Appendix A. TOAS Report

This appendix contains a report that was prepared under a separate contract. Requests for figure interpretation or other accessibility assistance for this appendix should be directed to the ODOT Senior Environmental Project Manager at (503) 731-4804.

Traffic Operations Analysis Summary

DRAFT

I-5 Broadway Weidler Interchange Improvements

Portland, OR

January 21, 2015

Contents

Appendices

Figures

Tables

Graphs

Introduction

As part of the I-5 Broadway-Weidler Interchange Improvements Project, the HDR Consultant Team (Team) evaluated alternatives for the optimal safety and operations design. This report summarizes the evaluation of the alternatives and includes project scope, summary of existing conditions and calibration, alternative model development, final analysis, and side-by-side comparisons of alternatives. All supplemental technical data and output files are provided in the Appendix for reference.

Study Area

I-5 is classified as an Interstate facility, based on FHWA Classification, and a freeway, based on ODOT classifications. It runs north-south along the West Coast of the United States and through the Portland Metropolitan area. The Broadway-Weidler Interchange is located between the I-405 and I-84 interchanges on I-5. It serves as a route for both local through traffic and as a connector for interstate traffic, which is integral to freight operations. At the Fremont Bridge, I-5 connects to the north end of the north-south I-405 loop. A mile south of this intersection, I-5 intersects the west end of east-west bound I-84. Figure 1 shows a schematic of the Study Area. Areas of focus for this project include all ramps on I-5 between Morrison Street and Going Street, the freeway mainline, and surface street intersections at the interchange.

The connection between I-405 and I-84 on I-5 also serves as a critical connection between the economic engine in Washington County and the Portland International Airport. These major job and economic generators include Intel, Nike, Genetech, Solarworld and other valuable industrial and job centers. Improvements at this location assist with regional economic growth.

In addition to the freeway, arterial, and local street network, the Rose Quarter includes several multimodal facilities that support all modes of transportation. Four light rail transit (LRT) lines operate within the project area, and a streetcar line is currently operating on the Broadway-Weidler couplet to connect the N/NE Quadrant with the Pearl District across the river. These facilities serve a large portion of pedestrian traffic, as well as bicyclists, within the Study Area.

Current Network Performance

As detailed in the 2012 *I-5 Broadway-Weidler Interchange Improvements Facility Plan*[1] (see Appendix A), the Broadway-Weidler Interchange experiences some of the highest traffic volumes in the state of Oregon. The heavy congestion in addition to short weave segments and a lack of roadway shoulder for accident recovery on either side of the freeway are direct contributors to the high number of crashes each year. There are significant safety concerns for the area, which are outlined by a crash analysis performed between 2005 and 2009. The aforementioned study found that:

- The I-5 Interchange at Broadway and Weidler was rated as the location with the highest accident rate in the State of Oregon.
- The southbound direction has more frequent crashes than the northbound.
- The most frequent crash types are: rear-end, sideswipe, fixed, and other.

A weaving analysis within the Study Area found that the sections of I-5 Northbound from I-84 Westbound to Weidler Off-ramp and I-5 Southbound from Wheeler On-ramp to I-84 Eastbound Off-ramp both currently

Figure 1 – Traffic Analysis Study Area

[1] URS Corporation, *I-5 Broadway/Weidler Interchange Improvements Facility Plan*, 2012.

perform at a failing level-of-service during the a.m. and p.m. peak periods. The I-5 Southbound section between Wheeler On On-Ramp and I-84 Eastbound Off-Ramp is projected to have the most critical failure in future operations, with bottlenecking that will cause severe queuing back to the Fremont Bridge.

Proposed Improvements

Improvements for the I-5 Corridor and Interchange will focus on increasing safety for all traveling vehicles, cyclists, and pedestrians within the Study Area. The interchange improvements analyzed for this report include additional lanes in both traveling directions on I-5 to help meet future demand and improve safety, as well as ramp reconfigurations to reduce weaving and alleviate congestion for the freeway. The ramp improvements will include significant improvement to the arterial. These improvements are designed to allow for more efficient access on and off the freeway, as well as to provide safer and smoother traveling conditions for bicyclists and pedestrians. These arterial designs are based on an increased focus for pedestrian and bicycle facilities in particular and include many new crosswalks and bike lane improvements to improve pedestrian and bicycle safety and travel time to/from the major transit amenities.

VISSIM Model Development

VISSIM was chosen to evaluate the improvements for this project in this phase. VISSIM is a microsimulation tool that allows the user to model complex geometry, include all modes of travel, and gather data to develop measures of effectiveness (MOE's) that many other tools are limited in. This section summarizes the components that went into developing the existing models for the Study Area. A more detailed report was developed at earlier stages in this project and is included in Appendix B[2]. The development of the VISSIM models followed ODOT's VISSIM Protocol Guidelines.[3]

Intersections and Geometry

The I-5 Broadway-Weidler VISSIM models include I-5 Northbound and Southbound and all ramps on I-5 between Morrison Street and Going Street. A portion of the I-84 mainline was also modeled along with the Grand Avenue on-ramp to eastbound I-84. The arterial network included the following eight Study Area intersections in addition to I-5 Northbound and Southbound:

- Weidler Street/Vancouver Avenue
- Weidler Street/Williams Avenue
- Weidler Street and Victoria Avenue/I-5 NB Off-Ramp
- Broadway/Victoria Avenue
- Broadway and Williams Avenue/I-5 NB On-Ramp
- Broadway/Vancouver Avenue
- Broadway/Flint Avenue
- Wheeler Avenue/Winning Way/I-5 SB On-Ramp

Model Hours

All VISSIM models were developed to analyze these intersections for three study periods (listed below). The first half hour of each VISSIM model was used for "seeding" purposes with data collection occurring during the remainder of the study period.

