 59 | 60 | 59 | 59 | 59 | 58 | 60 | 59 |

**Table 21. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, 15-Minute Increments, I-205 Northbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | |
| From | To | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 |
| I-5 ramps | Stafford Rd | 25 | 24 | 22 | 21 | 19 | 20 | 20 | 20 | 21 | 32 | 33 | 34 | 34 | 42 | 53 | 53 |
| Stafford Rd | 10th St | 31 | 26 | 25 | 24 | 23 | 25 | 23 | 23 | 40 | 30 | 28 | 28 | 29 | 29 | 36 | 53 |
| 10th St | OR 43 | 38 | 37 | 33 | 37 | 36 | 35 | 35 | 35 | 28 | 24 | 26 | 26 | 25 | 24 | 23 | 28 |
| OR 43 | OR 99E | 49 | 49 | 49 | 49 | 49 | 49 | 50 | 49 | 51 | 51 | 51 | 51 | 52 | 51 | 53 | 52 |
| OR 99E | OR 213 | 58 | 58 | 58 | 58 | 59 | 58 | 59 | 58 | 53 | 53 | 52 | 53 | 53 | 52 | 53 | 54 |
| Stafford Rd | Gladstone | 59 | 59 | 59 | 59 | 58 | 59 | 60 | 59 | 52 | 52 | 51 | 50 | 51 | 50 | 53 | 52 |

**Figure 36. 2015 Base Observed vs Modeled Speeds across Project Corridor: PM 2-hr Peak, 15-Minute Increments, I-205 Southbound Direction**

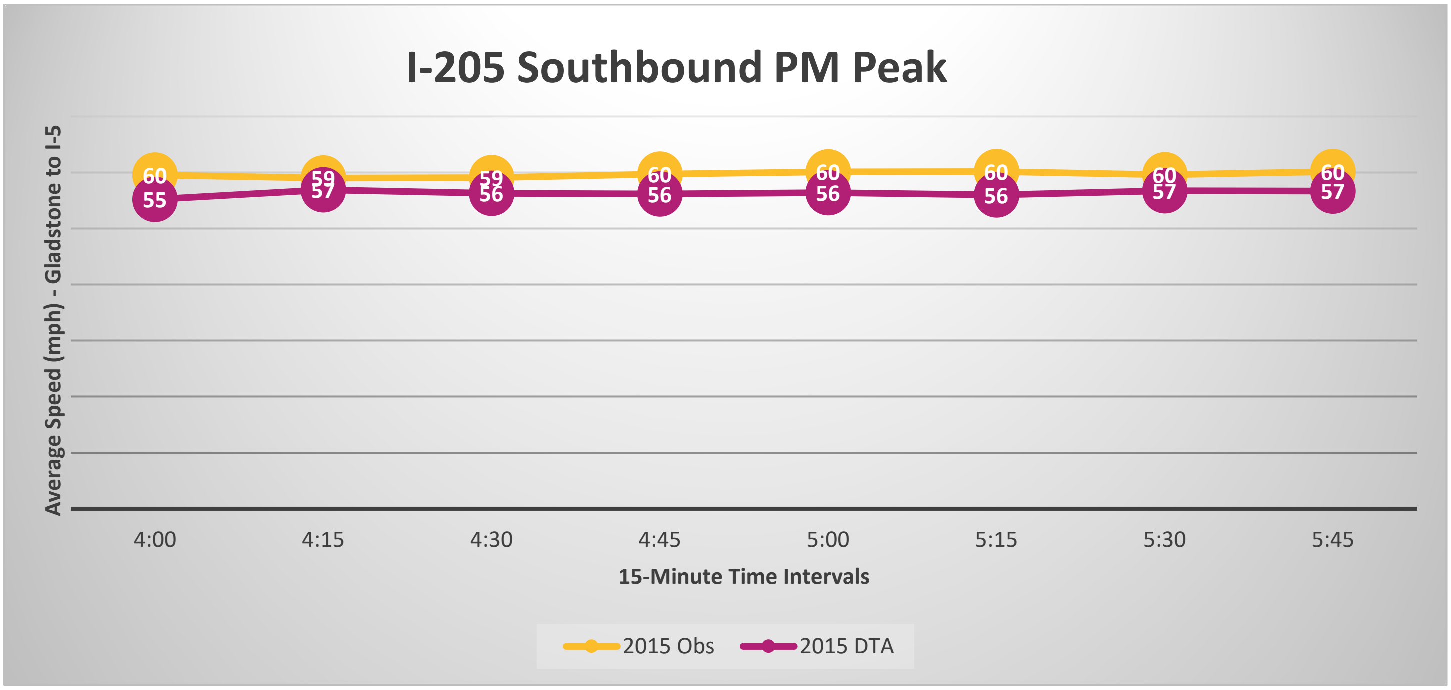
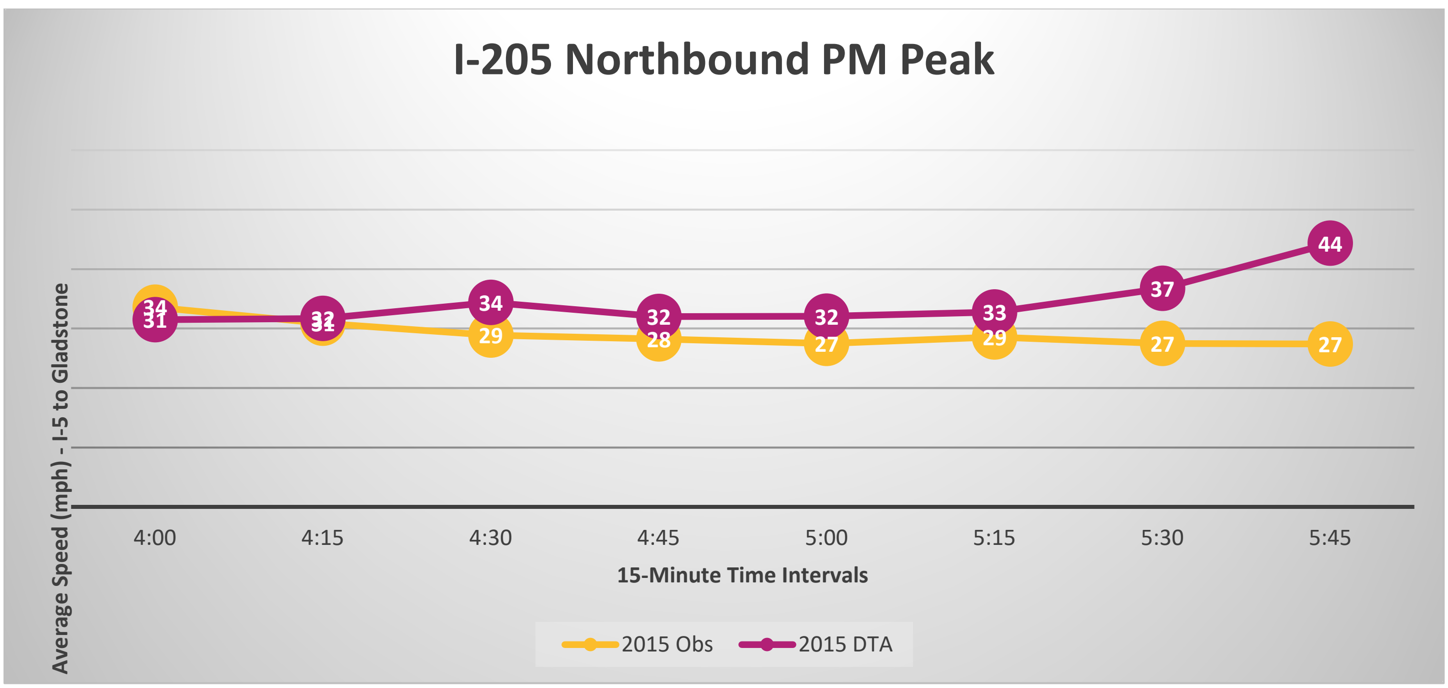



**Figure 37. 2015 Base Observed vs Modeled Speeds across Project Corridor: PM 2-hr Peak, 15-Minute Increments, I-205 Northbound Direction**




## Arterial Speeds

Table 22 and Table 23 show comparisons of the 2015 base year 15-minute increment speeds from INRIX (observed data) and from Dynameq (modeled data) along OR 99E between Gladstone (River Road) and Canby

(Grant Road) in the PM peak period for the southbound and northbound directions, respectively. This section of OR 99E was chosen to assess calibration performance more closely because it would be a likely diversion route once tolls are implemented on I-205.

For the southbound direction (Table 22), the Dynameq speeds fall within +/- 10 mph of the INRIX for all 15-minute intervals, though through the I-205 interchange (between Concord Road and 15th Street), the Dynameq DTA model shows generally higher speeds. However, this shows that the model matches the desired speed range for 100% of the segments and intervals analyzed. For the northbound direction (Table 23) the Dynameq speeds also fall within +/- 10 mph of the INRIX speeds for all segments and time periods, indicating a relatively high level of calibration.

Figure 38 and Figure 39 show plots comparing average observed versus modeled speeds across the OR 99E corridor between Oregon City (Main Street) and Canby (Grant Street) for the PM peak period for the southbound and northbound directions respectively. Averaged across the corridor, the DTA model is within +/- 10 mph of the observed speeds for all 15-minute time periods, indicating that this corridor is relatively well calibrated for the PM peak period in both directions.

Table 24 and Table 25 show comparisons of the 2015 base year 15-minute increment speeds from INRIX (observed data) and from Dynameq (modeled data) along Willamette Falls Drive/Borland Road between OR 43 and Stafford Road in the PM peak period for the westbound and eastbound directions, respectively. This section of roadway was also chosen to assess calibration performance more closely because it would be a likely diversion route once tolls are implemented on I-205.

For the westbound direction (Table 24), the Dynameq speeds fall within +/- 2 mph of the INRIX speeds for all 15-minute intervals, easily meeting the criteria of +/- 10 mph. For the eastbound direction (Table 25) the Dynameq speeds fall within +/- 10 mph of the INRIX speeds for all segments and time periods except for the interval between 4:00 and 4:15 p.m., where the Dynameq model speed is 10 mph lower than observed; however, for the remaining intervals the Dynameq model speeds are generally higher than observed. All told, the model meets the desired criteria across all segments and time periods 94% of the time.

Figure 40 and Figure 41 show plots comparing average observed versus modeled speeds across the Willamette Falls Drive/Borland Road corridor between OR 43 and Stafford Road for the PM peak period for the westbound and eastbound directions respectively. Averaged across the corridor, the DTA model is within +/- 10 mph of the observed speeds for all 15-minute time periods, indicating that this corridor is relatively well calibrated for the PM peak period in both directions. However, it is noted that the DTA model generally has higher speeds than observed for the eastbound direction. This is likely due to the eastbound back-ups from the stop-controlled intersection of Willamette Falls Drive with OR 43 that occur due to back-ups from the Arch Bridge and the difficulty of right-turning vehicles being able to enter the traffic flow on southbound OR 43.

**Table 22. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, 15-Minute Increments, OR 99E Southbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | |
| From | To | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 |
| River Rd | Concord Rd | 29 | 29 | 26 | 26 | 24 | 24 | 26 | 26 | 32 | 31 | 32 | 33 | 32 | 32 | 32 | 32 |
| Concord Rd | 15th St (OC) | 25 | 25 | 24 | 24 | 24 | 23 | 23 | 24 | 29 | 30 | 30 | 30 | 29 | 30 | 30 | 30 |
| 15th St (OC) | Railroad Ave | 22 | 22 | 23 | 23 | 22 | 22 | 22 | 23 | 21 | 21 | 20 | 21 | 22 | 24 | 24 | 23 |
| Main St | South End | 49 | 49 | 49 | 50 | 49 | 49 | 48 | 49 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| South End | Grant St (Canby) | 37 | 35 | 36 | 36 | 35 | 36 | 36 | 37 | 34 | 34 | 35 | 35 | 37 | 36 | 37 | 36 |

**Table 23. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, 15-Minute Increments, OR 99E Northbound Direction**

| | | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | |
| From | To | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 |
| Grant St (Canby) | South End | 36 | 37 | 37 | 34 | 34 | 34 | 35 | 35 | 37 | 36 | 37 | 37 | 38 | 38 | 37 | 38 |
| South End | Main St | 48 | 47 | 48 | 48 | 48 | 48 | 47 | 47 | 45 | 45 | 45 | 46 | 45 | 46 | 46 | 45 |
| Main St | I-205 SB | 12 | 11 | 12 | 13 | 12 | 11 | 11 | 13 | 14 | 14 | 14 | 15 | 18 | 17 | 18 | 17 |
| I-205 SB | Concord Rd | 30 | 30 | 31 | 31 | 31 | 30 | 30 | 30 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| Concord Rd | River Rd | 32 | 32 | 34 | 33 | 32 | 32 | 32 | 31 | 33 | 32 | 31 | 32 | 32 | 32 | 32 | 32 |

**Figure 38. 2015 Base Observed vs Modeled Speeds across Project Corridor: PM 15-Minute Increments, OR 99E Southbound Direction Oregon City to Canby**

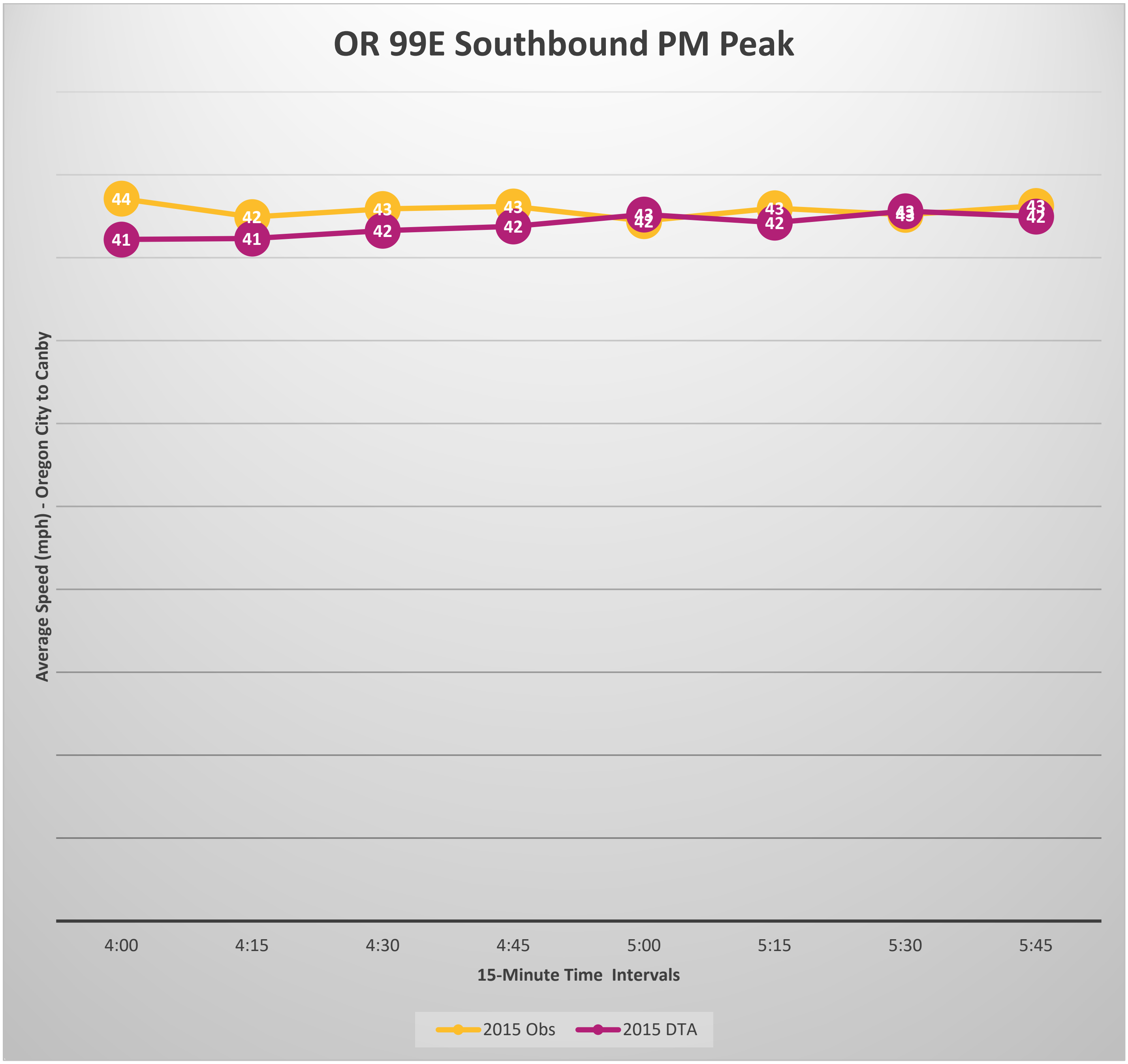


**Figure 39. 2015 Base Observed vs Modeled Speeds across Project Corridor: PM 15-Minute Increments, OR 99E Northbound Direction Canby to Oregon City**

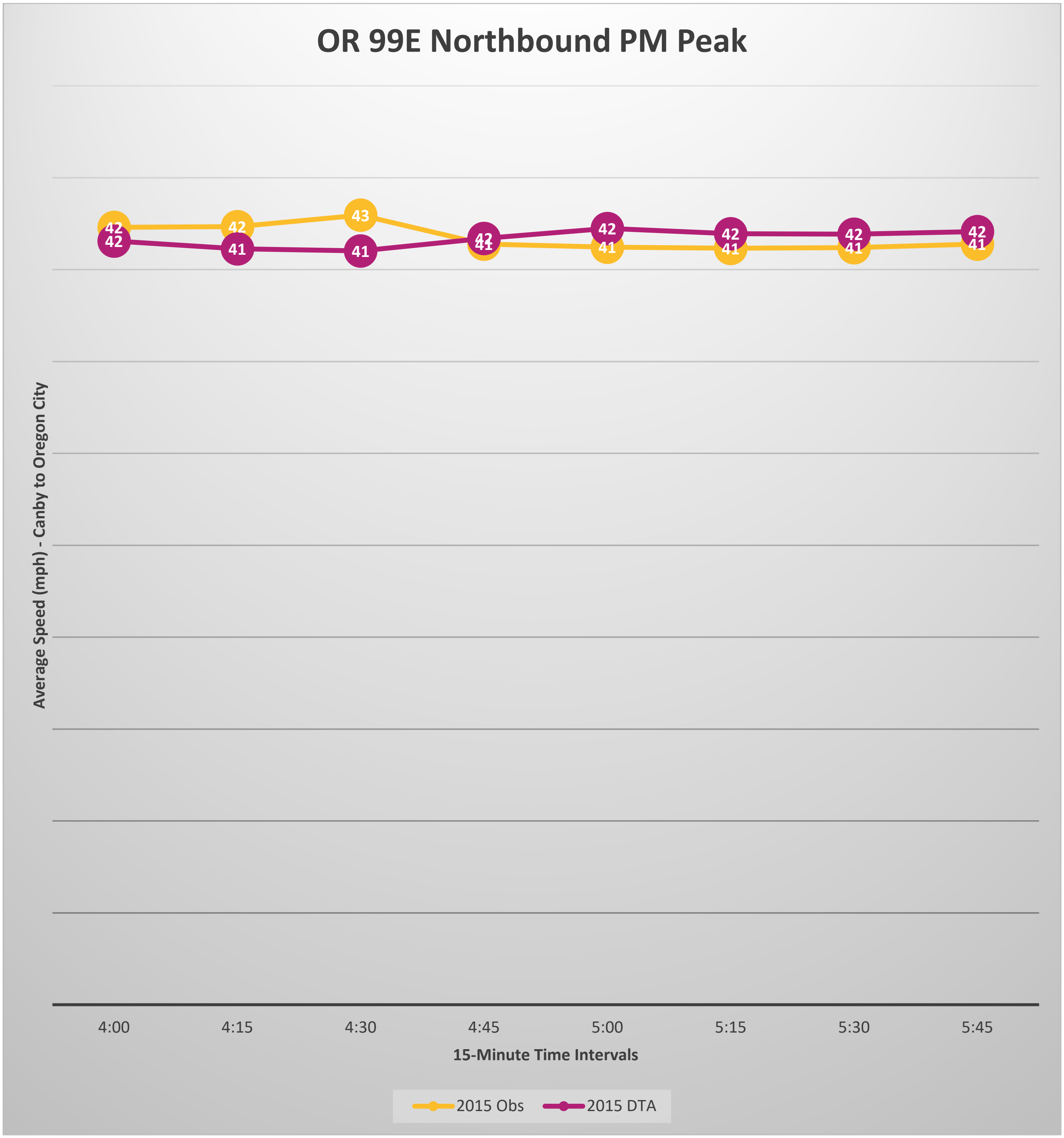


**Table 24. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, 15-Minute Increments, WFD/Borland Rd Westbound Direction**

| From | To | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | |
| | | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 |
| OR-43 | 10th St | 36 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 37 | 38 | 38 | 37 | 38 |
| 10th St | Stafford Rd | 34 | 34 | 34 | 34 | 33 | 33 | 33 | 33 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |

**Table 25. 2015 Base Observed vs Modeled Speeds: PM 2-hr Peak, 15-Minute Increments, WFD/Borland Rd Eastbound Direction**

| From | To | INRIX Average Speed | | | | | | | | Dynameq Average Speed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | | 4:00 - 5:00 PM | | | | 5:00 - 6:00 PM | | | |
| | | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 | 4:00 | 4:15 | 4:30 | 4:45 | 5:00 | 5:15 | 5:30 | 5:45 |
| Stafford Rd | 10th St | 30 | 27 | 28 | 29 | 28 | 28 | 27 | 28 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| 10th St | OR-43 | 34 | 34 | 34 | 30 | 30 | 30 | 28 | 28 | 24 | 37 | 35 | 36 | 36 | 34 | 35 | 37 |

**Figure 40. 2015 Base Observed vs Modeled Speeds across Project Corridor: PM 15-Minute Increments, Willamette Falls Drive/Borland Road Westbound Direction**

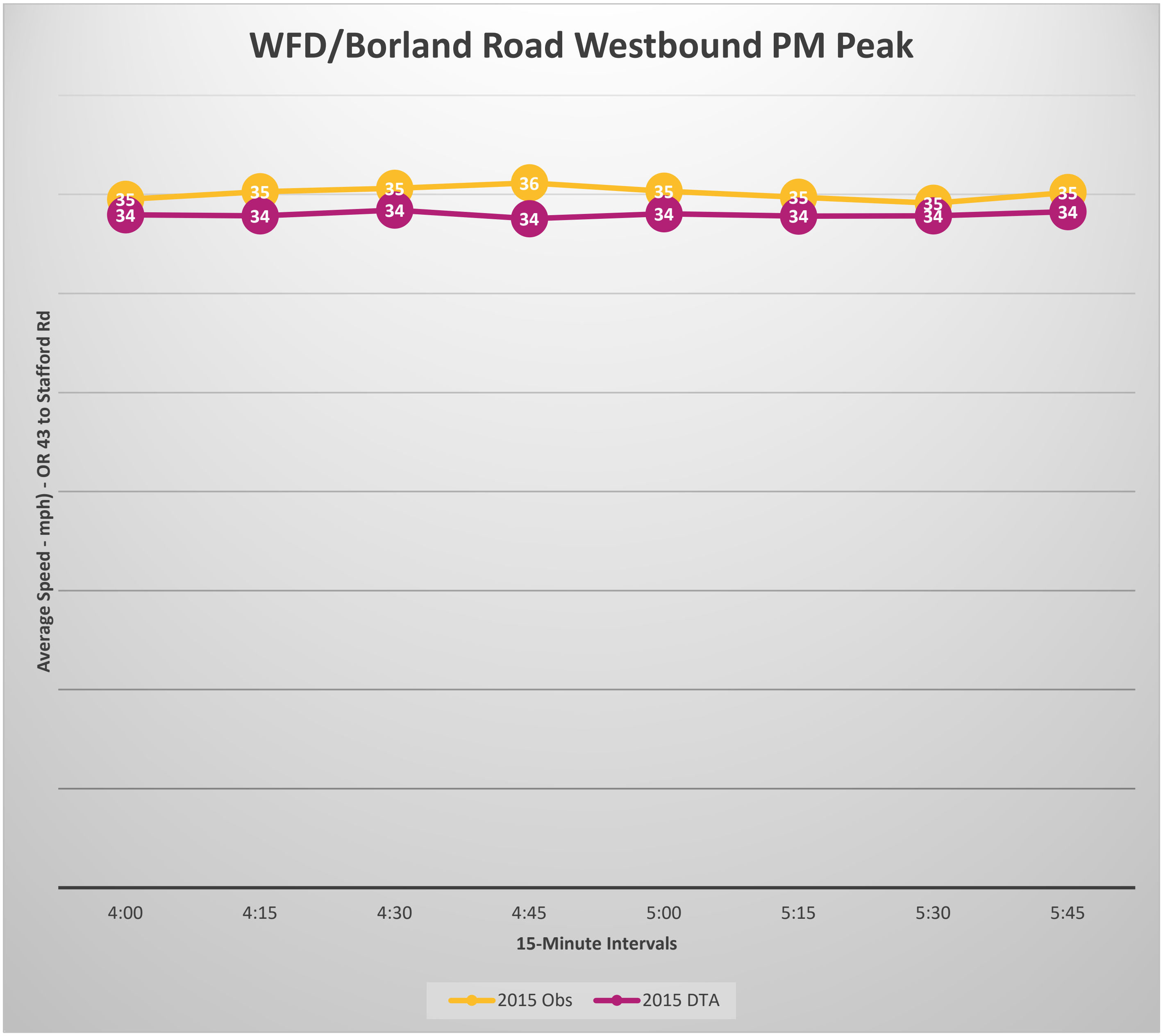
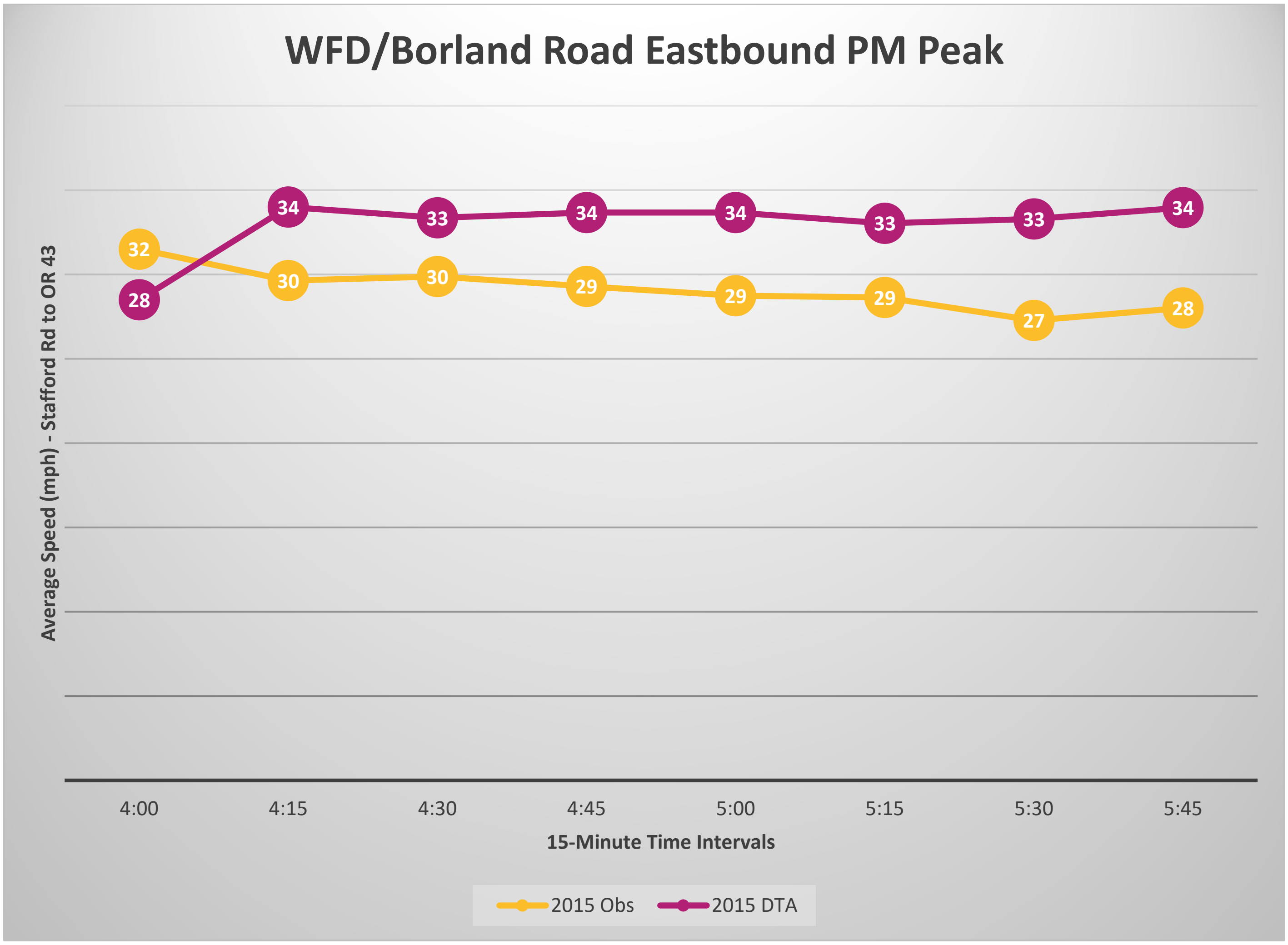


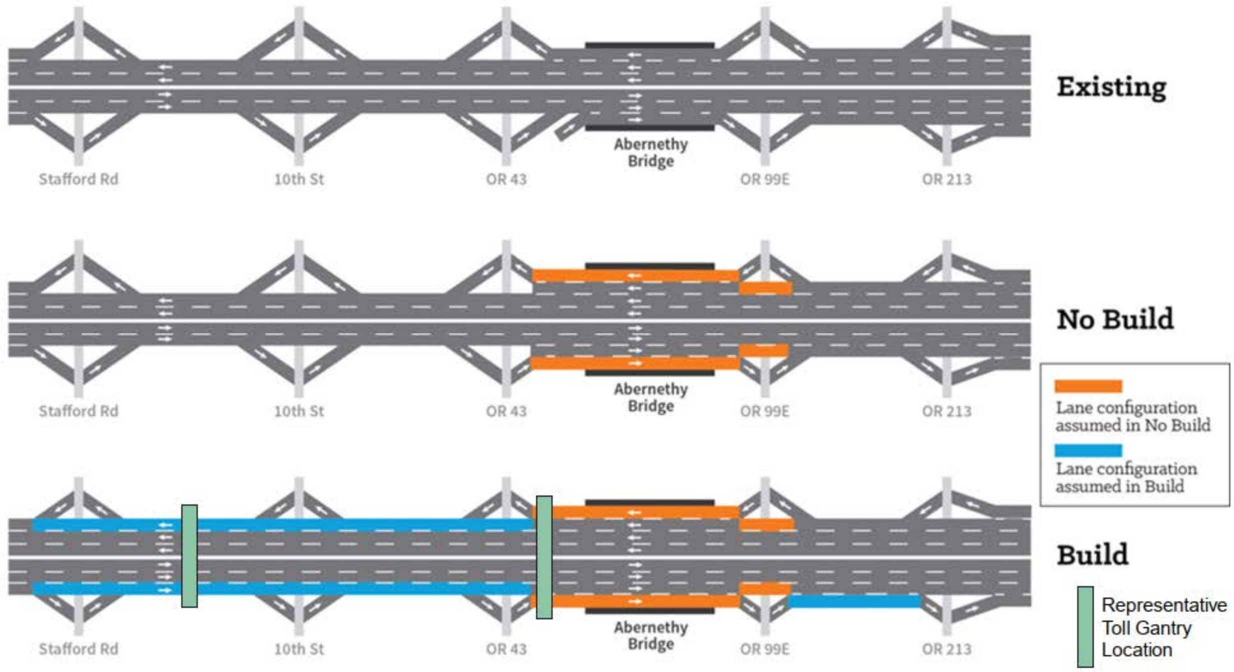
**Figure 41. 2015 Base Observed vs Modeled Speeds across Project Corridor: PM 15-Minute Increments, Willamette Falls Drive/Borland Road Eastbound Direction**




## Future Year Subarea DTA Models

To assess the relative reasonableness of model projections of future volumes, a comparison of model volume forecasts was plotted for three key corridors: I-205, OR 99E, and Willamette Falls Drive/Borland Road. These comparisons included 2015 Base and 2027 and 2045 No Build and Build alternative volumes. The objective of this comparison is simply to test whether the subarea DTA model produces future year results that reasonably reflect regional population and employment growth, i.e., they trend in an understandable direction. A schematic representation of I-205 lane configurations for existing, No Build and Build conditions is shown in Figure 42.

**Figure 42. I-205 Configuration for Existing, No Build and Build Alternatives**




**Future DTA Model Networks**

## No Build DTA Model Network

The key network changes in the 2027 and 2045 No Build models when compared to 2015 Base are:

- Increase in number of lanes across Abernethy Bridge from 3 lanes to 4 lanes in each direction
- Optimization of signals along corridors OR 99, OR 213 and OR 43 to better reflect future demand

## Build DTA Model Network

The key network changes in the 2027 and 2045 Build models when compared to the No Build are:

- The addition of a lane in each direction between Stafford Road and the Abernethy Bridge, as well as an additional northbound lane between OR 99E and OR 213
- Tolls implemented at two locations along I-205: on the Abernethy Bridge, and the Tualatin River bridges between Stafford Road and 10th Street
- Additional optimization of signals along corridors OR 99, OR 213 and OR 43 to better reflect future Build demand

#### I-205 Volume comparisons

### 2045 No Build Versus 2015 Base

Appendix C contains a comparison of peak period volumes between the 2015 Base Alternative and year 2045 No Build Alternative forecasted volumes on I-205. The key observations from this information include the following:

- Volumes increase in 2045 No Build over 2015 Base, however the increase is marginal in the peak directions where volumes are currently constrained and no capacity improvements are included (e.g., NB PM Stafford to 10th)
- In a few locations, while 2045 No Build demand is greater than 2015 Base demand, projected volumes are lower than 2015 Base which is likely due to congestion and breakdown conditions induced by the added demand

### 2027 No Build Versus 2015 Base

Appendix C contains volume comparisons between the 2027 No Build and 2015 Base alternative on I-205 in the AM and PM peak hours by segment and direction.  Key observations from this information include the following:

- Volumes generally increase in 2027 No Build over 2015 Base, however increase is marginal in the peak directions where volumes are currently constrained and no capacity improvements are included (e.g., northbound in the PM peak hour from Stafford to 10th)
- In a few locations 2027 volumes are lower than 2015 due to congestion and breakdown conditions caused by the added demand

#### I-205 Speed Comparisons by Segment

### 2045 No Build Versus 2015 Base

Appendix C contains a speed comparison between 2045 No Build and 2015 Base DTA modeled speeds in the AM and PM peak hours by direction on individual links across the corridor. The key observations from these data are:

- The speed of vehicles is generally maintained in the 2045 No Build at many locations and times while others have a notable decrease in comparison to the 2015 Base.
- The reductions of speed at some locations are due to traffic being constrained caused by added demand in the future and no added capacity improvements (except across the Abernethy Bridge).
- The increase in speed on I-205 southbound during 7-8 a.m. is due to the added capacity on the Abernethy Bridge. By 8-9 a.m. the capacity fills up and the bottleneck created at the OR 43 off-ramp (where 4 lanes drop to 2 lanes), results in lower speeds southbound across the bridge which spill back to affect the OR 213 to OR 99E segment as well. A similar effect occurs in the southbound PM peak period as well.

### 2027 No Build Versus 2015 Base

Appendix C also contains a speed comparison between 2027 No Build and 2015 Base speed in the AM and PM peak hours by direction. Key observations from this information are similar to those previously noted for 2045:

- The speed of vehicles is generally maintained in the 2027 No Build at many locations and times in comparison to the 2015 Base while other locations have a notable decrease.
- The reductions of speed at some locations are caused by traffic being constrained due to added demand in the future and no added capacity improvements (except along the Abernethy Bridge).

#### I-205 Corridor Average Speed Comparisons between Baseline, No Build and Build Alternatives

Figure 43 and Figure 44 compare AM peak period average speeds across the I-205 project corridor in 15-minute intervals for the southbound and northbound directions respectively. Included in these figures are observed and modeled speeds for the 2015 base year and modeled No Build and Build speeds for future years 2027 and 2045. These scenarios are plotted together to assess the general reasonableness of the changes reflected between the different scenarios. Figure 45 and Figure 46 compare similar speed information for the PM peak period for the southbound and northbound directions respectively. Key observations include the following:

- The northbound direction sees greater differences between the scenarios than the southbound direction. This reflects the northbound direction generally being more congested, and hence volatile, than the southbound direction—particularly for the PM peak period.
- 2027 and 2045 No Build speeds are generally lower than 2015 Base speeds except for AM peak southbound, where the 2045 No Build starts out higher than the 2015 Base speeds for the first 4 time intervals due to the added capacity of the Abernethy Bridge, and then in the latter portion of the 2-hour period the capacity fills up and the bottleneck created results in lower speeds southbound across the bridge which spill back to affect the OR 213 to OR 99E segment as well.
- Build conditions show average speeds consistently higher than No Build conditions for both directions and for 2027 and 2045. This is reasonable given that the Build contains capacity improvements to accommodate peak traffic demand, and also implements tolls to reduce overall demand.

**Figure 43. Southbound I-205 Project Corridor Observed and Modeled Speeds: AM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

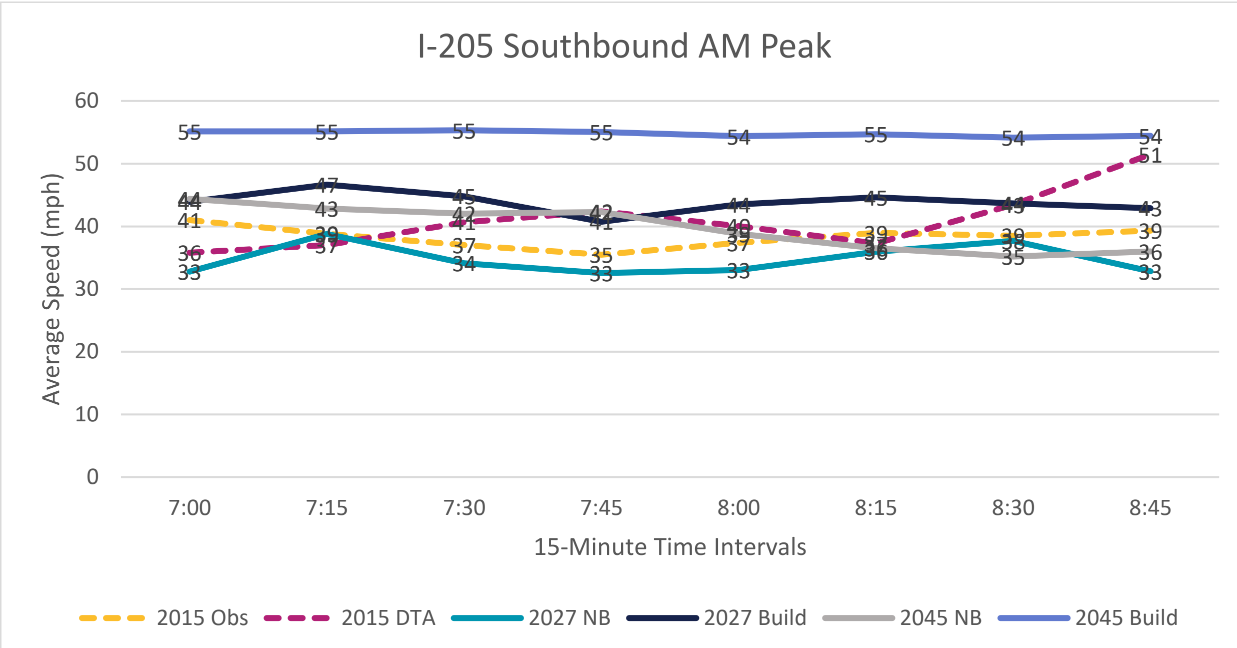



**Figure 44. Northbound I-205 Project Corridor Observed and Modeled Speeds: AM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

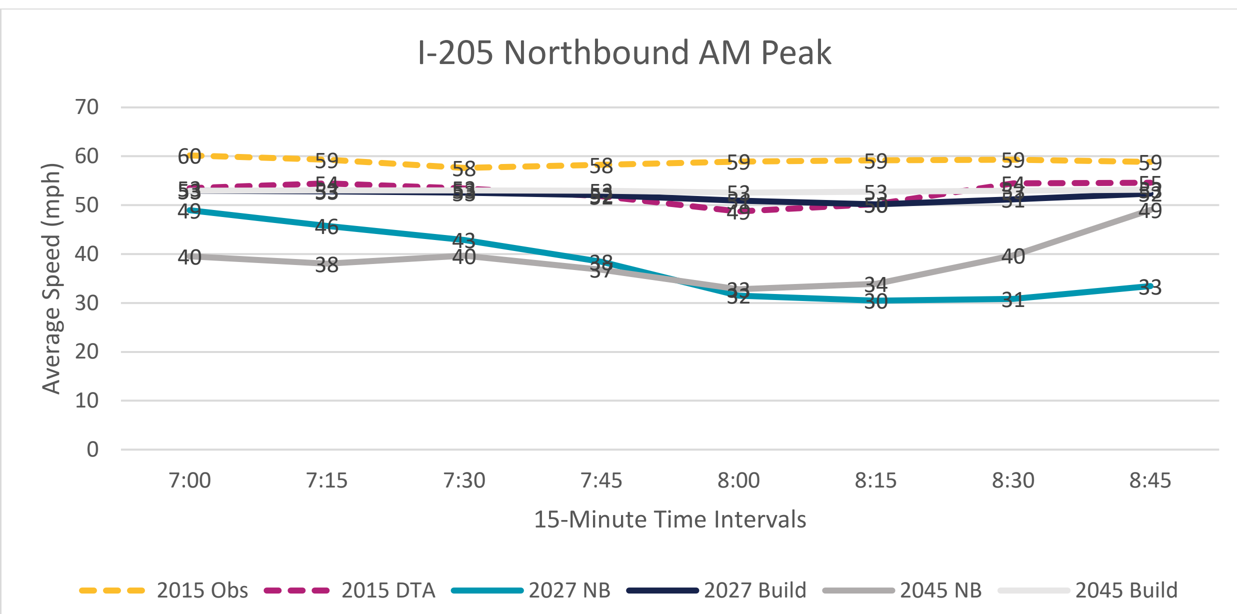


**Figure 45. Southbound I-205 Project Corridor Observed and Modeled Speeds: PM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

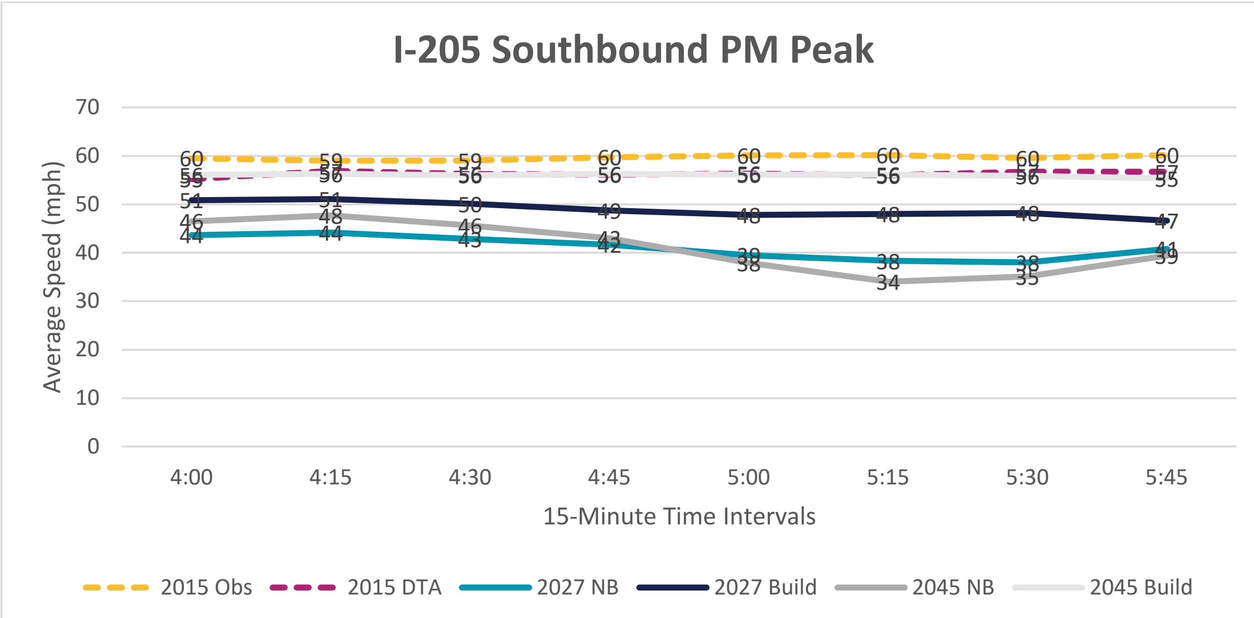
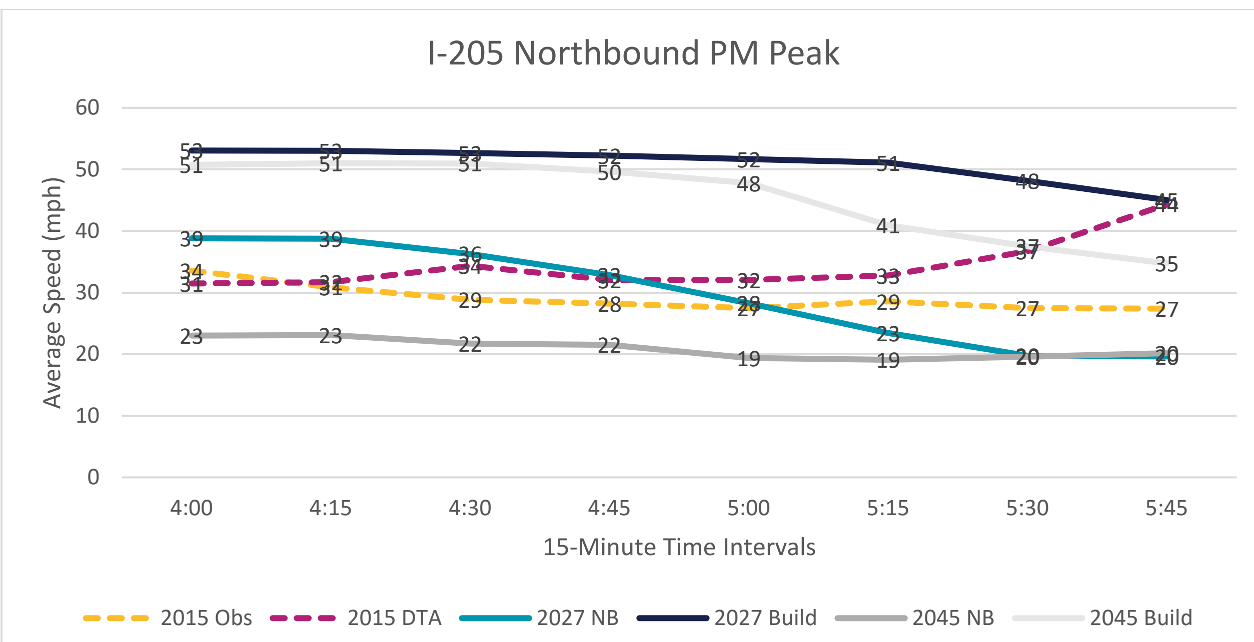



**Figure 46. Northbound I-205 Project Corridor Observed and Modeled Speeds: PM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**



#### Arterial Corridors Average Speed Comparisons between Baseline, No Build and Build Alternatives

To assess whether implementing tolls on I-205 would impact parallel facilities due to diversion of traffic, two likely parallel routes were chosen to assess both calibration performance and reasonableness of future volume forecasts. The two routes chosen are OR 99E between Oregon City and Canby; and Willamette Falls Drive/Borland Road between OR 43 and Stafford Road.

### OR 99E Between Oregon City and Canby

Figure 47 and Figure 48 compare AM peak period average speeds across the OR 99E corridor between Oregon City and Canby in 15-minute intervals for the southbound and northbound directions respectively. Included in these figures are observed and modeled speeds for the 2015 base year and modeled No Build and Build speeds for future years 2027 and 2045. These scenarios are plotted together to assess the general reasonableness of the changes reflected between the different scenarios. Figure 49 and Figure 50 compare similar speed information for the PM peak period for the southbound and northbound directions respectively. Key observations include the following:

- Speeds for the Build alternatives are generally lower than No Build speeds, which is reasonable due to the increased volumes in the Build condition on parallel routes due to toll diversion.
- In the AM peak period, year 2027 speeds are generally lower than year 2045 speeds. This indicates that there is more toll diversion in general in 2027 as compared to 2045 because the alternative routes are less congested in 2027 and hence more attractive than they are in 2045. However, in the PM peak period, the arterial system is more often at capacity in both 2027 and 2045, hence there is not a disproportionately higher share of diversion in 2027 than in 2045. Consequently, speeds for the 2045 alternatives are generally lower than speeds for the 2027 alternatives.

**Figure 47. Southbound OR 99E Corridor (Oregon City to Canby) Observed and Modeled Average Speeds: AM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

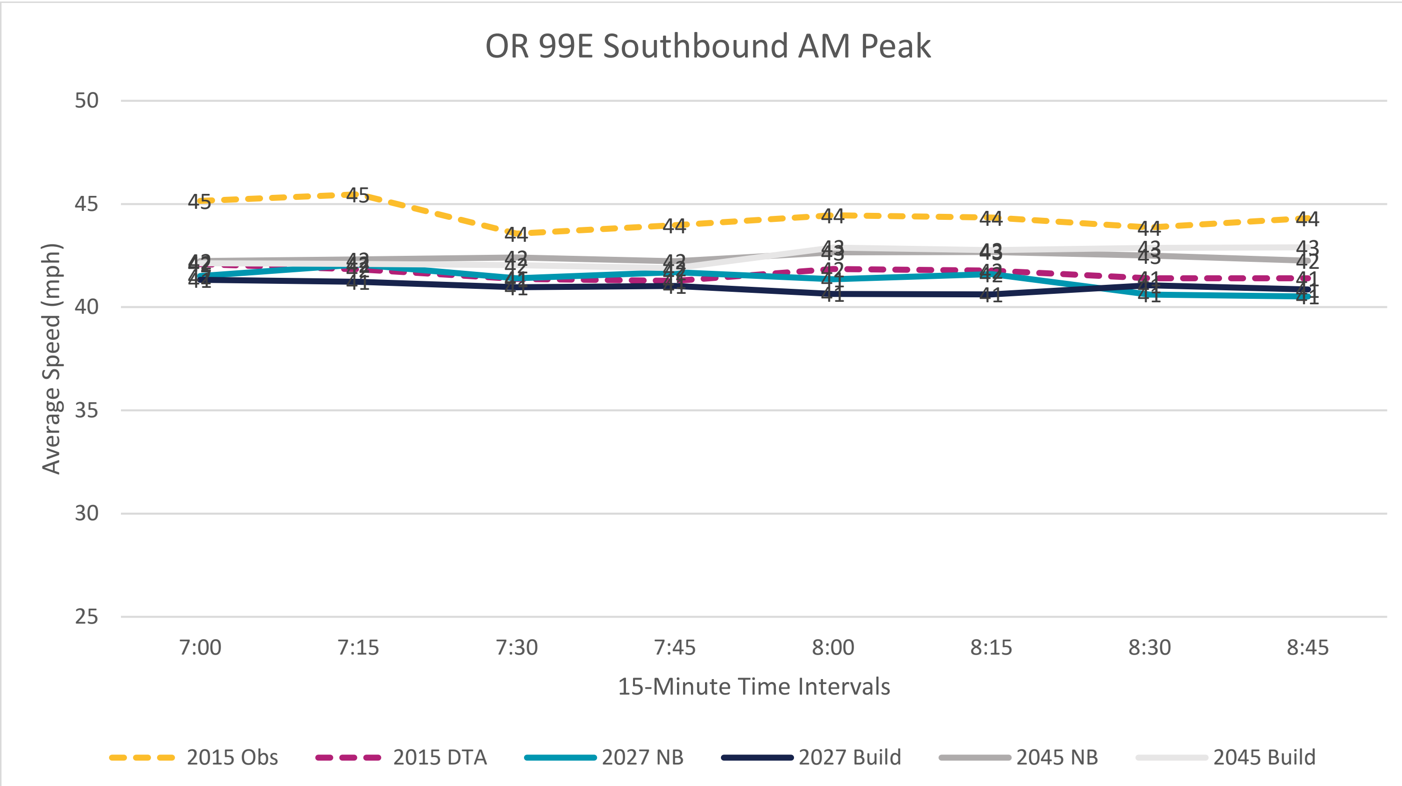



**Figure 48. Northbound OR 99E Corridor (Canby to Oregon City) Observed and Modeled Average Speeds: AM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

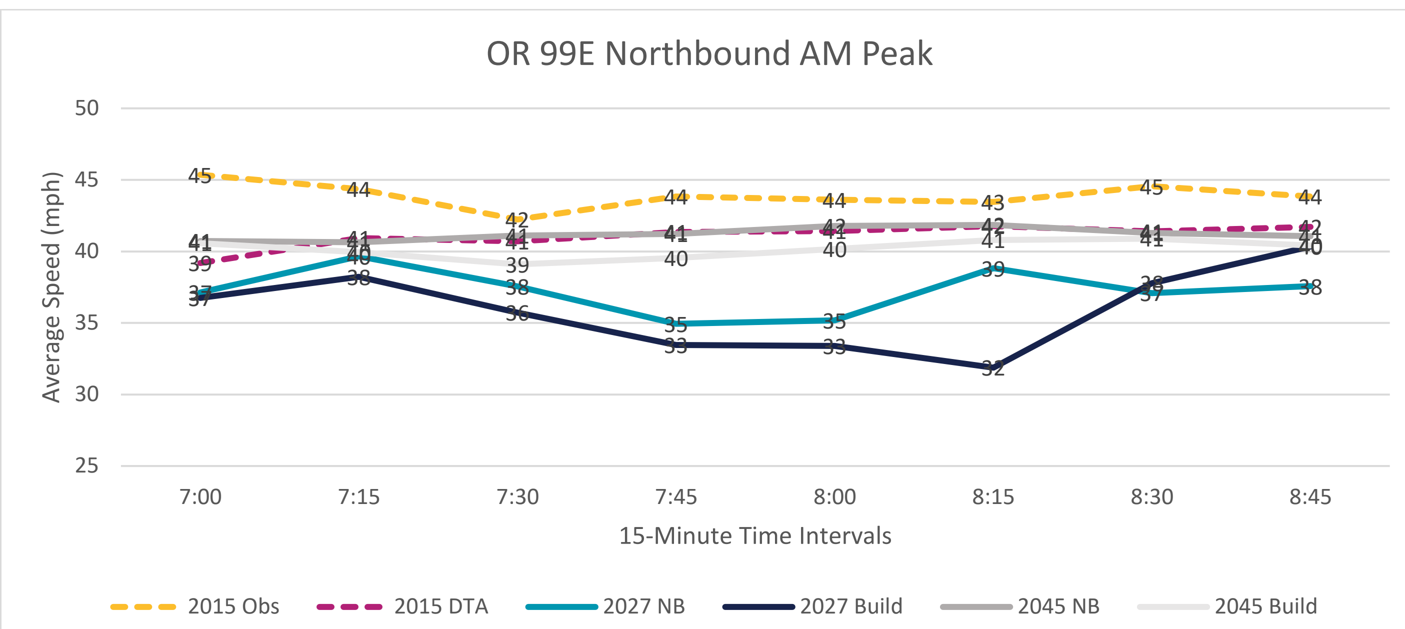


**Figure 49. Southbound OR 99E Corridor (Oregon City to Canby) Observed and Modeled Average Speeds: PM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

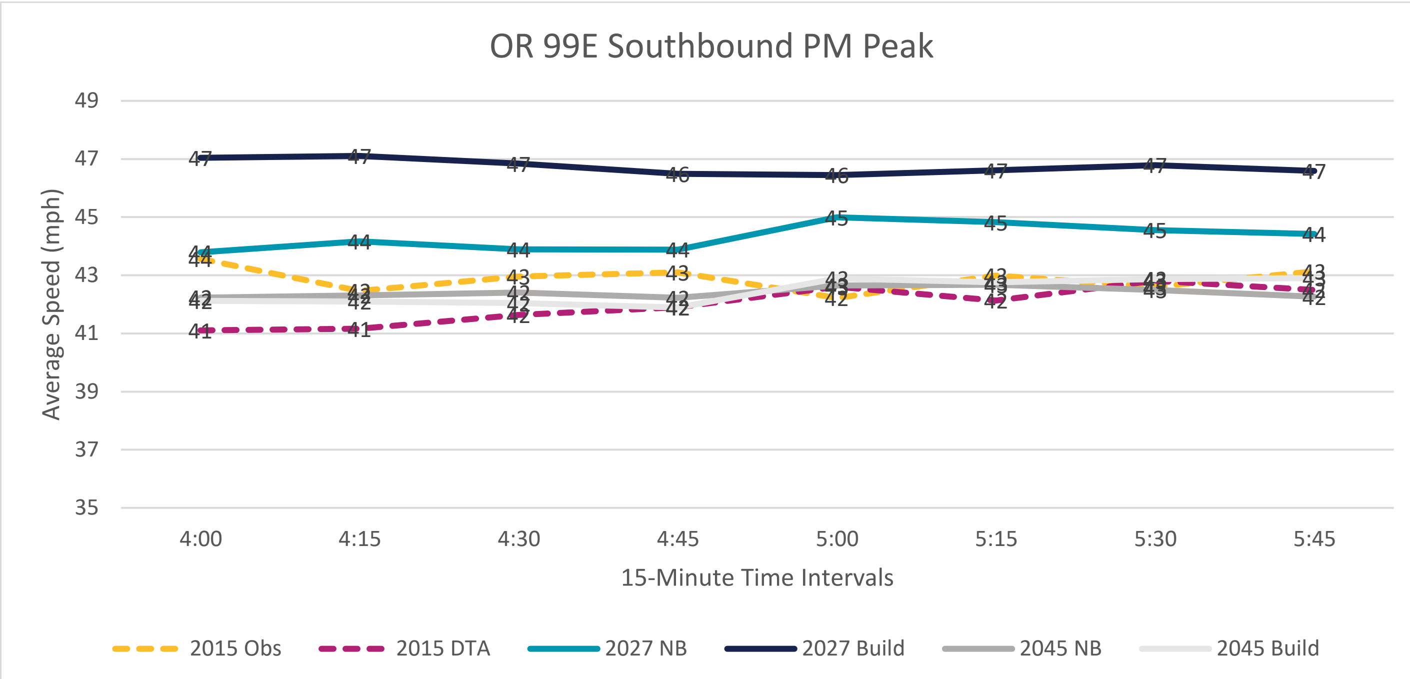
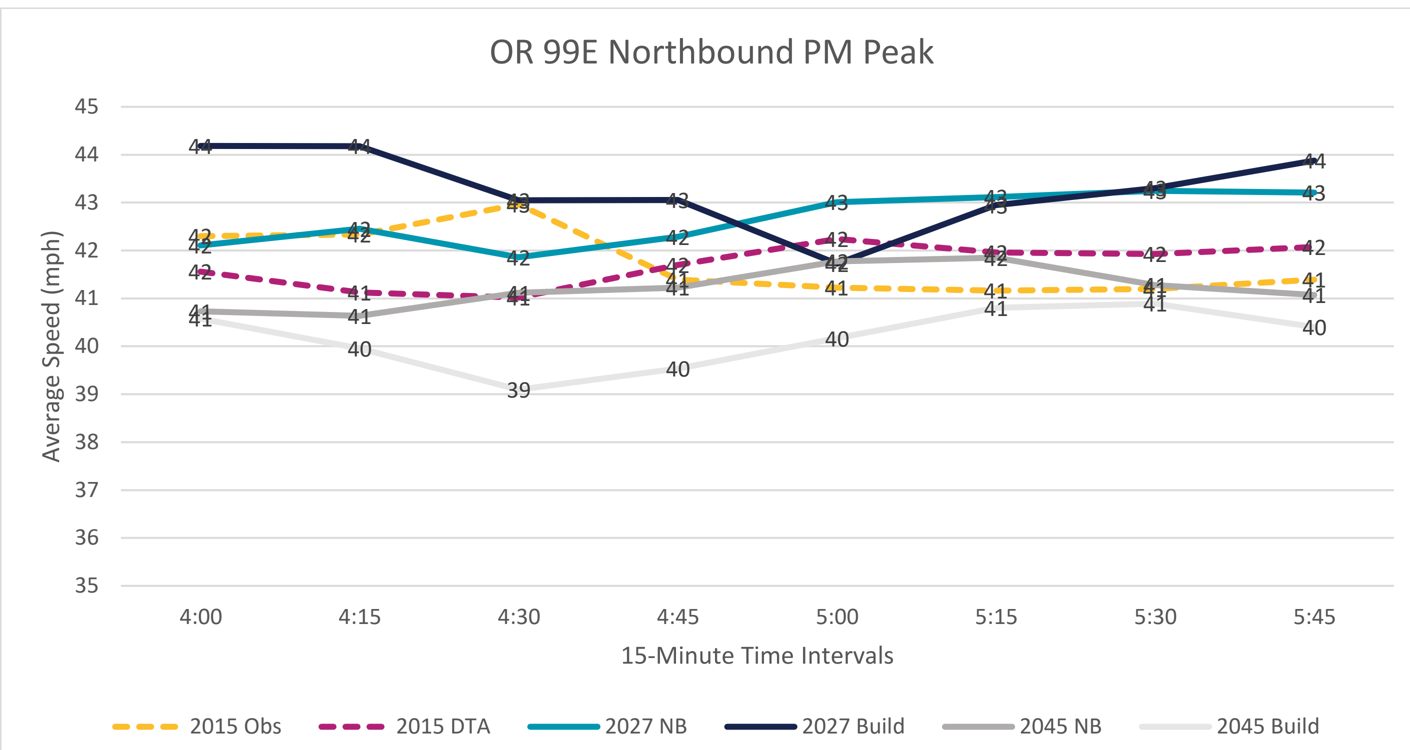



**Figure 50. Northbound OR 99E Corridor (Canby to Oregon City) Observed and Modeled Average Speeds: PM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**



### Willamette Falls Drive/Borland Road Between OR 43 and Stafford Road

Figure 51 and Figure 52 compare AM peak period average speeds across the Willamette Falls Drive/Borland Road corridor between OR 43 and Stafford Road in 15-minute intervals for the southbound and northbound directions respectively. Included in these figures are observed and modeled speeds for the 2015 base year and modeled No Build and Build speeds for future years 2027 and 2045. These scenarios are plotted together to assess the general reasonableness of the changes reflected between the different scenarios. Figure 53 and Figure 54 compare similar speed information for the PM peak period for the southbound and northbound directions respectively. Key observations include the following:

- Speeds for the Build alternatives are generally lower than No Build speeds, which is reasonable due to the increased volumes in the Build condition on parallel routes due to toll diversion.
- In the AM peak period, year 2027 speeds are generally lower than year 2045 speeds. This indicates that there is more toll diversion in general in 2027 as compared to 2045 because the alternative routes are less congested in 2027 and hence more attractive than they are in 2045. However, in the PM peak period, the arterial system is more often at capacity in both 2027 and 2045, hence there is not a disproportionately higher share of diversion in 2027 than in 2045. Consequently, speeds for the 2045 alternatives are generally lower than speeds for the 2027 alternatives.

**Figure 51. Westbound Willamette Falls Drive/Borland Road between OR 43 and Stafford Road - Observed and Modeled Average Speeds: AM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

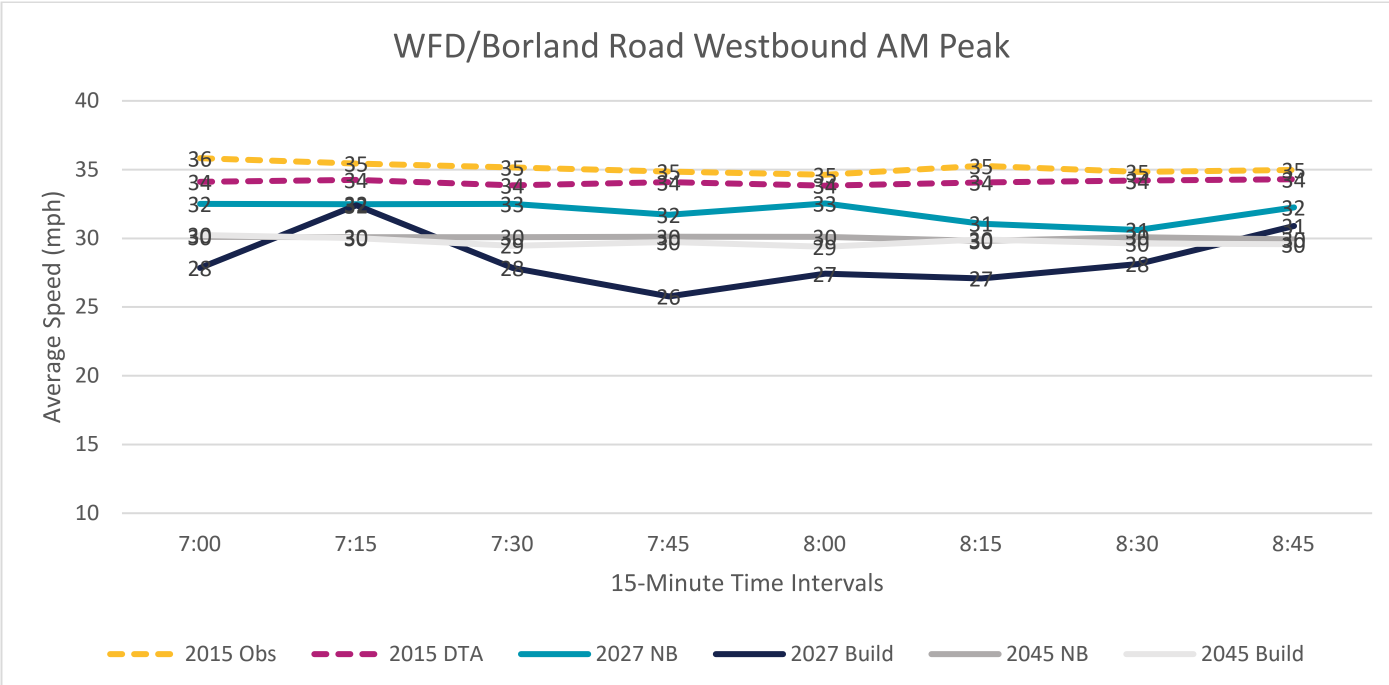



**Figure 52. Eastbound Willamette Falls Drive/Borland Road between Stafford Road OR 43 - Observed and Modeled Average Speeds: AM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

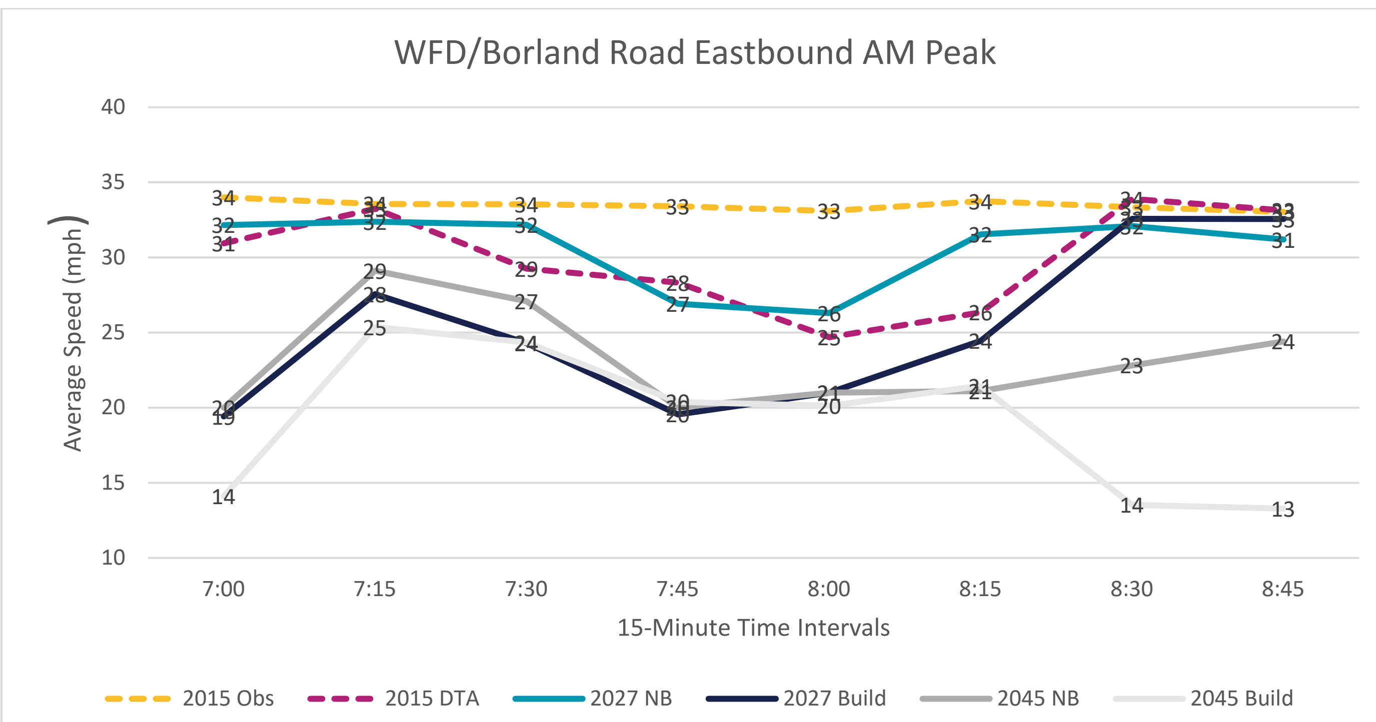


**Figure 53. Westbound Willamette Falls Drive/Borland Road between OR 43 and Stafford Road - Observed and Modeled Average Speeds: PM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**

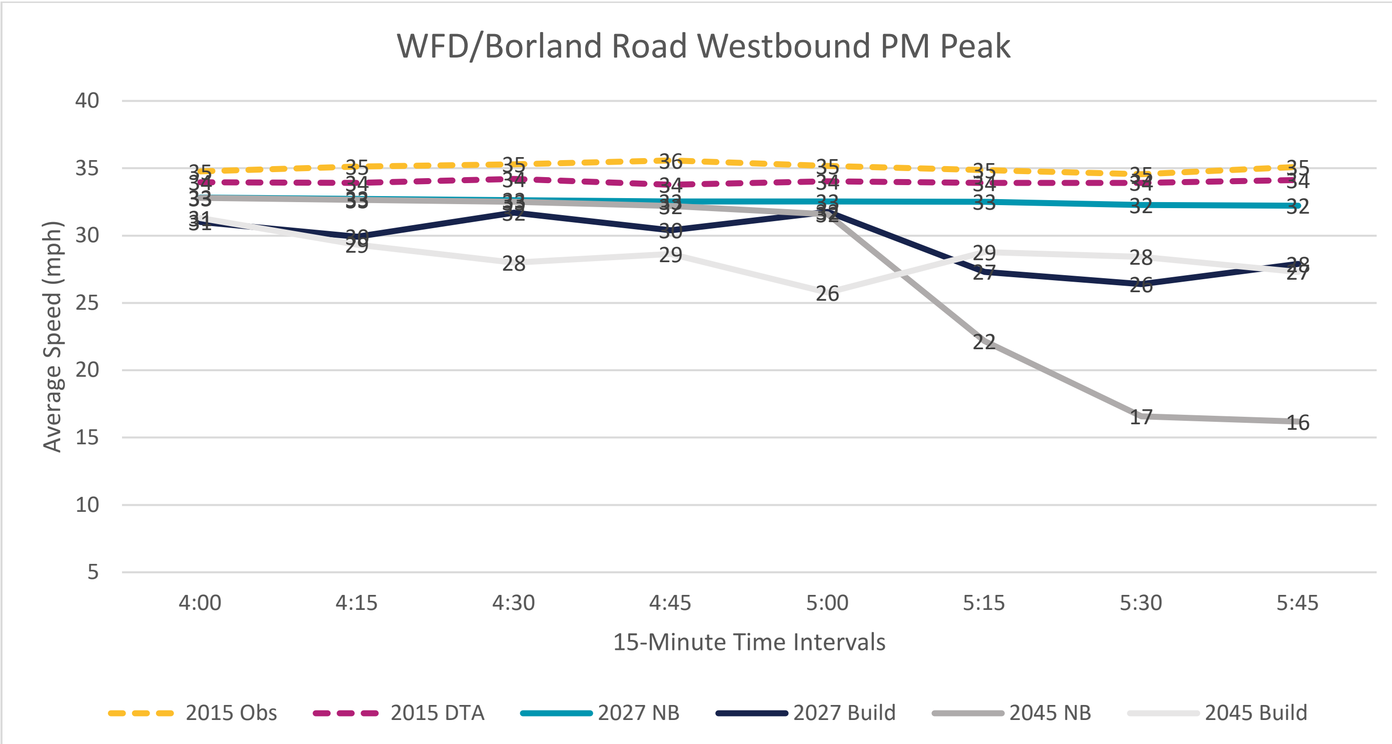
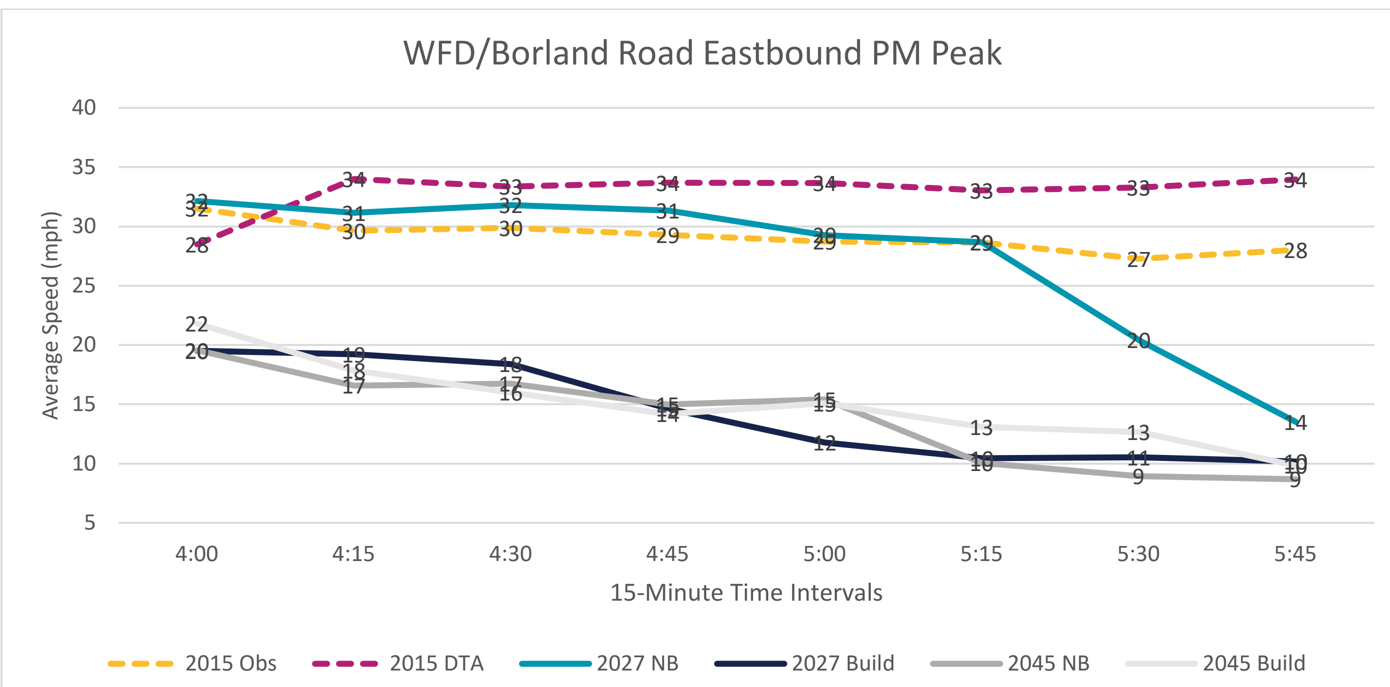



**Figure 54. Eastbound Willamette Falls Drive/Borland Road between Stafford Road OR 43 - Observed and Modeled Average Speeds: PM 15-Minute Increments, 2015 Base, 2027 and 2045 No Build and Build Alternatives**






Oregon Department of Transportation

## Subarea DTA Model Development Summary

This section summarizes the methods, assumptions, and findings of the I-205 DTA model development and calibration. The multi-step model development process involved an initial sub-area cutout of the larger, regional DTA model developed by Portland Metro and a set of network and input demand refinements for focus area calibration and testing. Since no standard calibration metrics have yet been established for DTA models, the project team compiled some aspirational calibration targets as goals based on metrics used for both macroscopic travel demand models and microscopic simulation models. Using these measures as guides, the base year AM and PM peak period models performed well and were determined to be reasonably calibrated along the I-205 corridor and surrounding arterials based on the following:

- Modeled versus observed volumes demonstrated reasonable goodness of fit based on R-squared values of approximately 0.98 for all four peak hours modeled; trendline slopes generally within +/- 8% of 1.0; and y-intercept values well below the 5% and 10% targets set for freeway and arterial facilities respectively

- Travel time comparisons for freeway segment trips less than 7 minutes in duration within the model subarea averaged across each 2-hour peak period met the project team's calibration targets over 90% of the time for the AM peak period, and 80% of the time for the PM peak period

- Travel time comparisons for freeway segment trips of 7 or more minutes in duration within the model subarea averaged across each 2-hour peak period met the project team's calibration targets 66% of the time for the AM peak period, and more than 70% of the time for the PM peak period

- Travel time comparisons for arterial segment trips less than 7 minutes in duration within the model subarea averaged across each 2-hour peak period met the project team's calibration targets 75% of the time for the AM peak period, and nearly 90% of the time for the PM peak period

- Speed comparisons on I-205 segments between observed (INRIX) and modeled data showed that the modeled speeds fall within +/- 10 mph of observed speeds for all segments and 15-minute intervals as follows: AM southbound (94%), AM northbound (83%), PM southbound (71%) and PM northbound (100%).

- Assessment of the 2027 and 2045 future No Build Alternatives indicated that the resulting volume changes and roadway conditions on I-205 demonstrated reasonable model outcomes.

- On the OR 99E corridor between River Road and Grant Street (Canby), modeled speeds fall within +/- 10 mph of observed speeds for all 15-minute intervals and segments as follows:  AM southbound (95%), AM northbound (100%), PM southbound (100%) and PM northbound (100%).

- On the Willamette Falls Drive/Borland Road corridor between OR 43 and Stafford Road, modeled speeds fall within +/- 10 mph of observed speeds for all 15-minute intervals and segments as follows:  AM westbound (100%), AM eastbound (81%), PM westbound (100%), and PM eastbound (94%).

Based on this assessment, the DTA model is considered to be well calibrated and a well-suited tool for developing future peak period volumes from which to develop project analysis volume forecasts using standardized post-processing procedures.  Given the corridor congestion shown in the base year, the subarea DTA model results reflect a notable enhancement relative to directly using peak hour RTDM model outputs for this analysis (see Table 2).

## METRO REGIONAL TRAVEL DEMAND MODEL

The Metro RTDM is the primary tool used to estimate regional multi-modal demand and account for future growth (employment, population, etc.) in future year forecasts. The RTDM is a macroscopic trip-based travel demand model that has been peer-reviewed and validated for use in the regional planning and traffic forecasting4. The model version developed for the 2018 Regional Transportation Plan (RTP) is called "Kate" and represents model base year of 2015. Future year scenarios were developed for 2027 and 2040, with an updated 2045 scenario developed for this project.5 The future model years include assumptions about expected land use growth and changes to the regional transportation network including anticipated projects, as appropriate to the project analysis needs.

Attached in support of this section on the RTDM are:

- Appendix D: Metro Time-of-Day Model Development Summary for I-205 Toll Project
- Appendix E: Value-of-Time Assumption Review

### Regional Model Refinements

The following refinements are incorporated into the Metro RTDM for the I-205 Toll Project EA.

- *Network refinements*

  The Metro RTDM modeling efforts for the EA incorporate network refinements in coordination with the I-205 DTA model calibration including, but not limited to, updates to free-flow speeds and road segment capacities.

- *Time of day choice*

  The Metro RTDM previously used time of day factors to break out trips by time of day. The factors were directional and developed from the 2010 to 2011 household activity survey (Metro 2015).[3] This leads to limited temporal sensitivity when evaluating the impacts of tolling on travel behavior.

  In order to better assess potential shifts in time-of-day travel choices due to toll rates that vary by time of day, a time-of-day (TOD) choice model was developed. The model was first developed for Home-Based Work (HBW) and Home-Based Other (HBO) trip purposes and then further extended to other trip purposes. As it was calibrated to existing time of day

[4] 2017 Kate v1.0 Trip-Based Demand Model Validation Report for Base Year 2015, August 2017 Draft, Portland Metro Research Center

[5] The 2018 RTP used a 2040 horizon year while this Project uses a 2045 horizon year. The 2045 model scenario uses the most recent land use assumptions developed in 2021 by Metro in conjunction with partner agencies, consistent with growth patterns identified in the RTP.

factors, the TOD model did not significantly affect overall RTDM calibration.[6] Details about the TOD choice model are documented in the *Metro Time-of-Day Model Development Summary for I-205 Toll Project Memorandum.*

- *Vehicle trip assignment segmented by income class*

  The Metro RTDM typically has four vehicle classes: SOV, HOV, medium trucks, and heavy trucks. For the EA model runs, the passenger vehicles (SOVs and HOVs) are further segmented by the RTDM's annual household income classes – low income (less than $25,000), medium income ($25,000 to $100,000), and high income (more than $100,000) and assigned different values of time to better represent a range of willingness to pay tolls by potential users of the toll facilities.[7]

  Refining the vehicle classes with updated values of time (VOTs) for each of the eight vehicle classes (described in the following section) is intended to generate more realistic responses to tolling by representing a range of responses and potential changes in travel behaviors for travelers with different willingness to pay.

  These changes results in a total of eight vehicle classes for roadway network assignment:

  – Low income SOV with low VOT
  – Medium income SOV with medium VOT
  – High income SOV with high VOT
  – Low income HOV with low VOT
  – Medium income HOV with medium VOT
  – High income HOV with high VOT
  – Medium truck
  – Heavy truck

- *Updated VOT assumptions*

  VOTs used in the model were updated to align with the eight vehicle classes identified in the previous section. The I-205 Travel Preference Survey was originally intended to update VOT assumptions in the Metro RTDM. Due to the onset of the COVID-19 pandemic and its associated restrictions and economic impacts, the I-205 Travel Preference Survey was suspended indefinitely. In lieu of the stated preference survey, updated VOT assumptions were developed based on detailed literature review, model practices in other regions, and

[6] The demand shifts were accounted for in the RTDM model results but do not apply directly in the (location-specific) traffic operations analysis because the traffic volumes are based on the subarea DTA model results. The process of transferring model results between the RTDM and the subarea DTA are described in Attachment A.
[7] Dollar value ranges are reported in 2010 dollars.

consideration of the results from the most recent similar stated-preference survey in the region.

Different VOTs were applied for travel during peak hours (6 a.m. to 9 a.m. and 4 p.m. to 6 p.m.), shoulder hours (5 a.m. to 6 a.m., 9 a.m. to 10 a.m., 3 p.m. to 4 p.m., and 6 p.m. to 7 p.m.), and other off-peak hours.

Details about the development of the VOT assumptions are documented in the *I-205 Toll Project Value-of-Time Assumption Review Memorandum.*

- *Toll rate schedule refinement*

  The toll rate schedule assumptions are refined for the EA to improve project outcomes. These assumptions were developed to balance the dual purposes of the project, as described in the Purpose and Need Statement: to generate revenue and manage congestion on I-205 while considering the overall project objectives including limiting potential diversion and rerouting onto other roadways.

## Regional Modeling Assumptions

### General Assumptions for EA Alternatives

Tolling alternatives for I-205 were evaluated in conjunction with the I-205 Improvements Project, including proposed reconstruction of the Abernethy Bridge, seismic upgrading of other bridges and widening of I-205 between the Stafford Road interchange at the south end and the OR 213 interchange at the north end.

Environmental clearance for the I-205 Toll Project will be obtained with an EA, which requires very well-defined alternatives. The I-205 Toll Project includes evaluation of two alternatives: Build and No Build. The No Build Alternative includes construction of Phase 1A of the I-205 Improvements Project because ODOT has financing tools that allow this phase to move forward without reliance on toll revenues. Phase 1A includes reconstruction of the Abernethy Bridge and adjacent interchange improvements on either side of the bridge, at OR 43 and OR 99E interchanges. The No Build Alternative does not include subsequent phases of the I-205 Improvements Project (Phases 1B, 1C, 1D, and 2). Tolling is assumed to be a revenue-generating mechanism necessary to fully fund construction of these subsequent improvements. Therefore, the Build Alternative includes tolls and construction of all phases of the I-205 Improvements Project, including those phases not included in the No Build Alternative.

The I-205 Toll Project proposes implementation of tolls at two locations: one between the Stafford Road and 10th Street interchanges (near to or on the Tualatin River Bridges) and one between the OR 43 and OR 99E interchanges (near to or on the Abernethy Bridge over the Willamette River). This configuration reflects the one alternative (Alternative 3) selected as the best option to advance for further study in the EA from the five alternatives identified in the screening analysis. For the EA, Alternative 3 will be the Build Alternative and compared to the No Build Alternative to assess overall project impacts. More details about the alternatives can be found in I-205 Toll Project Comparison of Screening Alternatives Technical Report.

Table 26 outlines the general modeling assumptions used for the analysis in the I-205 Toll Project EA. The EA travel demand and traffic operations were performed for the 2045 horizon year. Additional information was provided for the 2027 model year as needed.

The 2045 Metro RTDM scenarios were developed using the 2040 RTP transportation network[8] and the 2045 land use assumptions to reflect appropriate regional socio-economic growth. The project team recognizes the importance of consistency in the future modeling and analysis years for related regional projects and worked towards a common modeling approach and analysis horizon to be used across multiple projects in the region, to the extent that specific project needs, and contexts allow.

Potential land use changes resulting from pricing concepts were not evaluated formally; however, sensitivity testing was performed using Metro's land use model (Metroscope). Testing to-date using both the Oregon Statewide Integrated Model (SWIM) and Metroscope has shown that any anticipated land use shifts that would occur under proposed project configurations and assumed toll amounts would be relatively minor and unlikely to alter project findings.

[8] Deviations from RTP Network assumptions, including the removal of phases of the I-205 Improvements Project that are dependent on toll revenues, are noted in this memorandum.

**Table 26: General Modeling Assumptions for I-205 Environmental Assessment**

| Model Parameters | Assumptions |
|---|---|
| Future evaluation year | 2045 |
| Land use | Based on growth assumptions consistent with the RTP for 2040, extrapolated to 2045. Land uses are held constant across alternatives. |
| Transportation network | Includes projects in RTP Financially Constrained Project list based on project completion year, as shown in Table 27 below, except for modifications within the impacted area of the project, where noted. |
| Daily conditions | Average weekday conditions. Annual estimates (including weekends) are based on factoring weekday model results. |
| Value of time | Updated values applied to tolls are summarized in Table 28, segmented by vehicle type, income segmentation and time of day. In the Metro RTDM, tolls and values of time are expressed in 2010 dollars, which will be converted to 2020 dollars and/or year of collection dollars for reporting. |
| Toll-Paying Vehicle Classes | All modeled vehicle types (single occupancy vehicles, high occupancy vehicles, medium trucks, and heavy trucks) and income classes (low-income, medium-income, and high-income SOV and HOV) will be tolled. Monetary toll rates are summarized in Table 29 for through trips. |
| Toll rate pricing | Toll rates are assumed to vary by time of day following a fixed (known) daily schedule. No discounts or exemptions for any modeled vehicle types are assumed.[9] |
| Toll collection methods | Transponder tags or license-plate capture enforced by cameras. No toll booths or other vehicle delays are assumed. |

#### RTDM Network and Land Use Assumptions

The financially constrained RTP network and land use assumptions were applied for the Metro RTDM scenarios used for the EA, except where noted below.

Land use assumptions include jurisdiction-reviewed forecasted growth in population, households, and employment. The transportation network assumes construction of reasonably likely-to-be-funded improvements, based on the RTP process. As noted in the previous section, the 2045 scenarios were constructed by using the 2040 RTP transportation network, assuming no additional major projects will be completed by 2045. A summary of key major system

[9] While vehicle exemption policies have not been finalized at this time, it is important to note that some potentially exempt vehicles (e.g., emergency responders) are not explicitly broken out in the RTDM. Transit vehicles are assigned separately from general motor vehicle traffic and are not assessed a toll charge.

improvements assumed for the 2027 and 2040 financially constrained network (compared to the base year 2015 network) is shown in Table 27.

**Table 27. Major System Improvements Included in RTP Model Scenarios**

| Improvement | Expected Completion Year | In 2027 Network | In 2040 Network |
|---|---|---|---|
| I-5S: Lower Boones Ferry Exit to Lower Boones Ferry Entrance (Auxiliary Lane) | 2018 | √ | √ |
| I-5S: Lower Boones Ferry to I-205 (Auxiliary Lane) | 2018 | √ | √ |
| I-5 Rose Quarter (both directions) | 2027 | √ | √ |
| I-205N: I-84E Entrance to Killingsworth Exit (Auxiliary Lane) | 2019 | √ | √ |
| I-205S: I-84E Entrance to Washington/Stark (Auxiliary Lane) | 2019 | √ | √ |
| I-205N: Powell to I-84E Exit (Auxiliary Lane) | 2019 | √ | √ |
| I-205N: Sunrise to Sunnybrook (Auxiliary Lane) | 2020 | √ | √ |
| OR 217N: OR 99W to Scholls Ferry (Auxiliary Lane) | 2024 | √ | √ |
| OR 217S: Beaverton-Hillsdale to OR 99W (Auxiliary Lane) | 2024 | √ | √ |
| US 26: Widen to six lanes from Cornelius Pass to 185th (both directions) | 2018 | √ | √ |
| OR 224 Milwaukie Expressway Improvements[10] | 2027 | √ | √ |
| I-5N: Braided Ramps I-205 to Nyberg | 2040 | x | √ |
| I-5N: Nyberg to Lower Boones Ferry (Auxiliary Lane) | 2040 | x | √ |
| I-5S: Wilsonville Rd to Wilsonville-Hubbard Hwy (Auxiliary Lane) | 2040 | x | √ |
| I-5 Columbia River Bridge: Replace bridges, improve interchanges on I-5 (both directions), and implement tolls | 2040 | x | √ |
| I-5S: Truck Climbing Lane (Marquam to Multnomah Blvd). PE and ROW and CON phases | 2040 | x | √ |
| US 26: Widen to six lanes from Brookwood to Cornelius Pass (both directions) | 2040 | x | √ |
| OR 217S: Braided Ramps Beaverton-Hillsdale Hwy to Allen Blvd | 2040 | x | √ |
| OR 212/224 Sunrise Hwy Phase 2: SE 122nd to SE 172nd (CON) | 2040 | x | √ |

*Note: TriMet improvements associated with the SW Corridor project are assumed to be included.

The I-205 Improvements Project (including widening of I-205 between OR 213 and Stafford Road interchanges and Abernethy Bridge replacement) was included in the 2018 financially constrained RTP, with an expected completion year of 2027. However, only Phase 1A of the Improvements Project will be included in the Project's No Build Alternative because ODOT has

[10] Estimated year of 2027 as the project is currently on hold due to lack of funding.

financing tools that allow this phase to move forward without reliance on toll revenues. Phase 1A includes reconstruction of the Abernethy Bridge and adjacent interchange improvements on either side of the bridge, at OR 43 and OR 99E interchanges. The No Build Alternative, by excluding tolling, also excludes full construction of the I-205 Improvements Project, because it is assumed that tolling is needed to fund construction of Phases 1B, 1C, 1D, and 2. Therefore, Phase 1A is included in both the No Build and Build Alternatives. The No Build Alternative was evaluated as an alternative in the EA and used as a reference point for potential changes in travel patterns identified under the Build Alternative proposed for the I-205 Toll Project.

In addition to the improvements listed in Table 27, changes were made to the Metro RTDM networks to better reflect existing traffic conditions on the I-205 corridor and at the Oregon City Arch Bridge:

- The volume-delay function (VDF) used to estimate travel time based on volume at the Oregon City Arch Bridge was changed to match the one used for ramp meters. Compared with the previous VDF, this revision to a "steeper" VDF curve assigns more delay under congested travel conditions when the traffic volume surpasses capacity.
- Heavy trucks were prohibited from trip routings using the Arch Bridge to reflect the existing weight restriction not previously captured in the RTDM.
- A roadway connection was added between I-5 and OR 99E in the southern extent of the model network, approximately near Ehlen Road in Aurora, Oregon.
- Roadway network parameters on the I-205 corridor (such as free flow speed and capacity) were adjusted based on additional calibration performed during the subarea DTA model development process.

### Value of Time Assumptions

In the Metro RTDM, monetary tolls are applied as an equivalent time penalty (disincentive) based on an assumed value of travel time. Value of time (VOT) assumptions used for the I-205 Toll Project EA vary by time of day, vehicle type, and income classes for passenger vehicles. The VOTs used in the EA alternatives are based on the values shown in Table 28.

The tolls are represented in the model by applying VOT-equivalent time penalties (as travel delay), as appropriate for each pricing concept, based on the segment toll rate, time of day, and applicable VOT.

**Table 28: Value of Time Assumptions (2010 Dollars) [1,2]**

| Vehicle Class | Income Segmentation | Peak hours | Off Peak hours | Shoulder/Transition hours* |
|---|---|---|---|---|
| Single-Occupancy Vehicle Auto | Low Income (<$25K) | $8/hour | $6/hour | $7/hour |
| | Medium Income ($25K—$100K) | $17/hour | $14/hour | $16/hour |
| | High Income (>$100K) | $22/hour | $17/hour | $20/hour |
| High-Occupancy Vehicle Auto | Low Income (<$25K) | $15/hour | $10/hour | $13/hour |
| | Medium Income ($25K—$100K) | $30/hour | $20/hour | $27/hour |
| | High Income (>$100K) | $38/hour | $25/hour | $34/hour |
| Medium Trucks | Not Applicable | $39/hour | $39/hour | $39/hour |
| Heavy Trucks | Not Applicable | $61/hour | $61/hour | $61/hour |

*Shoulder/transition hour VOT estimates use a blended value between peak and off-peak; shown rounded to the nearest integer value.

#### Toll Rate Pricing Assumptions

The modeling performed for the EA and alternatives evaluation applies toll rate assumptions for the Build Alternative to estimate transportation system performance and effects.

During the Value Pricing Feasibility Analysis (VPFA), the Project team developed modeling assumptions for an initial toll rate schedule on I-205 at the Abernethy Bridge (Concept E). The toll rate schedule balanced maximizing throughput (with lower toll rates) and maximizing revenue (with higher toll rates) while considering the level of demand. That balance tended to yield toll rates closer to revenue maximization at off-peak times when demand is lower and closer to throughput maximization at peak times when congestion would otherwise be prevalent. This approach is consistent with variable rate schedules adopted by other toll facilities with revenue generation objectives.

For the initial I-205 screening of alternatives, modeled toll rates were based on the schedule developed for VPFA Concept E. [11] While the toll structure and number of toll locations are different for each alternative, the overall toll rates for through travelers on I-205 remained generally consistent with the Concept E rates, with expected differences in the tolls for shorter trips.

For the EA, toll rates were further refined, and toll configurations narrowed down to one Build Alternative to better achieve the dual purposes of the project: providing sufficient net toll revenues to fund (partially or completely) the construction of the I-205 Improvements Project

[11] Concept E reflected a single-point toll across the Abernethy Bridge.

and managing congestion. The following refinements were made to the toll schedule assumptions for the EA Build Alternative.

- Increase toll rates during peak hours
- Decrease auto toll rates during off-peak hours
- Vary toll rates to smooth the transition between peak and off-peak toll levels
- Extend the a.m. peak period to be three hours
- Charge minimal toll ($1) during the overnight period
- Present the toll schedule in current, 2020 dollars

Table 29 shows Through Trip Toll Rate for the EA Build Alternative (Screening Alternative 3). Toll rates are the same for both directions of travel.

**Table 29: Proposed Through Trip Toll Rate Assumptions by Time Period (2020 dollars)**

| Period | Hours | Toll |
|---|---|---|
| p.m. Peak | 4-6 p.m. | $4.00 |
| a.m. Peak | 6-9 a.m. | $3.50 |
| Shoulder | 3-4 p.m., 6-7 p.m. | $3.00 |
| Transition | 5-6 a.m., 9-10 a.m., 1-3 p.m., 7-8 p.m. | $1.80 |
| Off Peak | 10 a.m.-1 p.m., 8-11 p.m. | $1.20 |
| Overnight | 11 p.m.- 5 a.m. | $1.00 |

The total toll amount a traveler pays varies depending on the number of I-205 tolled segments traveled, though users only receive a single charge for each trip. For Alternative 3, half the toll rate shown in Table 29 is applied at the Tualatin River Bridge(s) and the other half is applied at the Abernethy Bridge. Thus, users who travel across only one of the two tolled segments would pay half the toll amount shown in Table 29.

## MODELING APPROACH OUTREACH AND REVIEW

Extensive coordination and partner agency outreach on the modeling approach and modeling results was performed, including the following:

- Weekly project modeling team meetings with technical experts from ODOT, Portland Metro, Southwest Washington Regional Transportation Council, Clackamas County and the consultant team to provide detailed progress updates and discuss the modeling approach and findings.
- Regular meetings with two working groups with technical staff from regional and local agencies – the Regional Modeling Group (RMG) and Transit/Multimodal Working Group (TMWG)- to summarize modeling efforts and solicit feedback and suggestions on approach.

In an effort to be transparent and collaborative, raw model data results of the I-205 screening results were shared with technical staff from partner agencies in July 2020. While these RTDM results were preliminary, they provided agency partners with a high-level overview of potential changes in travel patterns. Similar data-sharing was completed for the EA model results, both for RTDM results (in October 2021) and for DTA model results (in January 2022).

## REFERENCES

[1] The Value of Travel-Time: Estimates of the Hourly Value of Time for Vehicles in Oregon (2015). ODOT PIAU, November 2016

[2] Portland Metro Kate Trip-Based Travel Demand Model, 2018

[3] 2015 Trip-Based Travel Demand Model Methodology Report. Portland Metro. April 2015.

[4] NCHRP Report 765, Analytical Travel Forecasting Approaches for Project-Level Planning and Design, National Cooperative Highway Research Program, 2016.

[5] Transportation Research Circular E-C153, Dynamic Traffic Assignment-A Primer, Transportation Research Board, June 2011

## APPENDIX A: SUMMARY OF PEAK HOUR VOLUME POST-PROCESSING APPROACH

DTA model link volumes were used to develop the future No Build and Build volumes. The DTA peak periods are 7-9 AM in the morning and 4-6 PM in the afternoon. Based on guidance from ODOT, the 2-hour peak period volumes were processed by applying a factor of 0.52 to get the peak hour model volumes. These processed model peak hour volumes were then used for forecasting.

It should be noted that there are some links in the DTA model that have latent demand which does not get served during the peak hours. However, as the DTA model reports both demand and outflow for each link; unserved demands was calculated based on the difference between them. All links within the study area for both the No Build and Build scenarios were reviewed. Links where the unserved demand was significant and needed to be adjusted were flagged manually.

- If the demand is higher than or equal to the outflow, the link volume used for forecasting was adjusted to be equal to the demand
- If the demand is less than the outflow, which resulted in a negative "unserved demand", no adjustment was made to the link volume

The forecasting process follows the steps descripted in Chapter 6 from the ODOT's Analysis Procedures Manual (APM).

**Future No Build Forecasts (2027 and 2045)**

A spreadsheet was developed to track the post-processing calculations. Figure 55 shows a screenshot of the spreadsheet. Rows represent the turning movements, and the turning movements were grouped by approaches. Columns represent the following post-processing calculation steps:

1. Read in existing turning movement volumes, calculate the directional link volumes for each approach.
2. Read in DTA model peak hour link volumes and demands. Calculate the link volumes (52% of 2-hour outflows) and the adjusted link volumes (with unserved demand adjusted for each hour, and then calculated the 52% of the 2-hour adjusted link volumes).
3. Manually flag links where the unserved demand adjustment is needed.
4. Re-summarize the adjusted model volumes that will be used for forecasting.
5. Since the DTA model base year (2015) does not match with the project existing year (2021), the base year model volumes are adjusted following the formula given in APM:

   *Existing Year Model Volume = Base Year Model Volume x (1+ Annual Growth Rate x (Project Existing Year - Model Base Year))*
6. Apply growth method and difference method.

7. Select the method to use. Links where the difference in future year volumes between the difference and growth methods exceeded 10 percent are highlighted in this spreadsheet using conditional formatting. In the case where it exceeds 10 percent the difference method was selected, or in the case where it is less than or equal to 10 percent, the average of the two methods was used.
8. Eliminate negative growth and calculate the link forecast volumes. It is assumed that future no build volumes should be at least same or higher than the existing volumes.
9. Calculate the turning movement volumes by applying the existing turning movement proportions to the approach link forecast volumes. And the forecast turning movement volumes are rounded to the nearest 5.
10. After the forecasting step, the turning movement volumes need to be balanced between adjacent intersections and then bring back to this spreadsheet to check the balancing adjustments and make sure the adjusted balanced volumes are still same or higher than the existing counts. The balancing process was done in another spreadsheet. The last column in this spreadsheet calculates the difference between final forecast volumes with the existing counts, and conditional formatting was applied to highlight if there is any negative growth needs to be adjusted.

**Figure 55 Example Future Year No Build Forecasting Spreadsheet (2045 No Build AM)**

| ID | Int Description | Turn | (1) Existing Count Rounded Balanced | (1) Existing Count by App | (2) 2045 Model Demand and Volume (Hour 1) aDemand | aFlowO | Demand - Outflow | (2) Adjusted Hour 1 Link Volume | (2) 2045 Model Demand and Volume (Hour 2) aDemand | aFlowO | Demand - Outflow | (2) Adjusted Hour 2 Link Volume | (2) Calculated Peak Hour Volume (52%) Adjusted Unserved Demand | (2) Calculated Peak Hour Outflow (52%) | (3) Flag Adj Latent Demand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SW Stafford Rd & SW Borland Rd | NBL | 225 | | | | | | | | | | | | |
| 1 | | NBT | 385 | 670 | 855 | 755 | 100 | 855 | 1031 | 980 | 51 | 1031 | 981 | 902 | 1 |
| 1 | | NBR | 60 | | | | | | | | | | | | |
| 1 | | SBL | 40 | | | | | | | | | | | | |
| 1 | | SBT | 360 | 600 | 984 | 944 | 40 | 984 | 948 | 970 | -22 | 970 | 1016 | 995 | 0 |
| 1 | | SBR | 200 | | | | | | | | | | | | |
| 1 | | EBL | 140 | | | | | | | | | | | | |
| 1 | | EBT | 40 | 305 | 304 | 297 | 7 | 304 | 508 | 476 | 32 | 508 | 422 | 402 | 0 |
| 1 | | EBR | 125 | | | | | | | | | | | | |
| 1 | | WBL | 50 | | | | | | | | | | | | |
| 1 | | WBT | 100 | 200 | 192 | 186 | 6 | 192 | 214 | 198 | 16 | 214 | 211 | 200 | 0 |
| 1 | | WBR | 50 | | | | | | | | | | | | |
| 2 | SW Stafford Rd & I-205 NB Ramps | NBL | 0 | | | | | | | | | | | | |
| 2 | | NBT | 290 | 490 | 925 | 906 | 19 | 925 | 1429 | 1293 | 136 | 1429 | 1224 | 1143 | 1 |
| 2 | | NBR | 200 | | | | | | | | | | | | |
| 2 | | SBL | 180 | | | | | | | | | | | | |
| 2 | | SBT | 310 | 490 | 769 | 729 | 40 | 769 | 641 | 654 | -13 | 654 | 740 | 719 | 0 |
| 2 | | SBR | 0 | | | | | | | | | | | | |
| 2 | | EBL | 220 | | | | | | | | | | | | |
| 2 | | EBT | | 330 | 213 | 204 | 9 | 213 | 175 | 172 | 3 | 175 | 202 | 196 | 0 |
| 2 | | EBR | 110 | | | | | | | | | | | | |
| 2 | | WBL | 0 | | | | | | | | | | | | |
| 2 | | WBT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | | WBR | 0 | | | | | | | | | | | | |
| 3 | SW Stafford Rd & I-205 SB Ramps | NBL | 100 | | | | | | | | | | | | |
| 3 | | NBT | 410 | 510 | 662 | 627 | 35 | 662 | 989 | 921 | 68 | 989 | 859 | 805 | 0 |
| 3 | | NBR | 0 | | | | | | | | | | | | |
| 3 | | SBL | 0 | | | | | | | | | | | | |
| 3 | | SBT | 335 | 535 | 728 | 707 | 21 | 728 | 689 | 678 | 11 | 689 | 737 | 720 | 0 |
| 3 | | SBR | 200 | | | | | | | | | | | | |
| 3 | | EBL | 0 | | | | | | | | | | | | |
| 3 | | EBT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | | EBR | 0 | | | | | | | | | | | | |
| 3 | | WBL | 155 | | | | | | | | | | | | |
| 3 | | WBT | | 415 | 768 | 659 | 109 | 768 | 688 | 783 | -95 | 783 | 807 | 750 | 0 |
| 3 | | WBR | 260 | | | | | | | | | | | | |

| ID | Turn | (4) Raw Model Volume 2015 | (4) Raw Model Volume 2045 | (4) Adjusted Model Volume 2015 | (4) Adjusted Model Volume 2045 | (5) Annual Growth Rate | (5) Estimated Model Volume 2021 | (6) Growth Method 2045 | (6) Difference Method 2045 | (7) % Difference | (7) Selected Method | (7) Selected Method 2045 | (8) QC: Effective Rate | (8) Adjusted Rate | (8) Final Link 2045 | (9) Turn Volume 2045 | (9) Manual Adj 2045 | (9) Final Turn Volume 2045 | (9) Rounded Unbalanced Volume 2045 | (10) Final Balanced Volume 2045 | (10) Balance Difference 2045 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NBL | | | | | | | | | | | | | | | 306 | | 306 | 305 | 305 | 0 |
| 1 | NBT | 666 | 981 | 666 | 981 | 1.58% | 729 | 902 | 922 | 2.3% | Average | 912 | 1.50% | 1.50% | 912 | 524 | | 524 | 525 | 620 | 95 |
| 1 | NBR | | | | | | | | | | | | | | | 82 | | 82 | 80 | 80 | 0 |
| 1 | SBL | | | | | | | | | | | | | | | 59 | | 59 | 60 | 60 | 0 |
| 1 | SBT | 613 | 995 | 613 | 995 | 2.08% | 689 | 866 | 906 | 4.6% | Average | 886 | 1.98% | 1.98% | 886 | 531 | | 531 | 530 | 490 | -40 |
| 1 | SBR | | | | | | | | | | | | | | | 295 | | 295 | 295 | 295 | 0 |
| 1 | EBL | | | | | | | | | | | | | | | 180 | | 180 | 180 | 180 | 0 |
| 1 | EBT | 292 | 402 | 292 | 402 | 1.26% | 314 | 390 | 393 | 0.6% | Average | 392 | 1.18% | 1.18% | 392 | 51 | | 51 | 50 | 50 | 0 |
| 1 | EBR | | | | | | | | | | | | | | | 161 | | 161 | 160 | 150 | -10 |
| 1 | WBL | | | | | | | | | | | | | | | 59 | | 59 | 60 | 60 | 0 |
| 1 | WBT | 160 | 200 | 160 | 200 | 0.83% | 168 | 238 | 232 | 2.6% | Average | 235 | 0.73% | 0.73% | 235 | 118 | | 118 | 120 | 120 | 0 |
| 1 | WBR | | | | | | | | | | | | | | | 59 | | 59 | 60 | 60 | 0 |
| 2 | NBL | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 2 | NBT | 431 | 1224 | 431 | 1224 | 6.13% | 590 | 1,017 | 1,124 | 10.5% | Difference | 1124 | 5.39% | 5.39% | 1,124 | 665 | | 665 | 665 | 625 | -40 |
| 2 | NBR | | | | | | | | | | | | | | | 459 | | 459 | 460 | 460 | 0 |
| 2 | SBL | | | | | | | | | | | | | | | 222 | | 222 | 220 | 220 | 0 |
| 2 | SBT | 562 | 719 | 562 | 719 | 0.93% | 593 | 594 | 616 | 3.7% | Average | 605 | 0.97% | 0.97% | 605 | 383 | | 383 | 385 | 430 | 45 |
| 2 | SBR | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 2 | EBL | | | | | | | | | | | | | | | 220 | | 220 | 220 | 220 | 0 |
| 2 | EBT | 225 | 196 | 225 | 196 | -0.43% | 219 | 295 | 307 | 4.0% | Average | 301 | -0.37% | 0.00% | 330 | | | | | | 0 |
| 2 | EBR | | | | | | | | | | | | | | | 110 | | 110 | 110 | 110 | 0 |
| 2 | WBL | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 2 | WBT | 0 | 0 | 0 | 0 | 0.00% | 0 | 0 | 0 | 0.0% | Average | 0 | 0.00% | 0.00% | 0 | 0 | | 0 | 0 | 0 | 0 |
| 2 | WBR | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 3 | NBL | | | | | | | | | | | | | | | 177 | | 177 | 175 | 175 | 0 |
| 3 | NBT | 351 | 805 | 351 | 805 | 4.31% | 442 | 929 | 873 | 6.0% | Average | 901 | 3.20% | 3.20% | 901 | 725 | | 725 | 725 | 670 | -55 |
| 3 | NBR | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 3 | SBL | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 3 | SBT | 551 | 720 | 551 | 720 | 1.02% | 585 | 659 | 670 | 1.7% | Average | 664 | 1.01% | 1.01% | 664 | 416 | | 416 | 415 | 450 | 35 |
| 3 | SBR | | | | | | | | | | | | | | | 248 | | 248 | 250 | 250 | 0 |
| 3 | EBL | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 3 | EBT | 0 | 0 | 0 | 0 | 0.00% | 0 | 0 | 0 | 0.0% | Average | 0 | 0.00% | 0.00% | 0 | 0 | | 0 | 0 | 0 | 0 |
| 3 | EBR | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 | 0 |
| 3 | WBL | | | | | | | | | | | | | | | 201 | | 201 | 200 | 200 | 0 |
| 3 | WBT | 567 | 750 | 567 | 750 | 1.08% | 604 | 516 | 561 | 8.9% | Average | 539 | 1.24% | 1.24% | 539 | | | | | | 0 |
| 3 | WBR | | | | | | | | | | | | | | | 337 | | 337 | 335 | 335 | 0 |

**Future Build Forecasts (2027 and 2045)**

The 2045 build forecasts started with the future No Build forecasts volumes (2027 and 2045) and followed the steps below as shown in the example spreadsheet shown in Figure 56.

1. Read in the future no build directional link forecast volumes. These directional link volumes are calculated from the future no build turning movement forecast volumes.
2. Read in DTA model peak hour link volumes and demands.
3. Manually flag links (for both No Build and Build) where the unserved demand adjustments are needed.
4. Calculate the adjusted link volumes (for both No Build and Build scenarios) that will be used for forecasting.
5. Apply growth and difference equations between No Build and Build scenarios. Calculate the percent difference between two methods for each directional link. Select difference if the percent difference exceeds 10 percent, select the average of difference and growth methods if the percent difference is less than or equal to 10 percent.
6. Manual adjustment to overwrite the selected method.
7. Balance the inflows and outflows at each intersection and get the final directional link forecast volumes. For the unbalanced inflows and outflows, the differences were split half-half to each of the flows by increasing or decreasing link volumes in proportion to the total flow volume.
8. Determine intersection movements using TurnsW32.
9. Re-balance the volumes between adjacent intersections and round the numbers to the nearest 5.

**Figure 56. Example Future Build Link Forecasts Spreadsheet (2045 Build AM)**

| ID | Int Description | Link Direction | Dep /App | 2021 CNT | (1) 2045 No Build Balanced Forecast | (2) 2045 No Build Demand and Volume | | | | | | 2045 Build Demand and Volume | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Hour 7 aDemand | Hour 7 aFlowO | Hour 7 Demand - Outflow | Hour 8 aDemand | Hour 8 aFlowO | Hour 8 Demand - Outflow | Hour 7 aDemand | Hour 7 aFlowO | Hour 7 Demand - Outflow | Hour 8 aDemand | Hour 8 aFlowO | Hour 8 Demand - Outflow |
| 1 | SW Stafford Rd & SW Borland Rd | S Leg Departure | Dep | 535 | 700 | 726 | 708 | 18 | 690 | 677 | 13 | 996 | 965 | 31 | 998 | 978 | 20 |
| 1 | | S Leg Approach | App | 670 | 1,005 | 855 | 755 | 100 | 1,031 | 980 | 51 | 562 | 525 | 37 | 711 | 654 | 57 |
| 1 | | W Leg Departure | Dep | 525 | 720 | 536 | 521 | 15 | 457 | 453 | 4 | 589 | 567 | 22 | 422 | 429 | -7 |
| 1 | | W Leg Approach | App | 305 | 380 | 304 | 297 | 7 | 508 | 476 | 32 | 294 | 293 | 1 | 416 | 384 | 32 |
| 1 | | N Leg Departure | Dep | 575 | 860 | 804 | 712 | 92 | 1,359 | 1,261 | 98 | 637 | 598 | 39 | 1,103 | 1,019 | 84 |
| 1 | | N Leg Approach | App | 600 | 845 | 984 | 944 | 40 | 948 | 970 | -22 | 1,055 | 1,011 | 44 | 1,176 | 1,163 | 13 |
| 1 | | E Leg Departure | Dep | 140 | 190 | 250 | 237 | 13 | 218 | 229 | -11 | 252 | 243 | 9 | 245 | 242 | 3 |
| 1 | | E Leg Approach | App | 200 | 240 | 192 | 186 | 6 | 214 | 198 | 16 | 561 | 549 | 12 | 474 | 465 | 9 |
| 2 | SW Stafford Rd & I-205 NB Ramps | S Leg Departure | Dep | 420 | 540 | 613 | 565 | 48 | 544 | 577 | -33 | 396 | 367 | 29 | 503 | 483 | 20 |
| 2 | | S Leg Approach | App | 490 | 1,085 | 925 | 906 | 19 | 1,429 | 1,293 | 136 | 830 | 802 | 28 | 892 | 854 | 38 |
| 2 | | W Leg Departure | Dep | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | | W Leg Approach | App | 330 | 330 | 213 | 204 | 9 | 175 | 172 | 3 | 221 | 198 | 23 | 387 | 389 | -2 |
| 2 | | N Leg Departure | Dep | 510 | 845 | 661 | 639 | 22 | 990 | 925 | 65 | 595 | 566 | 29 | 910 | 875 | 35 |
| 2 | | N Leg Approach | App | 490 | 650 | 769 | 729 | 40 | 641 | 654 | -13 | 541 | 514 | 27 | 651 | 621 | 30 |
| 2 | | E Leg Departure | Dep | 380 | 680 | 636 | 641 | -5 | 704 | 645 | 59 | 593 | 582 | 11 | 519 | 518 | 1 |
| 2 | | E Leg Approach | App | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | SW Stafford Rd & I-205 SB Ramps | S Leg Departure | Dep | 490 | 650 | 769 | 729 | 40 | 641 | 660 | -19 | 541 | 510 | 31 | 650 | 628 | 22 |
| 3 | | S Leg Approach | App | 510 | 845 | 662 | 627 | 35 | 989 | 921 | 68 | 595 | 557 | 38 | 910 | 866 | 44 |
| 3 | | W Leg Departure | Dep | 300 | 425 | 525 | 498 | 27 | 710 | 701 | 9 | 754 | 715 | 39 | 877 | 872 | 5 |
| 3 | | W Leg Approach | App | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | | N Leg Departure | Dep | 670 | 1,005 | 855 | 755 | 100 | 1,031 | 980 | 51 | 562 | 525 | 37 | 711 | 654 | 57 |
| 3 | | N Leg Approach | App | 535 | 700 | 728 | 707 | 21 | 689 | 678 | 11 | 996 | 957 | 39 | 997 | 979 | 18 |
| 3 | | E Leg Departure | Dep | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | | E Leg Approach | App | 415 | 535 | 768 | 659 | 109 | 688 | 783 | -95 | 279 | 245 | 34 | 322 | 317 | 5 |
| 4 | SW Stafford Rd & SW Ek Rd | S Leg Departure | Dep | 380 | 475 | 590 | 537 | 53 | 541 | 580 | -39 | 389 | 364 | 25 | 495 | 481 | 14 |
| 4 | | S Leg Approach | App | 490 | 1,140 | 880 | 859 | 21 | 1,395 | 1,272 | 123 | 779 | 756 | 23 | 861 | 842 | 19 |
| 4 | | W Leg Departure | Dep | 10 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | | W Leg Approach | App | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | | N Leg Departure | Dep | 490 | 1,085 | 925 | 904 | 21 | 1,430 | 1,300 | 130 | 831 | 805 | 26 | 890 | 860 | 30 |
| 4 | | N Leg Approach | App | 420 | 540 | 613 | 565 | 48 | 544 | 577 | -33 | 396 | 367 | 29 | 503 | 483 | 20 |
| 4 | | E Leg Departure | Dep | 140 | 225 | 29 | 29 | 0 | 24 | 22 | 2 | 22 | 21 | 1 | 22 | 22 | 0 |
| 4 | | E Leg Approach | App | 90 | 100 | 60 | 60 | 0 | 49 | 49 | 0 | 69 | 69 | 0 | 48 | 48 | 0 |

| ID | Link Direction | (3) Adj Latent Demand Flag | | Model Volumes | | (4) Ramp-to-Ramp Volumes | | Adjusted Model Volumes | | | (5) Initial Forecast | | | | | | (6) Adjust Method | Rounded Adjust selected Method | (7) Manual Adj | Final Forecast |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No Build | Build | 2045 No Build | 2045 Build | 2045 No Build | 2045 Build | 2045 No Build | 2045 Build | Build - No Build | Difference Method | Growth Method | Averaged | Percent Difference | Recommend Method | Raw Forecast | | | | |
| 1 | S Leg Departure | 0 | 0 | 720 | 1,010 | | | 720 | 1,010 | 290 | 990 | 982 | 986 | 1% | Averaged | 986 | 986 | 986 | -3 | 983 |
| 1 | S Leg Approach | 0 | 0 | 902 | 613 | | | 902 | 613 | -289 | 716 | 683 | 700 | 5% | Averaged | 700 | 700 | 700 | 2 | 702 |
| 1 | W Leg Departure | 0 | 0 | 506 | 518 | | | 506 | 518 | 12 | 732 | 737 | 735 | 1% | Averaged | 735 | 735 | 735 | -3 | 732 |
| 1 | W Leg Approach | 0 | 0 | 402 | 352 | | | 402 | 352 | -50 | 330 | 333 | 332 | 1% | Averaged | 332 | 332 | 332 | 1 | 333 |
| 1 | N Leg Departure | 1 | 1 | 1,125 | 905 | | | 1,125 | 905 | -220 | 640 | 692 | 666 | 8% | Averaged | 666 | 666 | 666 | -2 | 664 |
| 1 | N Leg Approach | 0 | 0 | 995 | 1,130 | | | 995 | 1,130 | 135 | 980 | 960 | 970 | 2% | Averaged | 970 | 970 | 970 | 3 | 973 |
| 1 | E Leg Departure | 0 | 0 | 242 | 252 | | | 242 | 252 | 10 | 200 | 198 | 199 | 1% | Averaged | 199 | 199 | 199 | -1 | 198 |
| 1 | E Leg Approach | 0 | 0 | 200 | 527 | | | 200 | 527 | 327 | 567 | 632 | 600 | 10% | Difference | 567 | 567 | 567 | 2 | 569 |
| 2 | S Leg Departure | 0 | 0 | 594 | 442 | | | 594 | 442 | -152 | 388 | 402 | 395 | 3% | Averaged | 395 | 395 | 395 | -1 | 394 |
| 2 | S Leg Approach | 1 | 0 | 1,224 | 861 | | | 1,224 | 861 | -363 | 722 | 763 | 743 | 5% | Averaged | 743 | 743 | 743 | 2 | 745 |
| 2 | W Leg Departure | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | #DIV/0! | #DIV/0! | - | - | 0 | 0 | 0 |
| 2 | W Leg Approach | 0 | 0 | 196 | 305 | | | 196 | 305 | 109 | 439 | 514 | 477 | 15% | Difference | 439 | 477 | 477 | 1 | 478 |
| 2 | N Leg Departure | 0 | 0 | 813 | 749 | | | 813 | 749 | -64 | 781 | 778 | 780 | 0% | Averaged | 780 | 780 | 780 | -2 | 778 |
| 2 | N Leg Approach | 0 | 0 | 719 | 590 | | | 719 | 590 | -129 | 521 | 533 | 527 | 2% | Averaged | 527 | 527 | 527 | 2 | 529 |
| 2 | E Leg Departure | 0 | 0 | 669 | 572 | | | 669 | 572 | -97 | 583 | 581 | 582 | 0% | Averaged | 582 | 582 | 582 | -2 | 580 |
| 2 | E Leg Approach | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | #DIV/0! | #DIV/0! | - | - | 0 | 0 | 0 |
| 3 | S Leg Departure | 0 | 0 | 722 | 592 | | | 722 | 592 | -130 | 520 | 533 | 527 | 2% | Averaged | 527 | 527 | 527 | -2 | 525 |
| 3 | S Leg Approach | 0 | 0 | 805 | 740 | | | 805 | 740 | -65 | 780 | 777 | 779 | 0% | Averaged | 779 | 779 | 779 | 3 | 782 |
| 3 | W Leg Departure | 0 | 0 | 623 | 825 | | | 623 | 825 | 202 | 627 | 563 | 595 | 11% | Difference | 627 | 627 | 627 | -3 | 624 |
| 3 | W Leg Approach | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | #DIV/0! | #DIV/0! | - | - | 0 | 0 | 0 |
| 3 | N Leg Departure | 0 | 0 | 902 | 613 | | | 902 | 613 | -289 | 716 | 683 | 700 | 5% | Averaged | 700 | 700 | 700 | -3 | 697 |
| 3 | N Leg Approach | 0 | 0 | 720 | 1,007 | | | 720 | 1,007 | 287 | 987 | 979 | 983 | 1% | Averaged | 983 | 983 | 983 | 4 | 987 |
| 3 | E Leg Departure | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | #DIV/0! | #DIV/0! | - | - | 0 | 0 | 0 |
| 3 | E Leg Approach | 0 | 0 | 750 | 292 | | | 750 | 292 | -458 | 77 | 208 | 143 | 63% | Difference | 77 | 77 | 77 | 0 | 77 |
| 4 | S Leg Departure | 0 | 0 | 581 | 439 | | | 581 | 439 | -142 | 333 | 359 | 346 | 7% | Averaged | 346 | 346 | 346 | -2 | 344 |
| 4 | S Leg Approach | 1 | 0 | 1,183 | 831 | | | 1,183 | 831 | -352 | 788 | 801 | 795 | 2% | Averaged | 795 | 795 | 795 | 4 | 799 |
| 4 | W Leg Departure | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 15 | 15 | 15 | 0% | Averaged | 15 | 15 | 15 | 0 | 15 |
| 4 | W Leg Approach | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 20 | 20 | 20 | 0% | Averaged | 20 | 20 | 20 | 0 | 20 |
| 4 | N Leg Departure | 1 | 0 | 1,225 | 866 | | | 1,225 | 866 | -359 | 726 | 767 | 747 | 5% | Averaged | 747 | 747 | 747 | -3 | 744 |
| 4 | N Leg Approach | 0 | 0 | 594 | 442 | | | 594 | 442 | -152 | 388 | 402 | 395 | 3% | Averaged | 395 | 395 | 395 | 2 | 397 |
| 4 | E Leg Departure | 0 | 0 | 27 | 22 | | | 27 | 22 | -5 | 220 | 183 | 202 | 20% | Difference | 220 | 220 | 220 | -1 | 219 |
| 4 | E Leg Approach | 0 | 0 | 57 | 61 | | | 57 | 61 | 4 | 104 | 107 | 106 | 3% | Averaged | 106 | 106 | 106 | 0 | 106 |

## APPENDIX B: DTA MODEL VALIDATION CRITERIA FOR THE I-205 TOLLING STUDY

While both macroscopic traffic assignment models used in regional travel demand models and microscopic traffic simulation models have well established validation guidelines, currently mesoscopic DTA models do not. The limited guidelines for DTA model validation that do exist are rather general. For example, FHWA's *Traffic Analysis Toolbox Volume XIV: Guidebook on the Utilization of Dynamic Traffic Assignment in Modeling* suggests merely that comparisons of modeled network flows and speeds to observed counts and speeds should be made, and that agreement of validation measures and acceptable goodness-of-fit criteria should be stated and agreed upon by stakeholders.

This document outlines considerations for choosing those measures and criteria for the DTA model or models developed for the I-5 and I-205 Tolling Studies and recommends the specific criteria for use with the DTA model developed for the I-205 Tolling Study.

### Validation Criteria Background

DTA models are different from macroscopic and microscopic network models in that their spatial scope can vary widely. DTA models may be developed for rather small corridors or may be nearly regional in size. They may be linear in shape, where very little route choice would be represented or more geographically broad with a great deal of diverse route choice options. Criteria for a small, concise network could reasonably resemble that used for microscopic models while a larger more regional scale model would find it difficult to satisfy those stringent criteria. Note that even for the two tolling studies for I-205 and I-5, the scale of final DTA models or focus areas within those models will be quite different in geographic scale and complexity of network route diversions.

Federal and State publications of model development guidelines have been reviewed to guide specification of criteria for the I-5 and I-205 DTA models. A list of considered documents is provided at the end of this document. While specific validation criteria are not specified in these documents reviewed, there are concepts and examples included that provide some guidance in developing our process.

Some reports for DTA model development projects were also reviewed. In many cases, common aggregate measures such as %RMSE or scatter plots were prepared in model validation chapters and used as indicators of goodness-of-fit for their models, but comparison to specific quantitative criteria were not given. Past DTA model validation efforts seem to present evidence of validation and rely on qualitative interpretation and visual inspection of relationships. It is our desire to have explicit quantitative criteria that all involved parties agree on that substantiate the quality of the DTA model for use in alternatives analysis.

The data one would like to collect for calibration and validation of time-dependent network flow models is difficult to obtain and expansive. One would ideally like to have observed traffic counts and travel speeds for a good portion of the model network for every 15-minute period, with counts and speeds observed at the same time, and observed multiple times so that statistical analyses of model results would be possible. This idealistic data collection would be so expansive that some data could be used for model calibration and another independent set of data used for model validation. However, current public agency data collection practices do not afford such expansive idealistic data to be assembled. Rather, it is likely we will have a single set of observed link count and link speed data observed on different days, maybe different seasons, and at fewer locations than desired. The validation criteria for the DTA model validation should be defined in consideration of the type and quantity of data collected and the ability to resolve data anomalies.

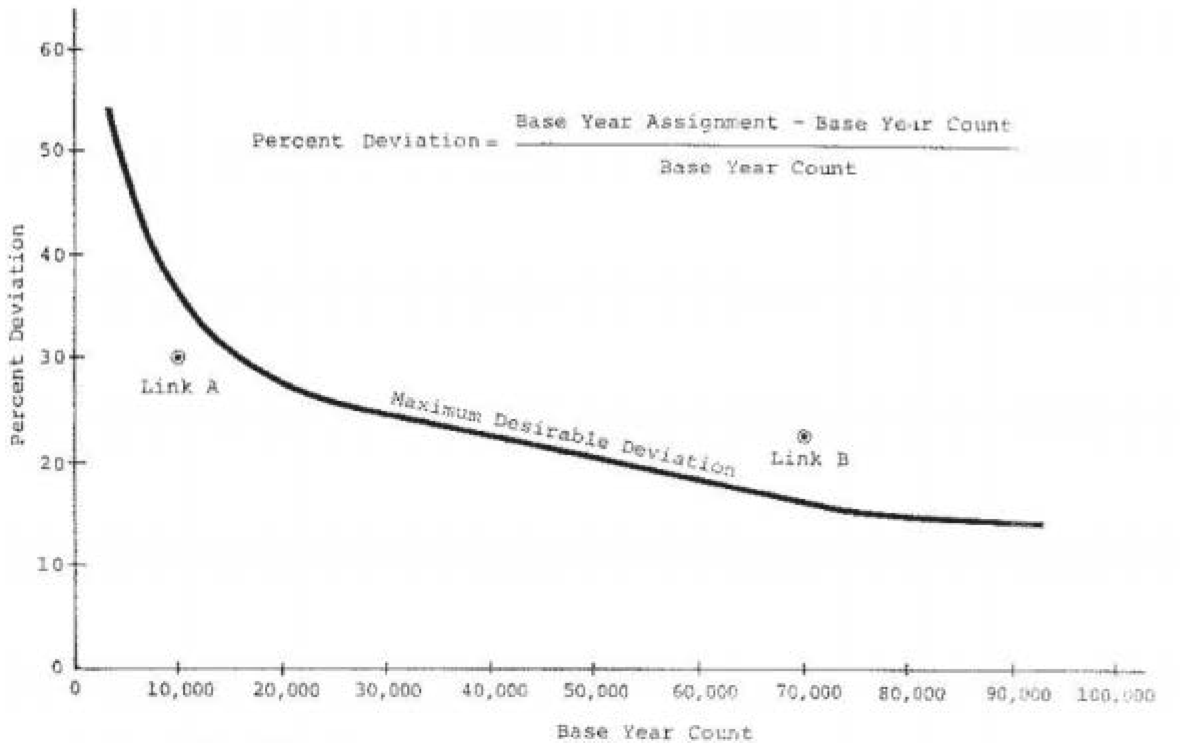
Having little in the way of past practical, suitable examples, we considered other sources for validation criteria. From regional travel demand modeling, NCHRP Report 716 provides an example summary table used to validate daily traffic volumes for some region. The table is shown below. The rightmost column provides the suggested acceptable relative errors for daily volumes compared to ADT by facility type. For our DTA, especially in characterizing the results of the Portland regional DTA model, a similar table as this might be constructed using hourly volumes and perhaps volume ranges. We would define our own acceptable volume group and error ranges, using the examples in the table below as a general structure.

*Acceptable volume group and error ranges*

| **Travel Demand Forecasting, Parameters and Techniques. NCHRP, Report 716. TRB, 2012** | | | | | |
|---|---|---|---|---|---|
| **Table 7.17. RMSE comparison of modeled volumes with traffic counts.** | | | | | |
| Functional Class | Links | ADT | Error | Percentage Error | Acceptable Error |
| Freeways | 18 | 228,340 | 15,021 | 6.6% | +/−7% |
| Principal Arterials | 90 | 538,210 | 37,674 | 7.0% | +/−10% |
| Minor Arterials | 226 | 730,030 | 80,303 | 11.0% | +/−15% |
| Collectors | 218 | 304,110 | 66,904 | 22.0% | +/−25% |
| Locals | 14 | 20,000 | 10,400 | 52.0% | +/−25% |

Along these same lines, an older version of this Travel Demand Forecasting report, NCHRP Report 255, suggested using the relationship shown graphically below:

*Maximum desirable error*




Source: *NCHRP Report 255* (*1*), Figure A-3, p.41.

These criteria, intended for macroscopic model validation (again using ADT), might be appropriate for DTA model links in the outer regions or that are not otherwise designated for tighter validation criteria.
At the other extreme of model geographic scale, a relatively small DTA model area or a detailed focus area within a larger DTA model, might be reasonably validated with microscopic network model criteria. Microscopic network models typically have associated with them a large proportion of the network with observed counts and speeds and the models are calibrated to closely replicate all those observed data. The models are then used for detailed operational studies of the traffic systems in these detailed study areas.

Criteria for travel time are shown in the following table:

*Travel Time Calibration Criteria*

| Criteria | Acceptance Targets |
|---|---|
| Modeled travel time within ±1 minute for routes with observed travel times less than 7 minutes. | All routes identified in the Data Collection Plan |
| Modeled travel time within ±15% for routes with observed travel times greater than 7 minutes. | All routes identified in the Data Collection Plan |

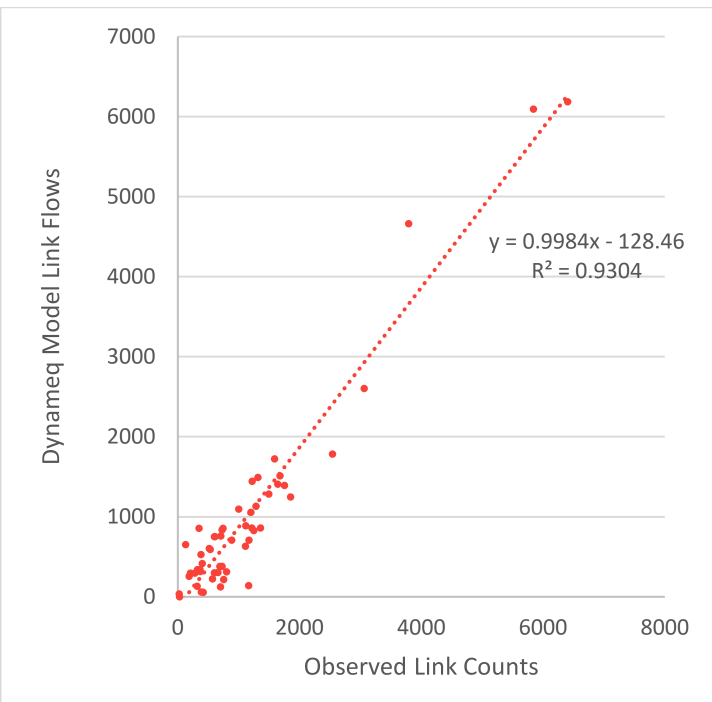
*Source: FHWA Traffic Analysis Toolbox Volume III (Wisconsin Department of Transportation)*

Depending on whether the I-5 and I-205 DTA models use the regional DTA or subarea DTA models, the Vissim Protocol criteria might be appropriate as stated, or we might want to consider relaxing it.

One area of concern in defining DTA model validation criteria is that making the criteria too difficult to obtain might result in a high degree of demand calibration to get the modeled flows to meet these criteria. For example, if the DTA network is larger geographically than a typical microscopic simulation model network, the Vissim Protocol criteria might be difficult to achieve and may require a great deal of demand adjustment in order to achieve the strict requirements of the microsimulation validation. The amount of change required to the demand tables might be less desirable than accepting relative errors in link flows for the larger network.

The last validation measure we will consider is an aggregate measure of modeled flow compared to observed count. This is a typical scatter plot where we will consider individual link hourly flows/counts with data points for all links where we have counts. Validation criteria based on the slope of the trend lines of the scatter plots and $R^2$ values will be specified. These criteria are mainly intended to demonstrate acceptable values for the entire DTA model at an aggregate level, including locations outside the focus and impactful areas. An example of relationships evaluated by these criteria is illustrated below.

*Scatter Plot Example of Dynameq Model vs Observed Link Volumes*




Specific travel time validation criteria are also needed for the DTA model. The Vissim Protocol used by ODOT (listed earlier in this document) identified the criteria to be met for model travel times. With no known evidence suggesting there is any question regarding definitions of these criteria, they will be used essentially as is, with some modification of the percentage of all links expected to satisfy the criteria, to relax the requirements for impactful area links as compared to focus area links.

Travel time validation measures consist of total travel time required to traverse fixed defined link sequences representing observable paths in the network. The target travel times for each path were obtained from 2015 HERE data, using the median speeds and segment distances corresponding to the DTA model links. Total path travel times computed from the HERE data are the validation targets and total path travel times computed from the DTA model results are the model values. The validation criteria are specified differently depending on whether the observed path times are < 7 minutes or greater than 7 minutes.

*Travel Time Validation Criteria*

| | | **Criteria** | **Target Percent** |
|---|---|---|---|
| | | | **Impactful Area** |
| **Highways** | Observed path time <= 7 minutes | +/- 1 minute | 80% |
| | Observed path time > 7 minutes | +/- 15% of path time | 80% |
| | | | |
| **Arterials** | Observed path time <= 7 minutes | +/- 1 minute | 75% |
| | Observed path time > 7 minutes | +/- 15% of path time | 75% |

## SPECIFIED VALIDATION CRITERIA FOR I-205 DTA MODELS

The validation criteria for the I-205 DTA model are specified in this section. . The DTA model validation criteria will be specified for link volumes within the modelled area. The same criteria are applied for each hour for which the DTA model results have been recorded (7-8 AM, 8-9 AM in the morning peak period and 4-5 PM, 5-6 PM in the evening peak period).

Scatter plots of individual link flows (directional and bi-directional) will also be prepared and goodness of fit measures of the scatter plot trendlines will be compared against stated target values.

The last set of DTA model validation criteria are the travel time criteria, where path travel times from the DTA model are compared to observed travel time data from HERE data.

The following tables describe all the validation criteria details.

### *Hourly DTA Link Flow vs Count Aggregate Criteria*

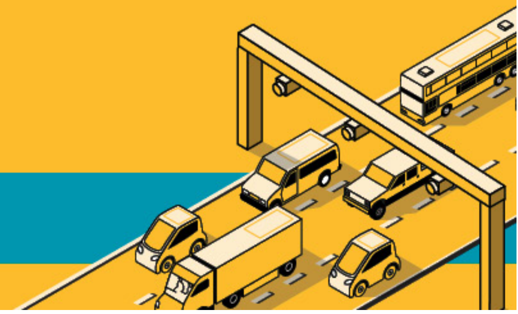
| | | Focus Area | Impactful Area |
|---|---|---|---|
| **Highways** | Trendline Slope | 1.0 +/- 0.025 | 1.0 +/- 0.03 |
| | Trendline y-intercept | +/- 5% maximum link Count | +/- 5% maximum link Count |
| | Trendline R2 | 0.975 | 0.97 |
| **Arterials** | Trendline Slope | 1.0 +/- 0.03 | 1.0 +/- 0.05 |
| | Trendline y-intercept | +/- 7.5% maximum link Count | +/- 10% maximum link Count |
| | Trendline R2 | 0.97 | 0.95 |

### *Travel Time Validation Criteria*

| | | Criteria | Target Percent |
|---|---|---|---|
| | | | **Impactful Area** |
| **Highways** | Observed path time <= 7 minutes | +/- 1 minute | 80% |
| | Observed path time > 7 minutes | +/- 15% of path time | 80% |
| | | | |
| **Arterials** | Observed path time <= 7 minutes | +/- 1 minute | 75% |
| | Observed path time > 7 minutes | +/- 15% of path time | 75% |

## DOCUMENTS REVIEWED FOR DEVELOPMENT OF CALIBRATION AND VALIDATION CRITERIA.

- Analytical Travel Forecasting Approaches for Project-Level Planning and Design. National Cooperative Highway Research Program, Report 765. Transportation Research Board, 2014.
- Travel Demand Forecasting, Parameters and Techniques. National Cooperative Highway Research Program, Report 716. Transportation Research Board, 2012.
- Dynamic Traffic Assignment. A Primer. Transportation Research Circular Number E-C153. Transportation Research Board, 2011.
- Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software, Publication No. FHWA-HRT-04-040. 2019 Update.
- Traffic Analysis Toolbox Volume XIV: Guidebook on the Utilization of Dynamic Traffic Assignment in Modeling, Publication No. FHWA-HOP-13-015, 2012.
- Protocol for Vissim Simulation, Oregon Department of Transportation, 2011.
- Puget Sound Gateway Program: DTA Model Documentation and Validation, Washington Department of Transportation, 2017.
- Development of a Dynamic Traffic Assignment Model for Northern Nevada, Nevada Department of Transportation, 2014.
- Application of Dynamic Traffic Assignment to Advanced Managed Lane Modeling, Florida Department of Transportation, 2013.
- Operational Modelling Guidelines, Version No. 1.1, Main Roads, Western Australia, 2018.



## APPENDIX C: DTA MODEL OUTPUT COMPARISON BETWEEN 2015 BASE AND FUTURE NO BUILD ALTERNATIVES

### Volume comparison between 2045 No Build and 2015 Base

The first table below shows the volume comparison between the 2045 No Build and 2015 Base alternatives on I-205 in the AM and PM peak hours by segment and direction. The second table shows the numerical difference between the two alternatives, while the third table shows the percent difference.

**2015 Base and 2045 No-Build Hourly Volumes along I-205**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2015 Base | between Stafford and 10th | 3,881 | 3,666 | 3,330 | 3,234 | 3,258 | 3,028 | 2,916 | 2,863 |
| 2045 No-Build | between Stafford and 10th | 3,840 | 3,675 | 3,861 | 3,478 | 4,199 | 3,785 | 2,837 | 2,851 |
| 2015 Base | between 10th and OR 43 | 3,563 | 3,460 | 3,566 | 3,534 | 3,248 | 3,033 | 3,189 | 3,179 |
| 2045 No-Build | between 10th and OR 43 | 3,514 | 3,541 | 4,375 | 4,353 | 4,390 | 4,361 | 3,404 | 3,474 |
| 2015 Base | between OR 43 and OR 99$^{E}$ | 3,735 | 3,773 | 3,330 | 3,234 | 3,689 | 3,584 | 2,916 | 2,863 |
| 2045 No-Build | between OR 43 and OR 99$^{E}$ | 3,988 | 4,187 | 4,850 | 5,306 | 5,060 | 4,849 | 3,969 | 4,255 |
| 2015 Base | between OR 99$^{E}$ and OR 213 | 3,199 | 3,053 | 5,009 | 4,710 | 3,867 | 3,385 | 4,664 | 4,605 |
| 2045 No-Build | between OR 99$^{E}$ and OR 213 | 3,466 | 3,524 | 5,713 | 5,882 | 5,086 | 4,971 | 4,836 | 4,923 |

**Peak Hour Volumes on I-205: 2045 No-Build minus 2015 Base**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2045 NB minus 2015 Base | between Stafford and 10th | -41 | 9 | 531 | 244 | 941 | 757 | -79 | -12 |
| 2045 NB minus 2015 Base | between 10th and OR 43 | -49 | 81 | 809 | 819 | 1,142 | 1,328 | 215 | 295 |
| 2045 NB minus 2015 Base | between OR 43 and OR 99$^{E}$ | 253 | 414 | 1,520 | 2,072 | 1,371 | 1,265 | 1,053 | 1,392 |
| 2045 NB minus 2015 Base | between OR 99$^{E}$ and OR 213 | 267 | 471 | 704 | 1,172 | 1,219 | 1,586 | 172 | 318 |

**Peak Hour Volumes on I-205: 2045 No-Build minus 2015 Base as a Percentage Difference**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2045 NB minus 2015 Base | between Stafford and 10th | -1% | 0% | 16% | 8% | 29% | 25% | -3% | 0% |
| 2045 NB minus 2015 Base | between 10th and OR 43 | -1% | 2% | 23% | 23% | 35% | 44% | 7% | 9% |
| 2045 NB minus 2015 Base | between OR 43 and OR 99E | 7% | 11% | 46% | 64% | 37% | 35% | 36% | 49% |
| 2045 NB minus 2015 Base | between OR 99E and OR 213 | 8% | 15% | 14% | 25% | 32% | 47% | 4% | 7% |

## Speed comparison between 2045 No Build and 2015 Base

The tables below contain speed data comparisons between 2045 No Build and 2015 Base DTA modeled speeds in the AM and PM peak hours by direction.

**2015 Base and 2045 No-Build Peak Hour Speeds along I-205**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2015 Base | between Stafford and 10th | 59 | 60 | 55 | 55 | 59 | 60 | 44 | 43 |
| 2045 No-Build | between Stafford and 10th | 59 | 59 | 30 | 28 | 58 | 59 | 50 | 37 |
| 2015 Base | between 10th and OR 43 | 54 | 54 | 54 | 52 | 54 | 55 | 28 | 26 |
| 2045 No-Build | between 10th and OR 43 | 54 | 54 | 53 | 54 | 51 | 52 | 53 | 53 |
| 2015 Base | between OR 43 and OR 99E | 40 | 44 | 55 | 55 | 51 | 50 | 44 | 43 |
| 2045 No-Build | between OR 43 and OR 99E | 45 | 17 | 53 | 53 | 28 | 13 | 53 | 38 |
| 2015 Base | between OR 99E and OR 213 | 23 | 23 | 52 | 53 | 52 | 53 | 52 | 52 |
| 2045 No-Build | between OR 99E and OR 213 | 53 | 20 | 51 | 52 | 48 | 29 | 50 | 49 |

**Peak Hour Speeds on I-205: 2045 No-Build minus 2015 Base**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2045 NB minus 2015 Base | between Stafford and 10th | 0 | 0 | -24 | -27 | -1 | 0 | 6 | -6 |
| 2045 NB minus 2015 Base | between 10th and OR 43 | 0 | 0 | 0 | 2 | -3 | -2 | 25 | 27 |
| 2045 NB minus 2015 Base | between OR 43 and OR 99E | 5 | -27 | -1 | -2 | -23 | -37 | 9 | -5 |
| 2045 NB minus 2015 Base | between OR 99E and OR 213 | 30 | -3 | -2 | -1 | -4 | -24 | -2 | -3 |

**Peak Hour Speeds on I-205: 2045 No-Build minus 2015 Base as a Percentage Difference**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2045 NB minus 2015 Base | between Stafford and 10th | 0% | 0% | -45% | -49% | -1% | -1% | 14% | -14% |
| 2045 NB minus 2015 Base | between 10th and OR 43 | 0% | 0% | 0% | 3% | -5% | -5% | 91% | 104% |
| 2045 NB minus 2015 Base | between OR 43 and OR 99E | 13% | -62% | -2% | -3% | -45% | -75% | 21% | -12% |
| 2045 NB minus 2015 Base | between OR 99E and OR 213 | 129% | -14% | -3% | -3% | -7% | -45% | -4% | -6% |

### Volume comparison between 2027 No Build and 2015 Base

The tables below show the volume comparison between the 2027 No Build and 2015 Base alternative on I-205 in the AM and PM peak hours by segment and direction. The other tables show the numerical difference between the two alternatives and the percent differences.

**2015 Base and 2027 No-Build Peak Hour Volumes along I-205**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2015 Base | between Stafford and 10th | 3,881 | 3,666 | 3,330 | 3,234 | 3,258 | 3,028 | 2,916 | 2,863 |
| 2027 No-Build | between Stafford and 10th | 3,682 | 3,429 | 4,109 | 3,725 | 3,875 | 3,679 | 2,870 | 2,955 |
| 2015 Base | between 10th and OR 43 | 3,563 | 3,460 | 3,566 | 3,534 | 3,248 | 3,033 | 3,189 | 3,179 |
| 2027 No-Build | between 10th and OR 43 | 3,548 | 3,566 | 4,376 | 4,474 | 4,220 | 4,292 | 3,456 | 3,579 |
| 2015 Base | between OR 43 and OR 99E | 3,735 | 3,773 | 4,035 | 3,974 | 3,689 | 3,584 | 4,118 | 4,049 |
| 2027 No-Build | between OR 43 and OR 99E | 3,939 | 4,146 | 4,960 | 5,474 | 4,747 | 4,824 | 3,848 | 4,368 |
| 2015 Base | between OR 99E and OR 213 | 3,199 | 3,053 | 5,009 | 4,710 | 3,867 | 3,385 | 4,664 | 4,605 |
| 2027 No-Build | between OR 99E and OR 213 | 3,489 | 3,652 | 5,939 | 6,385 | 4,741 | 4,665 | 4,724 | 5,231 |

**2027 No-Build minus 2015 Base Peak Hour Volume Difference**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2027 NB minus 2015 Base | between Stafford and 10th | -199 | -237 | 779 | 491 | 617 | 651 | -46 | 92 |
| 2027 NB minus 2015 Base | between 10th and OR 43 | -15 | 106 | 810 | 940 | 972 | 1,259 | 267 | 400 |
| 2027 NB minus 2015 Base | between OR 43 and OR 99E | 204 | 373 | 925 | 1,500 | 1,058 | 1,240 | -270 | 319 |
| 2027 NB minus 2015 Base | between OR 99E and OR 213 | 290 | 599 | 930 | 1,675 | 874 | 1,280 | 60 | 626 |

**2027 No-Build minus 2015 Base Volume Difference in Percentage**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2027 NB minus 2015 Base | between Stafford and 10th | -5% | -6% | 23% | 15% | 19% | 21% | -2% | 3% |
| 2027 NB minus 2015 Base | between 10th and OR 43 | 0% | 3% | 23% | 27% | 30% | 42% | 8% | 13% |
| 2027 NB minus 2015 Base | between OR 43 and OR 99E | 5% | 10% | 23% | 38% | 29% | 35% | -7% | 8% |
| 2027 NB minus 2015 Base | between OR 99E and OR 213 | 9% | 20% | 19% | 36% | 23% | 38% | 1% | 14% |

### Speed comparison between 2027 No Build and 2015 Base

The tables below show the speed comparison between 2027 No Build and 2015 Base speed in the AM and PM peak hours by direction.

**2015 Base and 2027 No-Build Peak Hour Speeds along I-205**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2015 Base | between Stafford and 10th | 59 | 60 | 55 | 55 | 59 | 60 | 44 | 43 |
| 2027 No-Build | between Stafford and 10th | 59 | 60 | 41 | 25 | 59 | 60 | 34 | 32 |
| 2015 Base | between 10th and OR 43 | 54 | 54 | 54 | 52 | 54 | 55 | 28 | 26 |
| 2027 No-Build | between 10th and OR 43 | 54 | 55 | 51 | 52 | 50 | 50 | 50 | 51 |
| 2015 Base | between OR 43 and OR 99E | 40 | 44 | 51 | 51 | 51 | 50 | 48 | 50 |
| 2027 No-Build | between OR 43 and OR 99E | 50 | 16 | 53 | 53 | 53 | 22 | 54 | 53 |
| 2015 Base | between OR 99E and OR 213 | 23 | 23 | 52 | 53 | 52 | 53 | 52 | 52 |
| 2027 No-Build | between OR 99E and OR 213 | 53 | 26 | 51 | 52 | 52 | 50 | 47 | 46 |

**2027 No-Build minus 2015 Base Peak Hour Speed Differences**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2027 NB minus 2015 Base | between Stafford and 10th | 0 | 0 | -14 | -30 | 0 | 0 | -10 | -11 |
| 2027 NB minus 2015 Base | between 10th and OR 43 | 0 | 0 | -3 | -1 | -4 | -4 | 22 | 25 |
| 2027 NB minus 2015 Base | between OR 43 and OR 99E | 10 | -28 | 2 | 2 | 2 | -28 | 6 | 3 |
| 2027 NB minus 2015 Base | between OR 99E and OR 213 | 30 | 3 | -1 | -1 | 0 | -3 | -5 | -7 |

**2027 No-Build minus 2015 Base Peak Hour Speed Differences in Percentage**

| Scenario | Road Segments | AM | | | | PM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SB | | NB | | SB | | NB | |
| | | 7-8 AM | 8-9 AM | 7-8 AM | 8-9 AM | 4-5 PM | 5-6 PM | 4-5 PM | 5-6 PM |
| 2027 NB minus 2015 Base | between Stafford and 10th | 0% | 0% | -26% | -55% | 0% | 0% | -24% | -25% |
| 2027 NB minus 2015 Base | between 10th and OR 43 | 0% | 0% | -5% | -1% | -7% | -8% | 79% | 94% |
| 2027 NB minus 2015 Base | between OR 43 and OR 99E | 25% | -64% | 4% | 4% | 4% | -56% | 13% | 8% |
| 2027 NB minus 2015 Base | between OR 99E and OR 213 | 130% | 13% | -3% | -2% | 0% | -5% | -10% | -12% |

# APPENDIX D: METRO TIME-OF-DAY MODEL DEVELOPMENT SUMMARY FOR I-205 TOLL PROJECT

| | |
|---|---|
| **Date** | February 9, 2022 |
| **To** | Oregon Toll Program Project Team |
| **From** | WSP Oregon Toll Program Project Team |
| **Subject** | Metro Time-of-Day Model Development Summary for I-205 Toll Project |
| **CC** | Metro Modeling Team |

## BACKGROUND

The current Metro regional travel demand model (RTDM) uses time-of-day (TOD) factors, also known as diurnal factors, to split the daily trips into trips for each hour of the 24-hour period. The existing diurnal factors are directional and were developed from the 2010-2011 Oregon Household Activity Survey (OHAS). In the current RTDM, a peak-spreading algorithm is also applied on top of the diurnal factors to further adjust the hourly automobile trips for single-occupancy vehicle (SOV) and high-occupancy vehicle (HOV) trips to better match base year observed count data and offset some of the severe network congestion that is forecasted in future years. The current time-of-day component in the RTDM is therefore limited in temporal sensitivity. This is particularly relevant when evaluating the potential impacts of variable rate tolling on shifts in time of departure.

## TOD MODEL

To better assess potential shifts in travel behavior due to both congestion and pricing, a TOD choice model was developed and applied to the I-205 Toll Project regional modeling. The goal of this model is to replace the current approach of using diurnal factors with peak-spreading adjustments algorithm.

As a proof of concept of the ability to estimate shifts in trips across time periods in response to variable road pricing, WSP developed initial TOD choice models for Home-Based Work (HBW) and Home-Based Other (HBO) trip purposes. Metro extended the model approach to other trip purposes.

The TOD choice model was estimated using OHAS data for HBW and HBO trip purposes. The model was implemented in R program as a logit choice model, computing the PA (Production-Attraction) and AP (Attraction-Production) trips by time-of-day for HBW and HBO trip purposes.

Estimated coefficients for HBW and HBO trip purposes were calibrated to match the time-of-day trip outputs from the TOD model to be similar to current model outputs for HBW and HBO after applying the existing diurnal factors and peak spreading algorithm. The TOD model elements developed by WSP were not applied/estimated for other trip purposes in the model. However, the HBO model results were applied to Home-Based Shop (HBS) and Home-Based Recreation (HBR). The Non-Home trip purposes do not use the updated TOD model, but the diurnal factors for Non-Home trips were re-calibrated as part of the TOD model calibration effort.

In the base year, there are no tolls in the regional network and therefore coefficient of cost was not estimated for the TOD choice. An appropriate coefficient of cost (for pricing/tolling) is vital in order to get the correct sensitivity of TOD model for the future scenarios with pricing. In the current implementation, a value for cost coefficient was asserted such that the implied value of time (i.e., coefficient for time/coefficient for cost) is reasonable and in line with value-of-time estimates for the project.

## MODEL ESTIMATION

### Variable Definitions

| | |
|---|---|
| HourP | Hour of trip production |
| HourA | Hour of trip attraction |
| Duration | Duration for the trip (HourA – HourP) |
| Const_Depart | Constant for departing in HourP |
| Const_Return | Constant for returning in HourA |
| Const_Duration | Constant for the trip duration |
| Coeff_Depart | Departure time coefficient |
| Coeff_Return | Return time coefficient |
| Coeff_Toll | Toll coefficient |
| Time_Out | Outbound OD travel time (for HourP) |
| Time_In | Inbound OD travel time (for HourA) |
| Toll_Out | Outbound OD toll value (for HourP) |
| Toll_In | Inbound OD toll value (for HourA) |

### Logit model utilities used in model (for departing in HourP and returning in HourA)

Simple zone-pair utility = Const_Depart + Const_Return + Const_Duration

Complex zone-pair utility = Const_Depart + Const_Return + Const_Duration + (Coeff_Depart * Time_Out) + (Coeff_Return * Time_In) + (Coeff_Toll * Toll_Out) + (Coeff_Toll * Toll_In)

### Coefficient (do not change by hour)

| | HBW | HBO |
|---|---|---|
| Coeff_Depart | -0.01992 | -0.04782 |
| Coeff_Return | -0.02300 | -0.10270 |
| Coeff_Toll | -0.82709 | -1.92967 |

### HBW Constants

| HourP | Const_Depart | HourA | Const_Return | Duration | Const_Duration |
|---|---|---|---|---|---|
| 1 | -13.18 | 1 | 5.19 | 0 | 4.14 |
| 2 | -13.83 | 2 | 5.79 | 1 | 4.77 |
| 3 | -23.09 | 3 | 5.90 | 2 | 4.25 |
| 4 | -0.34 | 4 | -6.02 | 3 | 3.28 |
| 5 | 0.79 | 5 | -7.39 | 4 | 2.81 |
| 6 | 1.14 | 6 | -7.99 | 5 | 1.80 |
| 7 | 0.91 | 7 | -9.16 | 6 | 1.35 |
| 8 | 0.00 | 8 | -8.23 | 7 | 0.76 |
| 9 | -1.37 | 9 | -7.64 | 8 | 0.31 |
| 10 | -2.78 | 10 | -6.99 | 9 | 0.00 |
| 11 | -4.27 | 11 | -5.75 | 10 | -0.72 |
| 12 | -5.76 | 12 | -4.80 | 11 | -1.86 |
| 13 | -6.12 | 13 | -3.71 | 12 | -2.94 |
| 14 | -6.78 | 14 | -3.17 | 13 | -4.47 |
| 15 | -7.58 | 15 | -2.19 | 14 | -5.67 |
| 16 | -8.28 | 16 | -1.04 | 15 | -6.99 |
| 17 | -9.05 | 17 | 0.00 | 16 | -10.23 |
| 18 | -9.66 | 18 | 1.07 | 17 | -10.23 |
| 19 | -10.18 | 19 | 1.33 | 18 | -10.23 |
| 20 | -11.86 | 20 | 1.67 | 19 | -10.23 |
| 21 | -12.72 | 21 | 2.40 | 20 | -10.23 |
| 22 | -13.61 | 22 | 3.69 | 21 | -10.23 |
| 23 | -12.78 | 23 | 4.34 | 22 | -10.23 |
| 24 | -13.72 | 24 | 5.33 | 23 | -10.23 |

### HBO Constants

| HourP | Const_Depart | HourA | Const_Return | Duration | Const_Duration |
|---|---|---|---|---|---|
| 1 | -10.74 | 1 | 1.42 | 0 | -0.24 |
| 2 | -10.56 | 2 | 1.45 | 1 | 0.00 |
| 3 | -8.10 | 3 | 1.33 | 2 | -0.84 |
| 4 | -3.81 | 4 | -5.01 | 3 | -1.82 |
| 5 | -1.45 | 5 | -6.50 | 4 | -2.95 |
| 6 | -0.42 | 6 | -5.90 | 5 | -4.02 |
| 7 | 0.25 | 7 | -6.18 | 6 | -4.56 |
| 8 | 0.00 | 8 | -6.04 | 7 | -5.10 |
| 9 | -0.39 | 9 | -5.36 | 8 | -6.39 |
| 10 | -1.02 | 10 | -4.88 | 9 | -6.46 |
| 11 | -1.95 | 11 | -4.37 | 10 | -7.77 |
| 12 | -2.65 | 12 | -3.62 | 11 | -7.62 |
| 13 | -3.64 | 13 | -2.98 | 12 | -9.16 |
| 14 | -4.05 | 14 | -2.24 | 13 | -9.16 |
| 15 | -4.53 | 15 | -1.43 | 14 | -9.36 |
| 16 | -5.08 | 16 | -0.56 | 15 | -9.36 |
| 17 | -5.48 | 17 | 0.00 | 16 | -9.36 |
| 18 | -5.85 | 18 | 0.57 | 17 | -9.36 |
| 19 | -5.92 | 19 | 0.75 | 18 | -9.36 |
| 20 | -7.09 | 20 | 1.10 | 19 | -9.36 |
| 21 | -8.25 | 21 | 1.86 | 20 | -9.36 |
| 22 | -9.39 | 22 | 2.21 | 21 | -9.36 |
| 23 | -9.05 | 23 | 2.39 | 22 | -9.36 |
| 24 | -9.12 | 24 | 2.27 | 23 | -9.36 |

## SWITCHING MODEL

A switching model was developed and incorporated into the new TOD model to restrict the unreasonable switching of trips for a build scenario, for instance, trip departure time shifting from morning period to night period because of toll in the morning period. As a result of switching model, trips departure time and/or arrival time can be shifted by up to the number of hours defined by the user. The default setting is 2 hours.

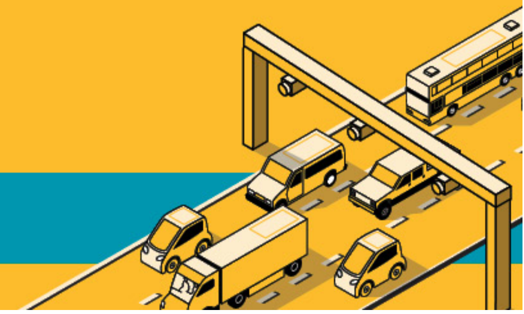
Running a switching model for a build scenario requires time-of-day probabilities (departing in hour P and arriving in hour A) from a no-build or reference scenario. The assumption is that the Origin-Destination trips in build scenario will have a similar underlying time-of-day distribution as no-build (baseline) scenario. After the TOD probabilities are computed for a build scenario (note that the TOD model before switching model does not pose any restriction on the departure and arrival shift), switching choices are restricted for departure and/or arrival time shift and the updated time-of-day distribution is calculated using the originally computed probabilities for build scenario and the probabilities from the referenced baseline scenario.

After encountering significant issues related to computer run time with the TOD model with the addition of switching model, a decision was made to limit the TOD model to a subset of trips that are most likely to see a potential change in travel time (generalized cost). This determination is made by comparing potential differences in travel time at different times of the day.

After sensitivity testing the threshold was set to a coefficient of variation of 0.25. This means that trips with less than a 25 percent variation in travel time (generalized cost) over the course of the day are not subject to potential shifts in time of departure via the TOD model. Thus, only trips with greater than 25 percent variation could potentially shift their time of departure. This approach had significant benefits in model run time while still representing most potential changes in trip departure time that would be reflected in the TOD model.

# APPENDIX E: VALUE-OF-TIME ASSUMPTION REVIEW

# I-205 Toll Project



MEMORANDUM

| | |
|---|---|
| **Date** | February 22, 2021 |
| **To** | ODOT Tolling Team |
| **From** | WSP Tolling Team |
| **Subject** | **Value-of-Time Assumption Review** |
| **CC** | Portland Metro Modeling Team |

## PURPOSE

The impacts of tolling on the transportation system, including changes in traffic routing and congestion, are key concerns. Travel models are essential tools used to estimate how people will behave with tolls in place. These models put a cost (value) on time to represent the choices people make. For example, a daily commuter may choose to take a different route to avoid paying a toll if they do not see enough value in the travel time saved on the tolled route. Meanwhile, a truck driver delivering valuable cargo may elect to pay the toll to save time or avoid the inconvenience of routing off the highway. These value choices can vary widely depending on the characteristics of the travelers, the purpose of the trip, and other situational and environmental factors.

This document provides recommended value-of-time (VOT) assumptions for the National Environmental Policy Act (NEPA) alternatives analysis to be performed for the I-205 Toll Project (Project). The recommended VOT assumptions may also be referred to as Value of Travel Time Savings and represent a range for driver willingness-to-pay a toll and will be applied in the Metro regional travel demand model (RTDM) for analysis of Project toll alternatives. These assumptions are especially relevant for determining changes in vehicle routing (rerouting) in response to tolls, as estimated in the model's traffic assignment step.

This document will be included as an addendum to the I-205 Modeling Methodology Memorandum for the Project NEPA alternatives analysis and modeling. This document first presents an overview of the recommendations and rationale, followed by detailed methodology used to conduct the evaluation and develop recommendations, and an overview of the research and tolling studies that WSP reviewed.

## RECOMMENDATIONS SUMMARY

Based on review of previous studies and available guidance materials, WSP recommends that the VOT assumptions presented in Table 30 be applied to the Project's NEPA alternatives analysis and modeling. The VOTs range between $6 and $61 per hour (2010$), depending on the type of vehicle, occupancy class, and time of day. Blended or average values may be applied for peak shoulder hours. All recommended values are rounded to the nearest dollar.

**Table 30. Recommended Value-of-Time Assumptions for National Environmental Policy Act Modeling (2010$)**

| Vehicle Class | Income Segmentation | Peak ($/hour) | Off Peak ($/hour) |
|---|---|---|---|
| Single-Occupancy Vehicle Auto | Low Income (<$25K) | $8 | $6 |
| | Medium Income ($25K–$100K) | $17 | $14 |
| | High Income (>$100K) | $22 | $17 |
| High-Occupancy Vehicle Auto | Low Income (<$25K) | $15 | $10 |
| | Medium Income ($25K–$100K) | $30 | $20 |
| | High Income (>$100K) | $38 | $25 |
| Medium Trucks | Not Applicable | $39 | $39 |
| Heavy Trucks | Not Applicable | $61 | $61 |

## CURRENT MODELING APPROACH

The RTDM uses VOT ($/hour) to convert monetary toll costs into travel-time penalties (disbenefit) to represent travel choices that include vehicle routing (traffic assignment) in the regional model network. Thus, for the same monetary toll, a higher VOT means a smaller time penalty and therefore fewer diversions via rerouting to untolled roads or shifts in mode choice, trip distribution, and time of day. Conversely, for the same toll, a lower VOT means more diversions.

The RTDM typically includes four vehicle classes for traffic assignment:

- Single-occupancy vehicle (SOV) auto.
- High-occupancy vehicle (HOV) auto.
- Medium truck.
- Heavy truck.

Each vehicle class is associated with a VOT for the peak periods (7:00 a.m. to 10:00 a.m. and 3:00 p.m. to 6:00 p.m.) and for the off-peak periods. The following RTDM trip purposes are used in earlier stages in the model but are combined for the traffic assignment:

- Home-Based Work.
- Home-Based Shopping.
- Home-Based Social/Recreational.
- Home-Based Other.
- Home-Based School.
- Non Home Based.

The RTDM structure does not distinguish between vehicle operating costs for autos and trucks. Consistent with standard practice for regional models, the RTDM represents average weekday conditions and therefore does not reflect potential considerations of travel-time reliability in routing.

Stated preference (SP) surveys conducted for the Columbia River Crossing (CRC) project in 2009 and 2013 serve as the basis of the RTDM's auto VOT assumptions. These differentiate VOT between peak and off-peak travel. For the Project, an SP survey was developed in Spring 2020 but not completed due to the onset of the COVID-19 pandemic. For the Project's screening analysis modeling (conducted using the RTDM), VOT assumptions were further differentiated for SOV and HOV trips, with HOVs assumed to have a 20% higher VOT than SOVs due to the presence of passengers.

For commercial trucks, the screening analysis used a VOT of $26 (2010$) for medium trucks and $28 (2010$) for heavy trucks, based on more recent Oregon Department of Transportation (ODOT) guidance.[12] In previous RTDM applications, including the CRC project, a higher VOT of $39 (2010$) had been applied for both medium and heavy trucks[13,14].

## KEY DIFFERENTIATORS FOR VALUE OF TIME

For people driving, willingness-to-pay for travel-time savings varies widely and is affected by a multitude of factors, including income, trip purpose, comfort, and situational factors that can vary from day to day. The model's VOT assumptions reflect a limited range of willingness-to-pay for tolled roads by different users of the tolled facility. While the full complexity and variability of willingness-to-pay cannot be captured in the model, key characteristics can be included to reflect some of the most influential differences.

Income is one of the most significant factors in willingness-to-pay, particularly for routine daily travel (e.g., commutes). Higher-income travelers are typically willing to pay more for travel-time savings than lower-income travelers. Federal VOT guidance for economic analysis[15] as well as VOT assumptions used in other tolling studies typically base VOT either directly on the household income or employee compensation in the facility catchment area or on discrete choice models developed based on SP survey data. The model estimations often directly include income (e.g., toll as a proportion of income) or are segmented by income (e.g., separate model or separate cost coefficient by income group).

Survey research shows that auto VOT varies based on the purpose of the trip. For example, business and airport access trips are generally associated with higher VOTs than commute and

---

[12] Oregon Department of Transportation Program Implementation and Analysis Unit. November 2016. *The Value of Travel-Time: Estimates of the Hourly Value of Time for Vehicles in Oregon 2015*. https://digital.osl.state.or.us/islandora/object/osl%3A76610

[13] Portland Metro. April 2015. *2015 Trip-Based Travel Demand Model Methodology Report*.

[14] Stantec. September 2009.*Columbia River Crossing: Recommendation for the Selection of the Value of Time to be Used in the Metro Modeling Runs*.

[15] U.S. Department of Transportation. 2016. *Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis Revision 2 (2016 Update)*. https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf

leisure trips. Because the composition of trip purposes and travelers may be quite different depending on time of day, VOTs are differentiated for peak versus off-peak travel hours.

Truck VOT is more complex than auto VOT. Truck VOT depends on a large number of factors, including shipment terms, employment terms, distance, commodity characteristics, and shipper and receiver characteristics. Truck VOTs can vary greatly depending on the cargo being shipped and supply-chain considerations, including those affected by travel-time reliability. For commercial trucks, federal VOT guidance for economic analysis recommends basing VOT on labor cost but recognizes that higher values that reflect truck operating costs are also used.[16]

## PROPOSED SEGMENTATION

Understanding differences in benefits and burdens of tolling is a central issue for the project. A straightforward way to take into consideration VOTs of different user segments in the RTDM is to disaggregate the two auto classes (SOV and HOV) each into three different income classes (2010 dollars):

- Low Income (annual household income of less than $25,000).
- Medium Income (annual household income between $25,000 and $100,000).
- High Income (household income of more than $100,000).[17]

After segmentation, six different vehicle classes for automobile trips and peak and off-peak VOT assumptions would need to be developed for each vehicle class. The two existing commercial truck vehicle classes would remain as previously defined.

## FINDINGS

WSP evaluated the VOTs used in the screening analysis and concluded that the auto VOTs were reasonable for average travel characteristics based on a review of Federal VOT guidance for economic analysis,[18] NCHRP 722,[19] and other research and tolling studies for other facilities in the United States (summarized in Table 35 and Table 36). However, to better evaluate tolling impacts for the Project NEPA analysis, the RTDM should apply additional segmentation by

---

[16] U.S. Department of Transportation. 2016. *Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis Revision 2 (2016 Update).* https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf

[17] Preliminary results of this segmented modeling indicate that I-205 Abernethy Bridge trips are broken out as follows: 8% Low Income SOV, 42% Medium Income SOV, 27% High Income SOV, 2% Low Income HOV, 10% Medium Income HOV, 7% High Income HOV, 1% Medium Truck, 3% Heavy Truck.

[18] U.S. Department of Transportation. 2016. *Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis Revision 2 (2016 Update).* https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf

[19] Parsons Brinckerhoff, Inc. 2012. *NCHRP Report 722, Assessing Highway Tolling and Pricing Options and Impacts.* http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.360.2910&rep=rep1&type=pdf

income to automobile vehicle classes. WSP also recommends returning to previously identified VOTs for medium trucks and using higher VOTs for heavy trucks. WSP developed recommended VOT assumptions for the eight vehicle classes and two time periods. Table 31 summarizes these values along with key considerations and rationale.

**Table 31. Recommended Value-of-Time Assumptions with Rationale (2010$)**

| Vehicle Class | Income Segmentation | Peak VOT ($/hour) | Off-Peak VOT ($/hour) | Rationale |
|---|---|---|---|---|
| Single-Occupancy Vehicle (SOV) Auto | Low Income (<$25K) | $8 | $6 | • Base VOT calculated as 60% of hourly income for top of income bracket ($25,000) to reflect higher incomes of vehicle owners.<br>• Peak VOT calculated as base VOT times 1.1 and off-peak VOT calculated as base VOT times 0.9 to account for different trip purpose mix.<br>• Additional 1.05 factor applied to peak VOT to account for reliability. |
| | Medium Income ($25K—$100K) | $17 | $14 | • Base VOT calculated as 50% of hourly income for midpoint of bracket ($62,500).<br>• Peak VOT calculated as base VOT times 1.1 and off-peak VOT calculated as base VOT times 0.9 to account for different trip purpose mix.<br>• Additional 1.05 factor applied to peak VOT to account for reliability. |
| | High Income (>$100K) | $22 | $17 | • Base VOT calculated as 30% of hourly income for representative income of $130,000 for the bracket.<br>• Peak VOT calculated as base VOT times 1.1 and off-peak VOT calculated as base VOT times 0.9 to account for different trip purpose mix.<br>• Additional 1.05 factor applied to peak VOT to account for reliability. |
| High-Occupancy Vehicle (HOV) Auto | Low Income (<$25K) | $15 | $10 | • Peak HOV VOT calculated as 1.75 times SOV based on NCRHP 722.<br>• Off-Peak HOV VOT calculated as 1.5 times the SOV VOT, assuming higher likelihood of family travel during off-peak. |
| | Medium Income ($25K—$100K) | $30 | $20 | |
| | High Income (>$100K) | $38 | $25 | |
| Medium Trucks | Not Applicable | $39 | $39 | Metro RTDM |

| Vehicle Class | Income Segmentation | Peak VOT ($/hour) | Off-Peak VOT ($/hour) | Rationale |
|---|---|---|---|---|
| Heavy Trucks | Not Applicable | $61 | $61 | NCHRP 722 |

Key consideration that led to these recommendations are as follows:

- Based on a review of other tolling studies, research reports and guidance, the relationship between VOT and income varies. The Federal VOT guidance considers a VOT of up to 60% of hourly household income reasonable for personal trips, including commute trips. The review of studies showed that VOTs typically account for a higher share of hourly income for lower-income households than for higher-income households. Based on these considerations, we assumed that the base VOT would account for 60% of hourly income in the lower-income segment, 50% of hourly income in the medium segment, and 30% in higher-income segment. To develop peak and off-peak VOTs, we recommend multiplying these base VOT values by additional factors as described in the following paragraphs.
- The bottom household-income segment in the RTDM is less than $25,000 (2010$), which represents households in or near poverty.[20] Because very low-income households are less likely to have access to an automobile, they are more likely to use transit or other non-motorized travel options. As such, their trips are often less likely to be represented in auto demand matrices. Therefore, users in this income segment who are represented in the model's vehicle traffic assignment are more likely to have an income near the top end of the bracket.
- Employment data for the four counties in the region suggests that a relatively large portion (22%) of the jobs are in high-wage industries: management of companies, financial services and technical and professional services. It is therefore reasonable to expect that household income of many of these workers will exceed the $100,000 threshold for the high-income segment. In the four counties that comprise most of the tolled facility's catchment area, the 2018 5-year American Community Survey (ACS) estimate showed that households with income (2018$) between $100,000 and $150,000 account for 18% of total households while households with incomes between $150,000 and $200,000 and above $200,000 account for 8% and 9%, respectively. Based on these considerations, WSP proposes the use of $130,000 (2010$) household income to represent the top income bracket for purposes of VOT estimation.
- Tolled roads offer travel-time reliability benefits in addition to improved average travel times. By including a buffer time for trips that are time-sensitive (such as business trips and

[20] The U.S. Census Bureau poverty threshold in 2018 was approximately $25,000 (2018$) for a family of four. Poverty Thresholds, U.S. Census Bureau, 2018, https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html

many commute trips), travelers set aside more time for travel than the actual (average) in-vehicle time. Because regional models do not account for reliability improvements offered by tolled roads, it is reasonable to increase VOT to reflect the reliability benefits offered by a tolled roadway, particularly during congested peak hours where travel times are more inconsistent. Federal VOT guidance recognizes that the reliability of travel time is an important consideration that is tied to travel-time savings. The Federal VOT guidance describes adding an allowance to the VOT as a possible approach to take into account reliability in the absence of reliability measures and a specified value of reliability. In the modeling for the CRC project, VOTs from the SP survey were increased by 10% to reflect reliability and the fact that not all drivers have information about the alternative routes available. WSP conservatively increased peak VOTs by 5% to take travel-time reliability into account.

- NCHRP 722 recommends auto-peak VOTs between 1.2 to 1.3 times as large as off-peak VOTs for most trip purposes and income segments. The difference between peak and off-peak VOT may in part reflect the different trip-purpose mix during peak and off-peak periods. Federal VOT guidance recognizes that the conditions of the time saved could affect its value. For example, reducing stressful driving in heavily congested traffic conditions could be more valuable than saving time when there is no traffic congestion. SHRP C04[21] recommends to add weights to congestion delays versus free-flow time of 1.5 to 2.0, if not accounting for reliability explicitly. In line with NCRHP 722 recommendations, the CRC SP Survey[22] conducted in 2013 found that peak VOTs were 1.2 times off-peak VOTs. Based on these considerations, WSP multiplied the base VOT that was developed based on household income by 1.1 for the peak period and by 0.9 for the off-peak period. Combined with the reliability adjustment, the resulting SOV peak VOTs are 1.28 times as large as off-peak VOTs.
- NCHRP 722 recommended HOV VOTs of 1.75 times SOV VOTs for two-person vehicles and 2.5 for higher occupancies. This reflects that some travel parties include children or other persons whose time is not factored into the route choice decision. SHRP C04[23] similarly found a factor of 1.7 for two-person vehicle occupancy and a factor of 2.4 for higher occupancies. WSP conservatively assumed that HOV VOTs equal 1.75 of the SOV VOT during the peak period and 1.5 during the off-peak period. The distinction between the peak and off-peak periods is based on the assumption that during the off-peak periods, HOV trips are more likely to be family trips (including children).

---

[21] National Academies of Sciences, Engineering, and Medicine. 2012. *Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand*. https://doi.org/10.17226/22689

[22] Resource Systems Group, Inc. November 2013. *I-5 Columbia River Crossing Stated Preference Travel Study Report*.
http://data.wsdot.wa.gov/accountability/ssb5806/Repository/4_Finance/Investment%20Grade%20Analysis/CRC%20Stated%20Preference%20Survey%20Draft%20Report%202013-11-01.pdf

[23] National Academies of Sciences, Engineering, and Medicine. 2012. *Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand*. https://doi.org/10.17226/22689

- Studies using SP surveys find a very wide range of VOTs for trucks. NCRHP 925[24] found VOTs that range from $13 to $358 (2010$) based on an SP survey of carriers and shippers. The study recommends using the most recent American Transportation Research Institute truck operational cost as a general VOT, which is $59.3 per hour (2010$), in addition to the value of reliability developed by the study. NCRHP 722 recommends a VOT of $30 for medium trucks and for $61 heavy trucks (2010$). While Federal guidance for truck VOT only includes driver compensation, they recognize that trucks' route choice also includes vehicle operating cost and other factors that depend on the type of commodity, supply-chain considerations, and/or value of the freight. The RTDM truck VOT of $39 was used in in previous studies including CRC and the ODOT Portland Metro Area Value Pricing Feasibility Analysis. Based on the higher VOTs found in other studies and to consider the effect of high vehicle operating costs and high value of reliability on truck route choice, it was reasonable to apply an increase for the heavy truck VOTs. Based on these considerations, WSP recommends using the NCHRP 722 VOT of $61 (2010$) for heavy trucks and the previously applied Metro RTDM VOT of $39 (2010$) for medium trucks.

Table 32 summarizes the differences between the VOT assumptions previously applied in the Project screening analysis and the VOT recommendations for the proposed segmentation by vehicle class, income class, and time of day for the Project's NEPA round of modeling.

**Table 32. Value-of-Time Assumptions Comparison (2010$)**

| | | Prior Assumptions* | | Recommended Assumptions for NEPA Analysis | | Difference in VOT Assumptions | |
|---|---|---|---|---|---|---|---|
| **Vehicle Class** | **Income Segmentation** | **Peak ($/hour)** | **Off-Peak ($/hour)** | **Peak ($/hour)** | **Off-Peak ($/hour)** | **Peak ($/hour)** | **Off-Peak ($/hour)** |
| Single-Occupancy Vehicle Auto | Low Income (<$25K) | $19 | $13 | $8 | $6 | -$11 | -$7 |
| | Medium Income ($25K–$100K) | | | $17 | $14 | -$2 | +$1 |
| | High Income (>$100K) | | | $22 | $17 | +$3 | +$4 |
| High-Occupancy Vehicle Auto | Low Income (<$25K) | $23 | $15 | $15 | $10 | -$8 | -$5 |
| | Medium Income ($25K–$100K) | | | $30 | $20 | +$7 | +$5 |
| | High Income (>$100K) | | | $38 | $25 | +$15 | +$10 |
| Medium Trucks | Not Applicable | $26 | $26 | $39 | $39 | +$13 | +$13 |
| Heavy Trucks | Not Applicable | $28 | $28 | $61 | $61 | +$33 | +$33 |

* The VOTs shown in the table represent the minimum value applied in the analysis, as specific VOTs varied by hour and direction of travel based on trip characteristic mix estimated in the ODOT Portland Metro Area Value Pricing Feasibility

[24] National Academies of Sciences, Engineering, and Medicine. 2019. *Estimating the Value of Truck Travel Time Reliability*. https://doi.org/10.17226/25655

Analysis. The applied VOTs for SOV travel ranged from approximately $13 to $17 in off-peak hours and $19 to $22 in peak hours.

## ANALYSIS METHODOLOGY

### Overview

This memorandum includes the three approaches used to review the reasonableness of the VOTs used during the screening analysis and to inform the development of recommendations for income-segmented auto VOTs and truck VOTs for the NEPA analysis.

### Federal VOT Guidance

WSP applied the Federal guidance on Valuation of Travel Time[25] to estimate the base VOTs for the recommended RTDM income segments. While the guidance was developed for economic analysis, it provides a useful reference point for estimating VOT for the Project. Federal VOT guidance recommends estimating VOT for passenger-vehicle travel based on household income as a simplified and uniform approach to estimate VOT for both personal and business travel by all modes and all time periods.

The recommended VOT for personal trips, which includes commute trips, equals 50% of median hourly household income while the VOT of business trips equals 100% of the median hourly household income. Hourly household income is estimated as annual household income divided by 2,080 hours and does account for household size or number of workers. Plausible ranges of VOT included in the guidance are between 35% and 60% of median hourly household income for personal travel and between 80% and 120% of median hourly household income for business travel. Federal VOT guidance reports that about 5% of local surface trips are business trips while the remainder are personal trips.

For freight transportation, the VOT is more complex, and Federal VOT guidance does not include a recommendation for freight VOT other than to use truck drivers' compensation to represent the VOT of the operator while recognizing that vehicle operating cost and the value and characteristics of the freight also affect the willingness-to-pay for time savings. The Federal VOT guidance reports that the weighted average hourly wage for heavy and light truck drivers from the National Occupational Employment and Wage Estimates is $27.20 (2015$).

Federal VOT guidance recognizes that VOTs also depend on traveler characteristics other than income, and on the circumstances of the trip and the available transportation options. They recognize that the conditions of the time saved could affect its value. That is, reducing stressful driving in heavy traffic could be more valuable than saving time when there is no traffic congestion. Federal VOT guidance also recognizes that the reliability of travel time is an important consideration that is tied to travel-time savings. By including a buffer time for trips

[25] U.S. Department of Transportation. *Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis (2016)* https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf

that are time-sensitive—such as business trips and many commute trips—travelers set aside more time for travel than the actual in-vehicle time. Federal VOT guidance describes adding an allowance to the VOT as a possible approach to take into account reliability in the absence of reliability measures and a value of reliability.

#### Wages

WSP also estimated the VOT for auto travel based on the hourly compensation of workers (employees)[26] to provide an alternative to the above Federal VOT guidance approach based on the household income of residents.[27] As recognized in the Federal VOT guidance, the hourly employee compensation is theoretically equal to the VOT for "on-the-clock" business travel. In a household with more than one worker, household income includes the combined salary and wages of all workers. To implement this alternative approach for developing VOT estimates, WSP reviewed data on wages and industries located in the facility's travel shed. Employee compensation was estimated by increasing wages by 30% to reflect benefits.

#### Other Studies

Finally, WSP reviewed research reports and tolling studies in other regions and recorded VOTs and methodologies used to estimate the VOTs in those studies that are relevant to the Portland Metro region. This provides points of comparison and reasonableness checks on the VOT recommendations developed.

### Federal Value-of-Time Guidance Using Income

As explained previously, Federal VOT guidance for economic analysis recommends estimating the VOT for passenger travel as a proportion of hourly household income, with VOTs for commute and other personal trips accounting for 50% of hourly household income and VOTs for business trips at 100% of hourly household income. While the guidance was developed for economic analysis purposes, it is frequently used to evaluate the reasonableness of the VOTs used in travel demand studies. WSP first reviewed the regional household-income distribution and then applied the Federal VOT guidance recommended approach to the three household-income segments included in the RTDM.

#### Regional Household-Income Distribution

Based on the 2018 ACS 5-year estimates' census-tract-level data on the number of households by household-income category, the average household income in the model area is estimated as $87,600 (2018$) and the median household income is about $75,000 (2018$). Figure 57 presents the household-income distribution for the model area used to estimate the average household

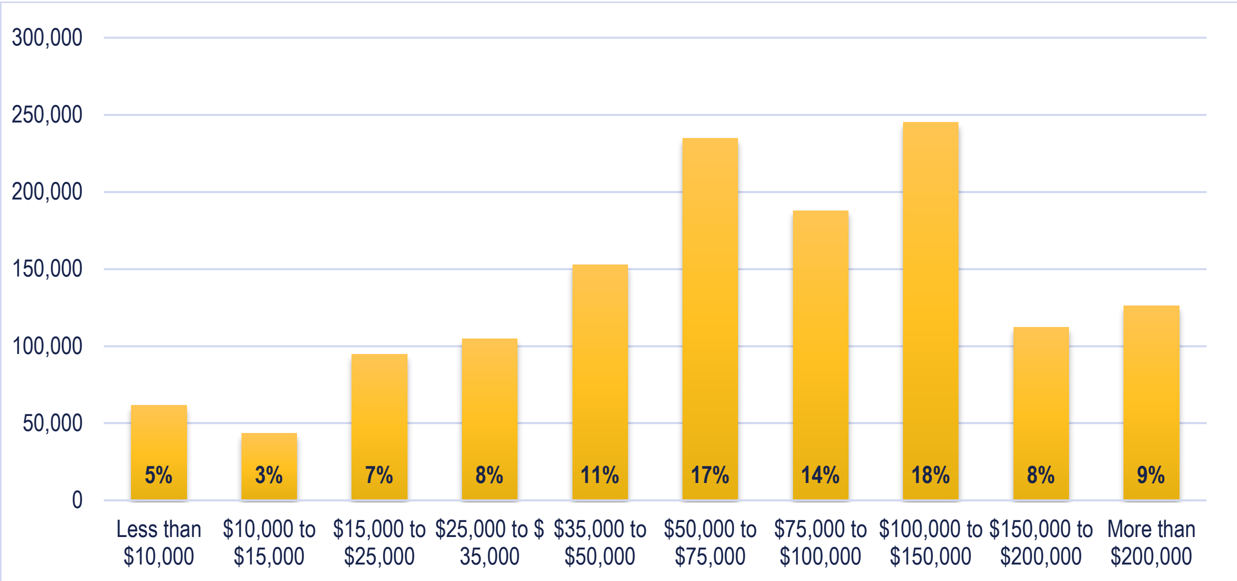
---

[26] Employee compensation is the income received by employees as remuneration for their work and includes gross (before taxes) salaries and wages, as well supplements to wages, such as employer contributions to health and life insurance and retirement plans.

[27] The U.S. Census Bureau defines household income as money income received by the household on a regular basis (excluding money receipts such as capital gains) before personal income taxes and social security and other deductions. Household income therefore does not include food stamps, health benefits, and subsidized housing

income. This model area includes areas in Multnomah, Washington, and Clackamas Counties in Oregon, and Clark County in Washington.

**Figure 57. Household-Income Distribution in the Model Area (2018$)**




Source: 2018 American Community Survey 5-year estimates

Figure 57 (2018$) shows the following:

- About 15% of model area households had an income of $25,000 or less (2018$, corresponding to $21,000 in 2010$).
- About 50% had incomes between $25,000 (2018s) and $100,000 (2018$, corresponding to $87,000 in 2010$).
- About 35% had an income of more than $100,000 (2018$).

For comparison, preliminary analysis using the segmented modeling assignment of the RTDM was used to obtain an approximate estimate of household-income distribution for drivers on the I-205 Abernethy Bridge.[28] The results indicate that I-205 Abernethy Bridge trips are broken out as follows:

- About 10% were low income (8% SOV and 2% HOV).
- About 52% were medium income (42% SOV and 10% HOV).
- About 34% were high income (27% SOV and 7% HOV).
- About 1% medium trucks.
- About 3% heavy trucks.

[28] A select link analysis was performed using Metro RTDM 2015 base year model, selecting the links that represent the Abernethy Bridge for average weekday daily (24-hour) travel.

The comparison between these data sources for lower-income users on I-205 (10% shown in the RTDM) and regional income characteristics (approximately 18% below $21,000 in 2010$) are generally reasonable. The lower-income corridor users should be expected to be less represented proportionally, because very low-income households are less likely to have access to an automobile and are therefore less likely to drive.

Figure 58 illustrates relative distribution of origins for AM peak period (7:00 a.m. to 10:00 a.m.) trips across the Abernethy Bridge based on the Metro RTDM traffic analysis zone (TAZ) system. Overlaid is the distribution of household income of its resident in each larger district. AM peak-period trip origin most often represents the trip maker's place of residence. (The household-income distribution in each of the 23 tolling districts is also presented in Attachment B, Table B-1.)

### Value-of-Time Calculations

Following Federal VOT guidance, travelers in the low-income segment (annual household income of less than $25,000 in 2010$ would have a VOT of less than $6/hour for personal trips, which includes commute trips, (50% of hourly income) and less than $12/hour for business trips (100% of hourly income). Table 33 shows the VOTs estimated for all three income segments. VOT estimates for peak and off-peak periods would be very similar with this methodology because business trips are expected to account for a small share (5%) of the total trips in the RTDM in both the peak and off-peak periods.

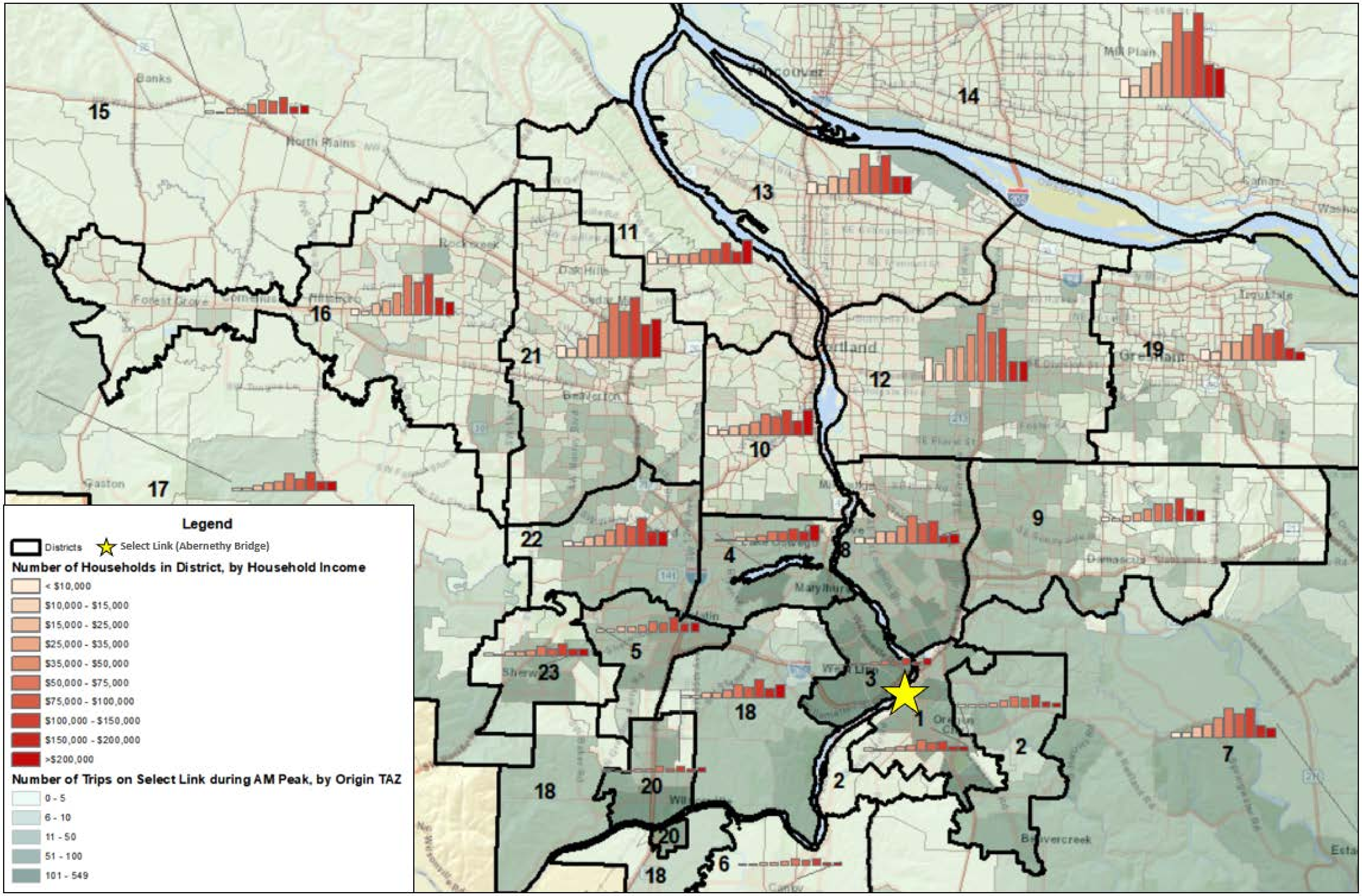
**Table 33. Value of Time for Household-Income Segments based on Federal VOT Guidance (2010$)**

| Model Income Segments | | SOV Auto - Low Income | SOV Auto - Med Income | SOV Auto - High Income |
|---|---|---|---|---|
| | | **< $25,000** | **$25,000 to $100,000** | **> $100,000** |
| Work | Commute | <$6/hour (50% of hourly income based on $25,000 annual income) | $15/hour (50% of hourly income based on $62,500—midpoint of $25,000 to $100,000 range—annual income) | >$24/hour (50% of hourly income based on $100,000 annual income) |
| | Business | <$12/hour (100% of hourly income based on $25,000 annual income) | $30/hour (100% of hourly income based on $62,500 annual income) | >$48/hour (100% of hourly income based on $100,000 annual income) |
| Non-Work | Personal | <$6/hour (50% of hourly income based on $25,000 annual income) | $15/hour (50% of hourly income based on $62,500 annual income) | >$24/hour (50% of hourly income based on $100,000 annual income) |

Note: Hourly income is estimated as annual household income divided by 2,080.

The regional income distributions based the 2018 5-year ACS estimates show that average income of the households in the $100,000 and above income segment is likely well above the $100,000 minimum threshold. In the four counties that comprise most of the tolled facility's catchment area, households with incomes of $130,000 (2010$) and higher account for 17% of the total households. Therefore, a significant portion of households in the high-income category would have a VOT for commute and non-work trips that is significantly higher than $24 when estimated based on the household-income-based approach of estimating VOT.

**Figure 58. Household-Income Distribution and AM Peak Trip Origin Distribution (from Regional Model)**



### VOT estimates using Wages

In addition to the Federal VOT guidance household-income-based approach, WSP estimated the VOT for auto travel for business purposes based on the hourly compensation of workers employed within the facility catchment area. WSP first reviewed the data on jobs located in the facility catchment area by wage category (low, medium and high) using 2017 Longitudinal Employer Household Data (LEHD[29]). Because the lower limit of the highest income category is relatively low, we also reviewed the number of workers employed in high-wage industries to obtain more information about the highest income category. These data were used to obtain a more detailed picture of the incomes of travelers using the facility.

WSP used the results of an RTDM select link analysis on I-205 Abernethy Bridge users to estimate the wage distribution and prevalence of employment in the high-wage industries for workers using the facility. More specifically, we first summarized the daily trips that use the Abernethy Bridge by origin tolling district and then combined these trips with the wage distributions in that tolling district. Thus, we developed a weighted average wage distribution of jobs in locations accessed via the Abernethy Bridge.

WSP collected LEHD data for jobs located in the four main counties in the travel shed—Clackamas, Multnomah, and Washington Counties, OR; and Clark County, WA—and summarized the jobs by tolling district. For each tolling district, we calculated the percentage share of jobs with low, medium and high wages (Attachment B, Table B-4).

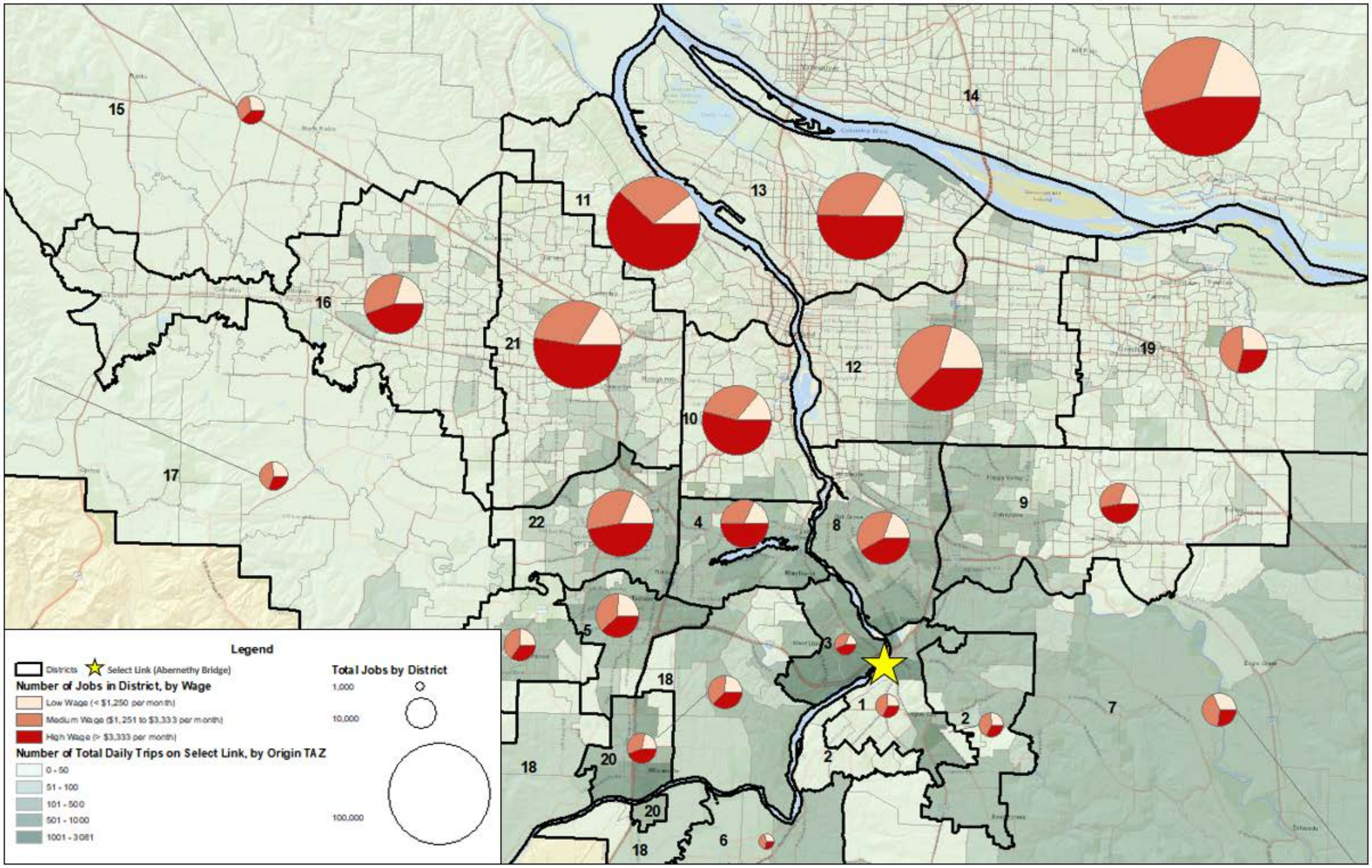
The wage categories are defined as $1,250 per month or less (low wage), between $1,250 and $3,333 per month (medium wage) and more than $3,333 per month or more (high wage) (2017 $). Based on these thresholds, a single earner household with a medium wage job may still fall in the model's low-income household category and a single earner household with a high-wage job may still fall in the model's medium-income category. To obtain more information about higher-income households, WSP calculated the percentage of jobs in three high-wage industries—management of companies and enterprises, finance and insurance, and professional and technical services—in each tolling district (Attachment B, Table B-5). Average wages in these industries are considerably higher (mostly 1.5 times or more) than the average wage for all industries combined (Attachment B, Table B-6).

Figure 59 shows, for each model TAZ, the number of daily trip origins that use the I-205 Abernethy Bridge and, for each tolling district, the number of jobs located in the district (represented by the size of the pie chart) and the split of these jobs by wage category (represented by the pie chart).

---

[29] LEHD data is developed by the U.S. Census Bureau in partnership with the states and is based on state unemployment insurance records, additional administrative data and data from censuses and surveys. LEHD includes data on employment at the census tract level broken down into low, medium and high wage jobs as well as broken down by industry.

**Figure 59. Origin Total Daily Trips on Select Link and Jobs Distribution by Wage**



As shown in Table 34, this approach yields an estimate that low-wage jobs account for 20% of the total jobs, medium-wage jobs account for 37% and high-wage jobs account for 43% of total jobs in the travel shed. Using that same methodology, WSP estimated that jobs in one of the three high-wage industries account for 22% of the jobs in the travel shed.

**Table 34. Estimated Wage Distribution and Share of Employment in High-Wage Industries for locations accessed via Abernethy Bridge**

| Employment Category | Estimated Percentage of Workers | Wage (2017 dollars) | SOV VOT (2017 dollars) | SOV VOT (2010 dollars) |
|---|---|---|---|---|
| **Low Wage** | 20% | <$15,000 | <$9 (business) | <$7.9 (business) |
| **Medium Wage** | 37% | $15,000 to $39,999 | $9 to $25 (business) | $7.9to $21 (business) |
| **High Wage** | 43% | >$40,000 | >$25 (business) | >$21 (business) |
| Finance & Insurance | 7% | $86,938 | $55 | $46 |
| Management | 5% | $106,576 | $66 | $56 |
| Professional and Technical | 10% | $92,347 | $57 | $48 |

## VOT Calculations

WSP assumed that employee compensation equals 130% of wages and converted annual compensation to hourly by assuming 2,080 work hours per year. WSP estimated business travel VOT as 100% of the hourly compensation.

The results of this approach cannot be directly applied to the income segmentation in the model, which is household-income based. However, the approach is useful because it shows that a relatively large portion (22%) of the workers employed in the locations accessed by the Abernethy Bridge are employed in high-wage industries and thus may be expected to have a higher VOT. Employees with average salaries in those industries would be estimated to have a business VOT of $46 to $56 (2010$), calculated as 100% of hourly compensation. Personal travel and commutes, calculated as 50% of hourly household income, by this same group could have VOTs that are similar to these business VOTs if there is more than one high-income earner in the household.

## Other Studies

The project team performed a literature review of other studies and research reports that were identified as potentially relevant to the Project. These provide additional data points for consideration and comparison to the Project's VOT assumptions and recommendations. Attachment A includes summaries of the other tolling studies and research reports reviewed. Summaries of the VOT values are provided in Table 35 for autos and Table 36 for trucks.

**Table 35. Overview Value of Time: Autos**

| Study | Location | Year | VOT ($/hour) | VOT in 2010$ | % of hourly income | Note |
|---|---|---|---|---|---|---|
| Columbia River Crossing Stated Preference Travel Study, Resource Systems Group, Inc. | Columbia River Crossing, Oregon/Washington | 2009 | Auto Peak: $14.68; Auto Off-Peak: $11.43; Commercial: $22.14 (SP Survey) | Peak: $14.92; Off-Peak: $11.62 Commercial: $22.50 | 40.7% peak, 31.7% off-peak based on sample avg hhinc | VOT from SP Survey was adjusted for the travel demand model to $18.89 for Peak and $15.09 for off-peak (2009$). VOT for commercial truck from survey was not used in the CRC model. Instead the METRO VOT of $35 (2005$) was used for trucks |
| I-5 Columbia River Crossing Stated Preference Travel Study, Resource Systems Group, Inc. | Columbia River Crossing, Oregon/Washington | 2013 | Peak: $13.83; Off-Peak:$11.94 (for med (SP Survey) | Peak: $12.95; Off-Peak: $11.18 Commercial:$26.84 | 32.9% peak, 28.4% off-peak based on sample avg hhinc | |

| Study | Location | Year | VOT ($/hour) | VOT in 2010$ | % of hourly income | Note |
|---|---|---|---|---|---|---|
| NCHRP Report 722 | nationwide | 2012 | Peak Commute: $7-$8 for household income <$50K; Off-Peak Personal: $5 for household income <$50K (2010$); Peak Commute: $14-$15 household income $50-$100K; Off-Peak Personal: $8-$9 household income $50-$100K (2010$); Peak Commute: $20-$22 for household income $100K+; Off-Peak Personal: $12-$13 for household income $100K+ (2010$) | Summary of Peak VOTs: $6.87, $12.49, and $17.82 respectively for income <$50k, $50k-$100k, and $100k+ | > 28.6%, 26% - 51.9%, and <37.1% peak respectively for income <$50k, $50k-$100k, and $100k+ | |
| E-470 Investment Grade Traffic and Revenue Study, CDM Smith (updated with E-470 Comprehensive T&R Study in 2020) | Denver | 2014 | $14 (2013$) Updated Study: $19 (2018$) | $13.10 Updated Study: $16 | | Separate VOT for each TAZ and time period |
| The Impact of Adopting Time-of-Day Tolling, Case Study of 183A in Austin, Texas, Light et al. | Austin, Texas | 2015 | $12 for mandatory trips (2012$); $7 for non-mandatory SOV trips; $10 for non-mandatory HOV trips (2012$) | $11.40 for mandatory trips; $6.65 for non-mandatory trips | mandatory trips: 25% for median sample hhinc of $100K; non-mandatory trips: 15% for median sample hhinc of $100K | |

| Study | Location | Year | VOT ($/hour) | VOT in 2010$ | % of hourly income | Note |
|---|---|---|---|---|---|---|
| Tampa Hillsborough Expressway Authority Investment Grade Traffic and Revenue Study, Jacobs | Tampa, Florida | 2017 | about $12 for $50-$75K household income (2015$) | $11.04 | 33% - 50% | Calculated as up to 50% of hourly wage using household-income distribution |
| SR 520 Stated Preference Survey, Wilbur Smith Associates (nka CDM Smith) | Seattle, Washington | 2009 | $12 for household income of $125K; $9 for household income of $60K | $12.00 and $9.00 for households with income at $125k and $60k, respectively | 20% and 31% for households with income at $125k and $60k, respectively | Increased VOT used in Tolling model to $18 (2010$) |
| Atlanta Regional Managed Lane System Plan, Stated Preference Survey Report, HNTB | Atlanta | 2010 | Average of VOT $7 to $15 depending on facility and based on average household income ($70-$86K) (2007$) and average distance for facility | $11.57 | 29% | |

**Table 36. Overview Value of Time: Trucks**

| Study | Location | Year | VOT($/hour) | VOT in 2010$ | Note |
|---|---|---|---|---|---|
| ODOT PIAU The Value of Travel-Time: Estimates of the Hourly Value of Time for Vehicles in Oregon | Oregon | 2015 | | Medium Trucks: $26<br>Heavy Trucks:$28 | |
| E-470 Investment Grade Traffic and Revenue Study, CDM Smith | Denver | 2014 | $42 (2013$) | | |
| RhodeWorks Truck Tolling Program Investment Grade Traffic and Revenue Study, Louis Berger (nka WSP) | Rhode Island | 2016-2017 | Average $29 for short distance and $46 for long distance; long distance ranges from $19 to $65 between second and fourth quintile (2016$) | $26.35 (short distance); $42.32 (long distance) | |
| RhodeWorks Truck Tolling Program Level 2 Traffic and Revenue Study, CDM Smith | Rhode Island | 2016 | $24 | $22.11 | Based on driver's wage |
| Value of Time for Commercial Vehicle Operators in Minnesota, Smalkoski, B. and Levinson, D. | Minnesota (multiple counties) | 2005 | $49 (2003$) | $58.70 | |
| NCHRP Report 722 | Nationwide | 2007 | | Medium Trucks: $30.41<br>Heavy Trucks: $60.82 | |
| NCHRP Report 925 | | 2019 | $15 to $412 (2018$) | $13 to $358 | |
| American Transportation Research Institute | | 2019 | $66.7 (2017$) | $59.60 | |
| Zamparini & Reggiani Meta Analysis | International | | $0.80 US (2002) to $47.21 US (2002) with a mean VOT of $20 | $0.97 to $57.22, $24 average | |
| Toledo et al | Indiana, Texas, Ontario | 2013 | from $30/hour and $235/hour (2012$) between the first and third quintiles. | $28 to $223 | |
| Texas A&M Transportation Institute, Updated Estimate of Roadway User Cost for Personal Vehicles and Commercial Trucks | Texas | 2019 | $41.33 per vehicle hour and $1.022 cents per mile for each additional mile of travel is added to the value of delay (2019$) | $35 and $0.87 per mile | |

## RANGE OF POTENTIAL VOT VALUES TO APPLY

WSP developed a range of potential VOT values building on the recommended VOT assumptions identified in Table 30. The ranges presented in Table 8: Recommended Value-of-Time Assumption Range are based on an overall assessment of the methodologies outlined in this memorandum. These could be used in future work to test a range of VOT assumptions and evaluate sensitivity of assumptions to outcomes.

**Table 37. Recommended Value-of-Time Assumptions Range (2010$)**

| Vehicle Class | Income Segmentation | Peak ($/hour) | Off Peak ($/hour) |
|---|---|---|---|
| Single-Occupancy Vehicle Auto | Low Income (<$25K) | $7 to $12 ($8) | $5 to $11 ($6) |
| | Medium Income ($25K–$100K) | $10 to $30 ($17) | $8 to $27 ($14) |
| | High Income (>$100K) | $14 to $63 ($22) | $11 to $56 ($17) |
| High-Occupancy Vehicle Auto | Low Income (<$25K) | $12 to $21 ($15) | $8 to $18 ($10) |
| | Medium Income ($25K–$100K) | $18 to $53 ($30) | $12 to $45 ($20) |
| | High Income (>$100K) | $25 to $109 ($38) | $17 to $94 ($25) |
| Medium Trucks | Not Applicable | $26 to $117 ($39) | $26 to $117 ($39) |
| Heavy Trucks | Not Applicable | $28 to $183 ($61) | $28 to $183 ($61) |

Note: Recommended values identified in Table 1 are shown in parentheses for reference.

For personal vehicles, the ranges of potential VOT assumptions for SOVs are based on the assumed hourly incomes for each income segment that were used to develop the recommended VOT assumptions (Table 31). The same adjustment factors applied to from SOV VOT to HOV VOT were used as for the recommended VOT assumptions, as described in Table 31.

For each of the three income segments ranges, the upper limit corresponds to 100 percent of the assumed hourly income. The upper limit reflects that a small portion of SOV and HOV trips during peak and off-peak periods, such as business trips, can be reasonably expected to be made by drivers with a VOT of 100 percent of their hourly income. The upper limit is supported by the federal VOT guidance, which recommends a VOT of 100 percent of the hourly income for business trips, as discussed in the methodology section.

The range lower limits vary depending on the income segment. For the low-income segment, the lower limit corresponds to 50 percent of the assumed hourly income, which is 10 percentage points lower than for the recommended base VOT for that segment. For the medium income segment, the lower limit corresponds to 30 percent of the assumed hourly income, which is 20 percentage points lower for than the recommended VOT for that segment. For the high-income segment, the lower limit corresponds to 20 percent of the assumed hourly income, which is 10 percentage points lower than the recommended VOT for that segment. The resulting base VOTs were adjusted for peak and off-peak using the assumptions used to develop the recommended peak and off-peak VOTs, as described in Table 31. The percentages to calculate the lower limits are in line with those found in the review of other studies summarized in Table 35.

The literature review indicates a high variance of VOTs for truck travel. As summarized in Table 36, NCHRP 922 (2019) found VOTs between $13 and $358 and Toledo et al (2013) found that VOTs ranged from $28 to $223 between the first and third quintiles. WSP proposes to use the ODOT (2015) medium and heavy truck VOTs as the lower limit. For the upper limit, WSP proposes a value of 3 times the recommended values to ensure that a wide range of VOTs are considered.

Further variation could be applied by varying the real VOT over time. The proposed VOT assumptions do not identify any real changes to future VOT (as expressed in constant 2010$). Although monetary inflation is expected, this implicit assumption in constant real VOT is that purchasing power remains consistent. This means that inflation would have an equivalent effect on wages and costs for goods and services. Alternative assumptions could be evaluated as needed by adjusting VOTs in future year evaluations either uniformly or for specific vehicle classes.

# ATTACHMENT A: OTHER STUDIES

## I-5 Columbia River Crossing

The VOT obtained from the Columbia River Bridge project SP surveys conducted in 2009[30] and 2013[31] was the primary source of the auto VOT assumptions for the screening analysis of the Project as well as previous applications of the RTDM. The 2009 SP survey was conducted to estimate VOT of trip makers using the existing interstate bridges over the Columbia River on I-5 and I-205, between Oregon and Washington. About 1,900 completed automobile surveys and 330 completed truck surveys were received. The survey data was used to estimate an average VOT of $14.68 for peak trips and $11.43 for off-peak trips (2009$) (Table A-1 Columbia River Crossing Stated Preference Surveys Values of Time). Based on the sample's median annual household income of about $75,000, the peak VOT and off-peak VOT correspond to 41% and 32% of hourly income, respectively. For commercial vehicles, VOT was estimated as $22.14 (2009$).

**Table A-1. Columbia River Crossing Stated Preference Surveys Values of Time**

| Mode | VOT Finding | 2009 Survey | | 2013 Survey | |
|---|---|---|---|---|---|
| | | in 2009$ | in $2010$ | in 2013$ | in $2010$ |
| Auto | Peak VOT ($/hour) | $15 | $15 | $14 | $13 |
| | Off-Peak VOT($/hour) | $11 | $12 | $12 | $11 |
| | Off-Peak VOT as % of Hourly Median Income | 41% | | 33% | |
| | Peak VOT as % of Hourly Median Income | 32% | | 28% | |
| | Median Income | $75,000 | | $87,500 | |
| Truck | Aggregated VOT ($/hour) | $22 | $23 | $28.66 | $26.84 |
| | 2-4 axles VOT ($/hour) | | | $17.36 | $16.26 |
| | 5+ axles VOT ($/hour) | | | $30.33 | $28.40 |

In 2013, a second SP survey was conducted with the purpose to develop VOT estimates for trip makers using the I-5 Bridge to support an investment-grade traffic and revenue study. About 1,940 completed automobile surveys and 320 completed truck surveys were received. The 2013

[30] Resource Systems Group, Inc. September 2009. *Columbia River Crossing Stated Preference Travel Study Report*.

[31] Resource Systems Group, Inc. November 2013. *I-5 Columbia River Crossing Stated Preference Travel Study Report*. http://data.wsdot.wa.gov/accountability/ssb5806/Repository/4_Finance/Investment%20Grade%20Analysis/CRC%20Stated%20Preference%20Survey%20Draft%20Report%202013-11-01.pdf

study found similar results as the 2009 study with estimated average VOT of $13.83 for peak trips and $11.94 for off-peak trips (2013$). The peak and off-peak VOTs correspond to 33% and 28% of the sample's median hourly household income, respectively. The commercial vehicle VOTs were $17.36 for 2 to 4 axles vehicle and $30.22 for vehicles with 5 or more axles (2013$)

For CRC modeling purposes, the VOTs from the 2009 SP Survey were adjusted to reflect reliability and the fact that infrequent or non-local travelers may not be aware of untolled alternative routes.[32] The adjusted VOTs based on the 2009 survey were $19 for peak and $13 for off-peak (2009$) (Table A-2 Columbia River Crossing 2009 Survey and Model Value of Time). These adjusted VOTs were converted to 2010 dollars and used as the basis the I-205 tolling screening analysis, along with adjustments specific to the hour of day and direction estimated specifically for the I-205 Abernethy Bridge during the ODOT Portland Metro Area Value Pricing Feasibility Analysis. The commercial VOTs from the SP survey were not used for the CRC model; instead the previously applied Metro truck VOT of $35 (2005$) was used.

**Table A-2. Columbia River Crossing 2009 Survey and Model Value of Time**

| | 2009 SP Survey | CRC Model |
|---|---|---|
| | In 2009$ | 2009$ |
| Auto Peak VOT ($/hour) | $14.68 | $18.89 |
| Auto Off-Peak VOT ($/hour) | $11.43 | $12.57 |

### Recommended values from NCHRP 722

NCRHP 722[33] provides recommended default VOTs for travel demand models by household-income segment, trip purpose and time of day. Table A-3 summarizes the VOTs into trip purposes (i.e., work/commute, work/business, non-work) that correspond to those used in the household-income-based assessment. These are generic values that are useful primarily as a point of reference and reasonableness check on applied VOT values. Unlike the Federal VOT guidance,[34] which was developed for the purpose of economic analysis, these recommendations were developed for the purpose of travel-demand modeling based on a review of VOTs used in previous studies.

**Table A-3. NCHRP 722 Recommended Default Values of Time for Single-Occupancy Vehicles by Household-Income Group, Trip Purpose, Peak/Off-Peak (2010$*)**

[32] Stantec. September 2009. *Columbia River Crossing: Recommendation for the Selection of the Value of Time to be Used in the Metro Modeling Runs*.

[33] Transportation Research Board. 2012. *NCHRP Report 722, Assessing Highway Tolling and Pricing Options and Impacts, Volume 2 Travel Demand Forecasting Tools.*

[34] Ibid.

| Household-Income Group | | Low | Medium | High |
|---|---|---|---|---|
| | | <$50,000 | $50,000 to $100,000 | >$100,000 |
| Work/Commute | Peak ($/hour) | $7.10 to $8.11 | $13.69 to $15.21 | $20.27 to $22.3 |
| | Off-Peak ($/hour) | $6.08 | $11.15 | $18.25 |
| Work/Business | Peak ($/hour) | $12.16 | $20.27 | $28.38 |
| | Off-Peak ($/hour) | $10.14 | $17.23 | $24.33 |
| Non-Work | Peak ($/hour) | $5.58 to $6.59 | $10.14 to $11.15 | $14.19 to $15.21 |
| | Off-Peak ($/hour) | $4.56 to $5.58 | $8.11 to $9.12 | $12.16 to $13.18 |

* VOTs in 2010$; income thresholds in 2008$; For peak work trips, the range represents AM (high) and PM (low) peak; For non-work trips, the range represents shopping and personal business trips (high) and leisure trips (low).

Table A-4 presents peak and off-peak VOTs calculated using the NCHRP 722 default VOTs and the trip purpose split in the model area. In the model area, work/college trips account for 45% of trips during the peak and 29% of trips during the off-peak. Taking into account this trip purpose split and using the average of the shopping/personal business VOT and leisure VOT for non-work, the peak VOT is 1.2 to 1.3 times the off-peak VOT. The calculation assumes that business trips account for 5% of work trips during the peak and off-peak. Table A-4 also shows the NCHRP recommended VOTs as a percent of hourly household income. The NCHRP VOTs are generally lower than the business and personal travel VOTs calculated based on the approach from the Federal VOT guidance, which are 100% and 50% of hourly household income, respectively. For the medium-income category, NCHRP peak VOT corresponds to 52% of hourly income for a household with a $50,000 income and to 26% of hourly income for a household with an income of $100,000. For the high-income category, the peak VOT for the lowest income in this category ($100,000) corresponds to 37% of hourly income. For a household in the high-income category with, for instance, an income of $130,000, the peak VOT of $18 equals 29% of the hourly household income.

**Table A-4. NCHRP 722 Recommended Default Value of Time for Single-Occupancy Vehicles by Household-Income Group summarized by Peak/Off-Peak (2010$*)**

| Household-Income Group | Time Period | VOT | Peak VOT/Off-Peak VOT Factor | Percentage of Hourly Household Income |
|---|---|---|---|---|
| Low (<$50,000) | Peak | $6.87 | 1.27 | >29% |
| | Off-Peak | $5.42 | | >23% |
| Medium $50,000 - $100,000 | Peak | $12.49 | 1.32 | 26% to 52% |
| | Off-Peak | $9.44 | | 20% to 39% |
| High >$100,000 | Peak | $17.82 | 1.24 | <37% |
| | Off-Peak | $14.38 | | <30% |

*Note: VOTs in 2010$; income thresholds in 2008$

The NCRHP report also provides recommendations for VOTs by vehicle type, time of day, income category and trip purpose for multiclass assignment. Table A-5 summarizes the values by vehicle type and time of day. For trucks, the recommendations do not provide a breakdown by time of day.

**Table A-5. NCHRP 722 Recommended Values of Times for Multiclass Assignment (2010$)**

| | | Range of VOT | Relative to SOV |
|---|---|---|---|
| Peak | SOV | $10.14 to $20.27 | 1 |
| | HOV2 | $17.74 to $35.48 | 1.75 |
| | HOV3 | $25.34 to $50.69 | 2.5 |
| Off-Peak | SOV | $8.11 to $15.21 | 1 |
| | HOV2 | $14.19 to $26.61 | 1.75 |
| | HOV3 | $20.27 to $38.01 | 2.5 |
| Light trucks and commercial vehicles | | $30.41 | 1.5* |
| Heavy trucks | | $60.82 | 3* |

Source: NCHRP 722 (converted to 2010 dollars)
Note:* ratio of Truck VOT to SOV AM Peak VOT. For peak, the range of VOT represents medium/high-income work trips during the AM (high) vs other trips during the PM (low). For off-peak, the range represents medium/high-income work trips (high) vs other trips (low).

### The Value of Travel-Time: Estimates of the Hourly Value of Time for Vehicles in Oregon [35]

The VOT from ODOT Program Implementation and Analysis Unit was the source of the truck VOT assumptions for the screening analysis of the Project. The VOT estimate for medium and heavy trucks is based on average employee compensation in Oregon for drivers of medium and heavy trucks, average vehicle occupancy, which is estimated as 1.27 persons for medium trucks and 1.02 for heavy trucks and a freight inventory value of $0.18/hour (2015$). The VOT equals $26 for medium trucks and $28 for heavy trucks (2010$).

### E-470 2014 Investment Grade Traffic and Revenue Study[36]

E-470 is a 47-mile toll road that runs along the eastern perimeter of the Denver Metro area and is part of the outer circumferential highway around Denver. The road was built in four phases with the first segment opened in 1991 and the last in 2003. In the 2014 study, CDM Smith used 2010 Census data on median household income, number of households and number of hours worked at the census tract level to estimate VOTs for passenger vehicles at the census tract level. They created a weighted VOT for each TAZ based on the split by trip purpose, including a "trip perception factor" for each trip purpose to represent the difference in the VOT by trip

[35] Oregon Department of Transportation. Program Implementation and Analysis Unit. November 2016. *The Value of Travel-Time: Estimates of the Hourly Value of Time for Vehicles in Oregon 2015*.
[36] E-470 Public Highway Authority. 2014. *E-470 2014 Investment Grade Traffic and Revenue Study*.

purpose. The result was individual VOTs for each TAZ, for each time period. In 2013, the average VOT was $13.99 for personal cars. They do not provide a separate VOT for SOV and HOVs. The model also included a vehicle operating cost (VOC) of $0.233 per mile for passenger cars in 2013. CDM Smith assumed that the VOT for trucks was three times the VOT of personal vehicles. This translates into a VOT of $42 in 2013$. VOC for trucks was assumed to be 3.25 times the VOC of passenger vehicles, or $0.757 per mile.

In 2020 CDM Smith prepared an updated forecast[37] that included VOT of $19.22 in 2019$. CDM Smith estimated the VOT by combining the VOTs developed from E-470 SP surveys conducted in 2017 with county-level VOTs estimates based on U.S. Census Bureau American Community Survey data and with information from the RTDM. Through this process, the relationships between income and VOT, as well as between peak and non-peak period trips obtained from the prior SP surveys were applied to the county-level VOTs developed using the U.S. Census Bureau data. This was done to normalize the VOTs to average incomes in the Denver region. This process produced an estimated VOT of $0.320 per minute, or $19.22 per hour at 2019 levels.

### Case Study of 183A, Austin, TX[38]

The 183A Turnpike is a toll road in southwestern Williamson County, TX, that traverses the cities of Leander and Cedar Park, as well as the northern border of Austin. The 183A runs generally parallel to U.S. 183, which is not tolled. The authors of the study conducted an SP survey of current and potential users to develop a tool to quantify how motorists' departure times and route choices would change in response to toll changes. The survey was administered online from February through April 2014. License Plate Reader data was collected and users were invited to participate by mail with follow up phone calls. A total of 550 completed surveys were received.

Using discrete choice analysis techniques, an average VOT of $12.13 (2012$) was estimated for mandatory trips. For the non-mandatory trips, a VOT of $6.89 was estimated for SOVs and $10.28 for HOVs. Based on the sample median household income of about $100,000, the VOT corresponds to 25% of hourly household income for mandatory trips and 15% for non-mandatory trips.

### Tampa Hillsborough Expressway Authority Investment Grade Traffic and Revenue Study[39]

Jacobs Engineering developed an investment-grade traffic and revenue study for the Lee Selmon Expressway, which the Tampa Hillsborough Expressway Authority operates. The

---

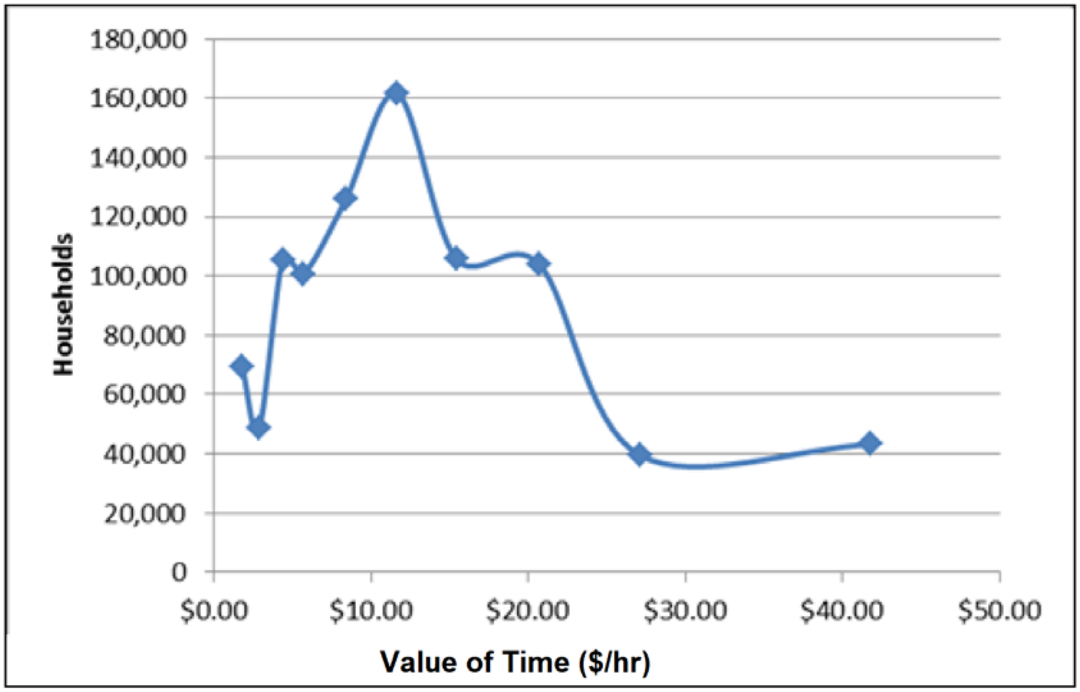
[37] E-470 Public Highway Authority. 2020. *E-470 Comprehensive Traffic and Revenue Study*. https://www.e-470.com/app/uploads/2020/10/E-470ComprehensiveTRStudyReport_May312020.pdf

[38] Light, T., Patil, S., Erhardt, G., Tsang, F., Burge, P., Sorensen, P., & Zmud, M. 2015. *The Impact of Adopting Time-of-Day Tolling: Case Study of 183A in Austin, Texas*. RAND Corporation. http://www.jstor.org/stable/10.7249/j.ctt15sk8tk

[39] Tamp Hillsborough Expressway Authority. August 2017. *THEA Investment Grade Traffic and Revenue Study*. https://selmonextension.com/wp-content/uploads/2017/09/THEA-Investment-Grade-Traffic-and-Revenue-Study-FINAL.pdf

14.168-mile toll road connects the South Tampa with Downtown Tampa and a bedroom community to the east of Tampa (Brandon). Jacobs developed a distribution of VOT based on the household-income distribution of the region. They assumed that VOT would correspond to 50% of hourly wage at lower levels of income with decreasing percentage share at higher levels, down to 30%. Figure A-1 Selmon Expressway Value of Time presents the VOT estimated included in the traffic and revenue model.

**Figure A-1. Selmon Expressway Value of Time**




### SR 520 Stated Preference Surveys

State Route 520 is an east-west highway and bridge that connects Seattle with its Eastside communities on Lake Washington in King County via the SR 520 floating bridge. SP surveys were conducted in 2003 and in 2009 to understand the toll sensitivity of travelers using the non-tolled bridge. The most recent SP survey was conducted by Resource Systems Group, Inc. in 2009 as part of the Traffic and Revenue (T&R) study produced for Washington State Department of Transportation.[40] Survey data were collected in late October and early November 2009. Invitations to participate were sent by email using addresses that were obtained from a previous origin-destination survey of the SR 520 floating bridge. To qualify for the survey, respondents needed to have made a recent weekday trip in a personal vehicle using SR 520 to cross Lake Washington. A total of 1,958 respondents completed the survey. The data was used to estimate the VOTs presented in Table A-6. The table shows that off-peak VOTs were found to be higher than peak VOT for all income segments shown except for the median sample income. For the median sample income, off-peak business VOT was 18% lower than peak business VOT.

[40] Resource Systems Group Inc. December 2009. *SR 520 Stated Preference Travel Study*.

The aggregate VOT corresponds to 20% of the hourly income for households with an income of $125,000. The percentage is higher for lower-income households with 46% for a $35,000 household income and 32% for a $60,000 household income.

**Table A-6. SR 520 2009 Survey Value of Time (2009$)**

| Income Group | Annual Income | Value of Time ($/hr) | | | | |
|---|---|---|---|---|---|---|
| | | Aggregate | Peak business (includes commute) | Peak non-business | Off-peak business (includes commute) | Off-peak non-business |
| Median Sample Income (Aggregate) | $125,000 | $11.85 | $13.59 | $9.44 | $11.12 | $12.95 |
| Low Income | $25,000 | $6.83 | $6.73 | $5 | $9.62 | $9.47 |
| Low–Medium Income | $35,000 | $7.67 | $7.79 | $5.71 | $9.92 | $10.11 |
| Medium–High Income | $60,000 | $9.22 | $9.86 | $7.06 | $10.41 | $12.23 |

In the 2011 investment-grade T&R study for the SR 520 corridor, CDM Smith points out that the VOTs estimated based on the 2009 stated preference survey were demonstrably lower than VOT results from a similar stated preference survey of SR 520 users in 2003 and too low given the income level of travelers in the corridor, which was estimated as $100,000 on average. Therefore, they made adjustments to the VOTs for the SR 520 T&R forecasting. Based on annual household income and annual number of hours worked for the bridge influence area from the census and perception factors of 30% to 60% to reflect the different VOTs by trip purpose, they estimated a VOT for the highest income group based on an annual household income of $125,000. They then used the survey results to calculate the proportional VOTs for other SOV segments. They also compared their results to the Puget Sound Regional Council VOT, which corresponds to almost 75% of the hourly wage rate and was based on a very small sample of 275 respondents and a non-traditional methodology. The VOTs for peak work trips are presented in Table A-7.

**Table A-7. SR 520 SP Surveys and Model Peak Work Trip Value-of-Time Comparison (2010$)**

| | Value of Time ($/hour) |
|---|---|
| 2003 SP Survey | $15.11 |
| 2009 SP Survey | $10.72 |
| Puget Sound Regional Council Model | $28.63 |
| SR 520 Tolling Model | $17.70 |

### Decision Making Process and Factors Affecting Truck Routing[41]

An SP survey of truck drivers was conducted at three rest area and truck stop locations along major highways in Texas, Indiana, and Ontario with about 250 responses. The authors found a wide range of VOT with values from $30/hour and $235/hour (2012$) between the first and third quintiles (i.e., excluding the respondents with the lowest and highest VOTs). VOT varied based on employment terms (e.g., method of pay calculation and whether the driver is responsible for toll and fuel cost) and shipment terms. The authors found that most drivers are responsible for choosing their routes, both during the planning stage and en-route.

### RhodeWorks Truck Tolling Program Traffic and Revenue Study[42]

Rhode Island Department of Transportation (RIDOT) developed RhodeWorks, a road improvement funding program that calls for the repair of the state's bridges. Under the program, a significant portion of the financing of the repairs is expected to be obtained from tolls assessed on tractor trailers. RIDOT engaged the Louis Berger team to develop a level 3 investment-grade T&R study. The level 3 study evaluated 14 toll locations across the state along six major highway corridors (I-95, I-195, I-295, US Route 6, RI Route 146, and RI Route 10).

As part of the study, the Louis Berger team conducted an SP survey to understand willingness-to-pay for travel-time savings associated with not diverting to alternative roads in response to a toll on the highway. Drivers of tractor trailers were intercepted at two locations in Rhode Island in October 2016. To qualify for the full survey, the driver needed to be in charge of the route-planning decision or be authorized to make en-route changes, either independently or with approval of the fleet manager/dispatcher. Of all 437 intercepted tractor trailer drivers who agreed to participate, 75% (327) met these qualifications.

The survey data was used to develop a distribution of VOT for short (less than 2 hours) and long-distance trips (2 hours or more). The distribution of VOT was summarized into quintiles to be incorporated in the Rhode Island Statewide Travel Demand Forecasting Model (RISM) as shown in Table A-8 RhodeWorks Values of Time for Short- and Long-Distance Truck Trips. The RISM was customized to include separate truck-trip tables for short- and long-distance trips for each time period. Each trip table was then further split into five equal-sized trip tables with each trip table being assigned a VOT from one of the five short- or long-distance quintiles.

**Table A-8. RhodeWorks Values of Time for Short- and Long-Distance Truck Trips (2016$)**

| | Short Distance | | | Long Distance | | |
|---|---|---|---|---|---|---|
| | Upper Threshold | | | Upper Threshold | | |
| Quintile | Percentage | VOT ($/hour) | Average VOT | Percentage | VOT ($/hour) | Average VOT |
| 0 to 20 | 20% | $12.00 | $8.89 | 20% | $19.00 | $13.79 |

---

[41] Toledo, T., et al. "Decision-Making Process and Factors Affecting Truck Routing," *Freight Transport Modelling*, pp. 233-249. 2013. https://doi.org/10.1108/9781781902868-012

[42] *Rhode Island Department of Transportation Investment-Grade Tolling Study Final Report*. November 3, 2017. http://www.dot.ri.gov/documents/news/Investment-Grade-Tolling-Study.pdf

| Quintile | Short Distance | | | Long Distance | | |
|---|---|---|---|---|---|---|
| | Upper Threshold | | | Upper Threshold | | |
| | Percentage | VOT ($/hour) | Average VOT | Percentage | VOT ($/hour) | Average VOT |
| 20 to 40 | 40% | $18.00 | $15.45 | 40% | $29.00 | $24.41 |
| 40 to 60 | 60% | $27.00 | $22.70 | 60% | $42.00 | $35.60 |
| 60 to 80 | 80% | $41.00 | $33.65 | 80% | $65.00 | $52.55 |
| 80 to 100 | 100% | $212.00 | $65.48 | 100% | $336.00 | $103.52 |

To validate the VOT estimates, a literature review on VOT for commercial travel was conducted as part the RhodeWorks report. The review returned a wide range in the reported VOTs based on several different methodological approaches and analytical perspectives. An adaptive stated preference study in Minnesota derived the truck VOT at $49/hour[43] while a stated preference study in California estimated the VOT for trucks at $23/hour.[44] Table A-9 RhodeWorks Value of Time Benchmark Comparison compares the RhodeWorks VOTs with those obtained from two comparable studies in the United States: an SP survey conducted as part of the Atlanta Managed Lane System Plan,[45] and the I-710 Study[46] in Los Angeles.

**Table A-9. RhodeWorks Study Value of Time Benchmark Comparison (2016$)**

| | Atlanta Managed Lanes (2010) | I-710 Major Corridor-Los Angeles (2005) | RIDOT Study (2016) | |
|---|---|---|---|---|
| | | | Short Distance | Long Distance |
| Mean | $22.81 | $30.00 | $28.93 | $45.87 |
| Median | $15.32 | $18.00 | $22.15 | $35.12 |

The RhodeWorks report also compared the VOT to the Level 2 RhodeWorks T&R Study that was completed by CDM Smith in early 2016 and that resulted in the identification of 14 toll locations across the state. The previous Level 2 Study used the driver wage approach set forth in U.S. DOT guidelines to set the VOT assumptions. Starting with an estimated hourly wage of $19.00/hour, a 25% increase was also applied to account for company overhead and other potential opportunity costs. This resulted in a single VOT assumption of $23.76/hour.

---

[43] Smalkoski, B., Levinson, D. 2005. "Value of Time for Commercial Vehicle Operators in Minnesota," *Journal of the Transportation Research Forum 44:1*, pp. 89-102.

[44] Kawamura, K. January 1, 2000."Perceived Value of Time for Truck Operators," *Transportation Research Record 1725, Paper No. 00-0711*. Transportation Research Board, Washington, D.C.

[45] HNTB for Georgia Department of Transportation. 2010. *Atlanta Regional Managed Lane System Plan, Stated Preference Survey Report.* http://www.dot.ga.gov/BuildSmart/Studies/ManagedLanesDocuments/Stated%20Preference%20Survey.pdf

[46] https://www.metro.net/projects/i-710-corridor-project/

### NCHRP Report 925: Estimating the Value of Truck Travel-Time Reliability[47]

NCHRP 925 developed a reliability valuation framework for freight transportation that recommends VOT and VOR (Value of Reliability) estimates for benefit-cost and other planning analyses. As part of the study, an SP survey of motor carriers and shippers was conducted with about 1,000 qualified responses. The authors found that VOT and VOR vary widely based on respondent type (i.e., motor carriers, shipper with transportation, shipper without transportation), shipment distance, company size, shipment characteristics and receiver characteristics, and other factors. VOTs based on submodels that focused on a specific segment of the market ranged from $15 to $412/hour. The VOT estimates based on the whole sample were not significant. Therefore, the authors recommended using the American Transportation Research Institute VOT of $66.7 per hour in 2017 dollars.[48] Using the whole sample, the authors estimated a VOR of $160/hour.

### Meta Analysis of Freight VOT[49] (2007)

This paper provides 46 estimates of truck VOT from studies in 22 countries. VOTs vary widely in part because they were developed using different methods and in part because of differences in terms of the location of the studies. They found a wide range of VOTs with a mean VOT of $20 (2002$).

### Updated Estimate of Roadway User Cost for Personal Vehicles and Commercial Trucks[50]

TxDOT publishes updated values of delay every year. For trucks, the value includes vehicle occupancy, wage, employee benefits and the cost of the additional fuel needed because of slower speed. If the delay increases distance, the value includes the additional operating cost per mile and accident cost, which is based on insurance cost). The 2019 value of delay was estimated as $41.33 per vehicle hour, which includes $36.62 for the value of travel time plus $4.71 due to excess fuel burn in congested traffic, and is based on an average vehicle occupancy of 1.14 persons per vehicle. If rerouting increases the distance traveled, $1.022 cents per mile for each additional mile of travel is added to the value of delay.

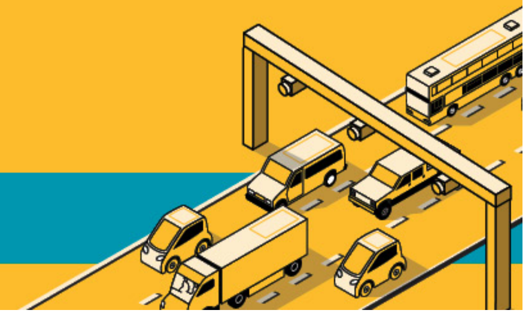
---

[47] National Academies of Sciences, Engineering, and Medicine. 2019. *NCHRP Report 925: Estimating the Value of Truck Travel Time Reliability*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25655

[48] American Transportation Research Institute. November 2019. *An Analysis of the Operational Costs of Trucking: 2019 Update*. https://truckingresearch.org/wp-content/uploads/2019/11/ATRI-Operational-Costs-of-Trucking-2019-1.pdf

[49] Luca Zamparini & Aura Reggiani. 2007. "Freight Transport and the Value of Travel Time Savings: A Meta-analysis of Empirical Studies," Transport Reviews, 27:5, 621-636. https://doi.org/10.1080/01441640701322834

[50] Texas A&M Transportation Institute. March 10, 2020. *Updated Estimate of Roadway User Cost for Personal Vehicles and Commercial Trucks*. https://ftp.txdot.gov/pub/txdot-info/cst/ruc-methodology-memo.pdf



## ATTACHMENT B: SUPPORTING DATA

**Table B-1. Number of Households by Income Group**

| Income Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Tolling District** | **< $10,000** | **$10,000 to $15,000** | **$15,000 to $25,000** | **$25,000 to $ 35,000** | **$35,000 to $50,000** | **$50,000 to $75,000** | **$75,000 to $100,000** | **$100,000 to $150,000** | **$150,000 to $200,000** | **- > $200,000** |
| 1 | 779 | 583 | 1,095 | 1,481 | 2,249 | 3,967 | 3,201 | 3,902 | 1,443 | 1,276 |
| 2 | 764 | 599 | 1,084 | 1,504 | 2,573 | 4,265 | 3,494 | 4,486 | 1,863 | 1,631 |
| 3 | 429 | 326 | 641 | 652 | 1,211 | 1,864 | 1,358 | 2,782 | 1,583 | 2,870 |
| 4 | 934 | 558 | 1,658 | 1,800 | 2,446 | 3,912 | 3,848 | 5,394 | 3,871 | 6,763 |
| 5 | 1,078 | 761 | 2,317 | 2,082 | 2,817 | 4,563 | 3,677 | 5,788 | 3,065 | 3,915 |
| 6 | 433 | 476 | 1,165 | 1,273 | 1,704 | 3,064 | 2,462 | 3,146 | 1,247 | 1,271 |
| 7 | 2,305 | 2,001 | 4,390 | 5,479 | 8,113 | 12,193 | 9,837 | 11,787 | 5,076 | 3,790 |
| 8 | 3,027 | 2,194 | 4,940 | 4,989 | 7,094 | 11,522 | 8,203 | 9,559 | 3,371 | 4,051 |
| 9 | 1,312 | 986 | 2,039 | 3,165 | 4,567 | 7,115 | 7,039 | 9,161 | 4,597 | 4,269 |
| 10 | 3,468 | 1,815 | 3,862 | 4,310 | 5,261 | 8,548 | 7,583 | 10,621 | 5,892 | 10,242 |
| 11 | 5,393 | 2,255 | 4,022 | 4,128 | 4,755 | 6,433 | 6,190 | 9,093 | 5,041 | 9,934 |
| 12 | 10,051 | 7,173 | 13,820 | 14,294 | 19,635 | 28,001 | 20,385 | 22,252 | 8,493 | 8,182 |
| 13 | 5,349 | 3,710 | 7,021 | 6,708 | 10,848 | 16,432 | 11,906 | 15,920 | 7,119 | 7,508 |
| 14 | 7,340 | 5,105 | 12,783 | 14,453 | 23,239 | 34,921 | 27,272 | 35,312 | 13,621 | 11,951 |
| 15 | 1,373 | 980 | 2,661 | 2,112 | 3,984 | 5,743 | 5,170 | 6,805 | 2,929 | 3,504 |
| 16 | 2,964 | 2,134 | 5,413 | 6,342 | 9,743 | 16,770 | 13,927 | 17,430 | 7,281 | 5,473 |
| 17 | 1,087 | 1,098 | 2,159 | 3,109 | 4,133 | 6,989 | 5,147 | 7,718 | 3,683 | 3,851 |
| 18 | 959 | 908 | 2,088 | 2,169 | 3,416 | 5,639 | 4,556 | 7,491 | 4,044 | 5,731 |
| 19 | 4,483 | 3,477 | 7,599 | 7,864 | 10,567 | 14,652 | 10,778 | 12,665 | 4,661 | 3,081 |
| 20 | 499 | 403 | 790 | 1,060 | 1,158 | 2,589 | 1,508 | 2,594 | 1,436 | 1,941 |
| 21 | 4,780 | 3,643 | 7,871 | 9,525 | 14,767 | 22,608 | 19,581 | 24,999 | 13,700 | 16,075 |
| 22 | 2,059 | 1,742 | 3,824 | 4,567 | 6,487 | 9,538 | 8,028 | 11,346 | 5,782 | 5,948 |
| 23 | 837 | 552 | 1,385 | 1,594 | 2,019 | 3,531 | 2,800 | 4,921 | 2,505 | 2,878 |
| Total | 61,703 | 43,480 | 94,628 | 104,659 | 152,787 | 234,858 | 187,949 | 245,171 | 112,304 | 126,135 |

Source: 2018 American Community Survey 5-Year Estimates

**Table B-2. Personal Travel and Business Travel by Income Group**

| Income Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | < $10,000 | $10,000 to $15,000 | $15,000 to $25,000 | $25,000 to $ 35,000 | $35,000 to $50,000 | $50,000 to $75,000 | $75,000 to $100,000 | $100,000 to $150,000 | $150,000 to $200,000 | - > $200,000 |
| Midpoint | $8,000 | $12,500 | $20,000 | $30,000 | $42,500 | $62,500 | $87,500 | $125,000 | $175,000 | $202,000 |
| VOT Personal | $1.92 | $3.00 | $4.81 | $7.21 | $10.22 | $15.02 | $21.03 | $30.05 | $42.07 | $48.56 |
| VOT Business | $3.85 | $6.01 | $9.62 | $14.42 | $20.43 | $30.05 | $42.07 | $60.10 | $84.13 | $97.12 |

**Table B- 3. 2015 Select Link (Abernethy Bridge) Trips by Origin District 2015**

| | SOV Auto - Low Income | SOV Auto - Med Income | SOV Auto - High Income |
|---|---|---|---|
| Model Income Group | < $25,000 | $25,000 to $100,000 | > $100,000 |
| 1 | 104 | 670 | 334 |
| 2 | 31 | 278 | 186 |
| 3 | 157 | 1038 | 1145 |
| 4 | 59 | 346 | 400 |
| 5 | 61 | 327 | 226 |
| 6 | 0 | 0 | 0 |
| 7 | 85 | 772 | 457 |
| 8 | 212 | 1270 | 613 |
| 9 | 75 | 736 | 547 |
| 10 | 13 | 85 | 74 |
| 11 | 0 | 2 | 5 |
| 12 | 129 | 772 | 296 |
| 13 | 5 | 56 | 30 |
| 14 | 6 | 293 | 105 |
| 15 | 0 | 9 | 8 |
| 16 | 13 | 209 | 86 |
| 17 | 3 | 59 | 42 |
| 18 | 21 | 144 | 190 |
| 19 | 42 | 415 | 163 |
| 20 | 62 | 312 | 222 |
| 21 | 58 | 410 | 224 |
| 22 | 69 | 390 | 240 |
| 23 | 21 | 196 | 173 |

Table B-4. Wage Distribution by Tolling District

| Tolling District | Low Wage | Medium Wage | High Wage |
|---|---|---|---|
| 1 | 25% | 42% | 33% |
| 2 | 27% | 47% | 26% |
| 3 | 24% | 40% | 36% |
| 4 | 17% | 29% | 55% |
| 5 | 22% | 38% | 40% |
| 6 | 31% | 39% | 30% |
| 7 | 35% | 41% | 24% |
| 8 | 21% | 41% | 38% |
| 9 | 18% | 33% | 49% |
| 10 | 15% | 32% | 54% |
| 11 | 10% | 26% | 65% |
| 12 | 21% | 41% | 38% |
| 13 | 16% | 33% | 51% |
| 14 | 20% | 34% | 46% |
| 15 | 30% | 38% | 32% |
| 16 | 19% | 34% | 47% |
| 17 | 31% | 44% | 25% |
| 18 | 16% | 34% | 51% |
| 19 | 26% | 45% | 29% |
| 20 | 24% | 35% | 41% |
| 21 | 16% | 30% | 54% |
| 22 | 20% | 36% | 44% |
| 23 | 32% | 43% | 25% |
| **Total** | **18%** | **35%** | **47%** |

Table B-5. Jobs in High-Wage Industries by Tolling District

| | Number of Jobs | | | | Percentage of Total Jobs | | | |
|---|---|---|---|---|---|---|---|---|
| Tolling District | Finance & Insurance | Management of Companies and Enterprises | Professional & Technical Services | Total | Finance & Insurance | Management of Companies and Enterprises | Professional & Technical Services | Total |
| 1 | 308 | 69 | 557 | 6,486 | 5% | 1% | 9% | 100% |
| 2 | 256 | 55 | 577 | 6,871 | 4% | 1% | 8% | 100% |
| 3 | 270 | 24 | 406 | 5,321 | 5% | 0% | 8% | 100% |
| 4 | 3,700 | 1,200 | 5,019 | 27,335 | 14% | 4% | 18% | 100% |
| 5 | 1,228 | 1,347 | 2,041 | 22,411 | 5% | 6% | 9% | 100% |
| 6 | 130 | 4 | 247 | 2,886 | 5% | 0% | 9% | 100% |
| 7 | 481 | 517 | 1,024 | 13,447 | 4% | 4% | 8% | 100% |
| 8 | 1,835 | 1,373 | 2,558 | 32,800 | 6% | 4% | 8% | 100% |
| 9 | 839 | 706 | 1,205 | 18,742 | 4% | 4% | 6% | 100% |
| 10 | 6,520 | 2,784 | 9,191 | 56,503 | 12% | 5% | 16% | 100% |
| 11 | 11,211 | 8,931 | 24,239 | 103,849 | 11% | 9% | 23% | 100% |
| 12 | 3,964 | 3,638 | 8,187 | 87,141 | 5% | 4% | 9% | 100% |
| 13 | 3,461 | 7,706 | 8,823 | 89,040 | 4% | 9% | 10% | 100% |
| 14 | 7,105 | 3,539 | 10,320 | 166,600 | 4% | 2% | 6% | 100% |
| 15 | 209 | 341 | 1,047 | 9,078 | 2% | 4% | 12% | 100% |
| 16 | 2,036 | 929 | 3,570 | 41,193 | 5% | 2% | 9% | 100% |
| 17 | 290 | 81 | 524 | 9,495 | 3% | 1% | 6% | 100% |
| 18 | 737 | 432 | 1,138 | 13,508 | 5% | 3% | 8% | 100% |
| 19 | 2,252 | 456 | 1,485 | 26,562 | 8% | 2% | 6% | 100% |
| 20 | 239 | 535 | 1,840 | 10,513 | 2% | 5% | 18% | 100% |
| 21 | 6,386 | 12,863 | 9,942 | 91,364 | 7% | 14% | 11% | 100% |
| 22 | 7,297 | 2,176 | 9,269 | 51,858 | 14% | 4% | 18% | 100% |
| 23 | 388 | 636 | 1,184 | 11,959 | 3% | 5% | 10% | 100% |
| Total | **61,142** | **50,342** | **104,393** | **904,962** | **7%** | **6%** | **12%** | **100%** |

**Table B-6. Average Annual Wages by Industry**

| Job Location | All Industries | Finance & Insurance | Management of Companies and Enterprises | Professional & Technical Services |
|---|---|---|---|---|
| Clackamas County, Oregon | $51,719 | $87,291 | $95,570 | $97,785 |
| Clark County, Washington | $50,850 | $87,166 | $106,262 | $75,005 |
| Multnomah County, Oregon | $57,171 | $94,031 | $97,903 | $87,122 |
| Washington County, Oregon | $68,162 | $75,506 | $173,398 | $75,177 |