- Morning Peak – 5:30 a.m. to 10:00 a.m.
- Mid-day – 11:30 a.m. to 2:00 p.m.
- Afternoon Peak – 1:30 p.m. to 6:00 p.m.

Base Model Inputs

This section provides a brief summary of the information gathered in the *Existing Conditions Data Summary*[4] Memo. This Memo is provided in Appendix C for reference.

The Team followed Oregon Department of Transportation's (ODOT) VISSIM Protocol for processing of all model inputs. Multiple data sources were used to develop the data inputs and calibration targets for the VISSIM models for the I-5 Broadway-Weidler project. The VISSIM model data inputs, their sources, and their use relating to the model are shown below in Table 1.

Table 1 – VISSIM Model Data Inputs

Inputs for I-5 Broadway Weidler Improvements		
Data	**Source**	**Use**
Traffic Volumes	ODOT/Portal	Input and Calibration
Origin-Destination	Bluetooth – ODOT	Input
Signal Timing Data	ODOT	Input
Ramp Meter Data	ODOT	Input
Transit Data	TriMet Website	Input
Speed Data	INRIX – ODOT/Portal	Input and Calibration

Traffic Volumes

The Team obtained traffic volumes for the freeway mainline, ramps, arterials, and heavy vehicles from ODOT and Portland State University's (PSU) Portal website. The Team exported mainline volumes for the entire year 2013 (for Tuesdays, Wednesdays, and Thursday, excluding major holidays) and collected volumes for two locations near ramps within the Study Area: Broadway Street Northbound and Broadway Street Southbound. Both locations accurately capture the demand within the Study Area and are outside of the bottleneck location. The team also collected ramp volumes in 2014 at 15-minute intervals using Automatic Traffic Recorder (ATR) road tubes. These multi-daily volumes were averaged to determine one daily volume.

Since arterial a.m. and p.m. volume turning movements were only provided for peak period hours for the majority of the intersections within the Study Area, the Team used Portland Bureau of Transportation's (PBOT) ATR data to obtain volumes for the entire study periods. The Team collected arterial mid-day volumes for this project, eliminating the need for calculations for additional time periods. Balancing was required for data collected over multiple years for all arterial volumes. Additionally, the Team obtained bicycle and pedestrian volumes from PBOT's count website[5]. Since not all hours were available, the Team made conservative assumptions where the data was missing. Heavy vehicle percentages were developed using the short duration (24-hour) classification counts provided by ODOT and fleet distributions for both medium and heavy trucks. Heavy vehicle fleet distributions were calculated using the classification count on

[2] *VISSIM Model Calibration Methodology and Results*, August 2014, HDR Engineering
[3] ODOT VISSIM Protocol: http://www.oregon.gov/odot/td/tp/apm/addc.pdf
[4] *Existing Conditions Data Summary,* August 2014, HDR Engineering
[5]http://www.portlandmaps.com/

I-5 south of Weidler Street, as this location provides a good representation of the types of trucks within our Study Area.

Origin-Destination

ODOT provided a Bluetooth origin-destination (OD) summary. This data was put into TflowFuzzy to create OD matrices for the VISSIM model. The Team developed hourly OD matrices and coded from TflowFuzzy into VISSIM.

Signal Timing

ODOT via PBOT provided signal timing data. Due to the length of the study period, the Team coded multiple coordination patterns to replicate the field operations. Signal timing was coded in VISSIM using the Ring-Barrier Controller (RBC). Detector data was provided for some of the intersections via as-builts. In other cases, the data was interpolated based on standards and signal timing sheets.

Ramp Meter

ODOT provided ramp meter data as saturation flow rates in 15-minute increments. Because the flow rates were similar between 15-minute periods and given the limitation of the number of different timing patterns available in VISSIM, the flow rates were averaged by hour.

Transit

The Team obtained transit data for bus and streetcar operations from TriMet's website. Headways were determined based on the scheduled stops, and average dwell times were based on data provided by TriMet which equated to 25 seconds per stop. Within the Study Area there are four bus lines (4, 17, 44, and 85) and a streetcar (Central Loop) that travel on the both NE Broadway and NE Weidler. Bus line and streetcar stops located within the Study Area are listed below and transit lines are found in Figure 3:

- Bus 4: N Williams/Wheeler, N Williams/NE Broadway, and N Vancouver/Weidler
- Bus 17: NE Broadway/Vancouver and N Weidler/Williams
- Bus 44: N Williams/Wheeler and N Williams/NE Broadway
- Bus 85: No stops in the Study Area but travels through the Study Area
- Streetcar: No stops in the Study Area but travels through the Study Area

Speeds

The Team obtained INRIX data to determine mainline freeway speed distribution. Various data collection points were gathered during "free-flow" periods on I-5 to build a large enough data set to create the profile. Figure 2 shows the calculated profile:

Speed limits posted in the field provided the basis for arterial speeds. All roadways were 30 miles per hour (mph), with the exception of Flint Road which was 25 mph.

The Team assumed pedestrian speeds to be between 3.5 feet per second (fps) and 5.0 fps with a linear distribution, which matched known typical values and was checked against research done in Portland, Oregon.[6] For bicycles, the Team used local research in Portland, Oregon to set 15th percentile and average speeds (15th = 9.5 fps and 50th = 10.7 fps).[7] To obtain minimum and maximum values, AASHTO standards[8] were evaluated to determine a minimum of 7.0 fps and a maximum of 15 fps as shown in Figure 2 (note values in figure are in mph).

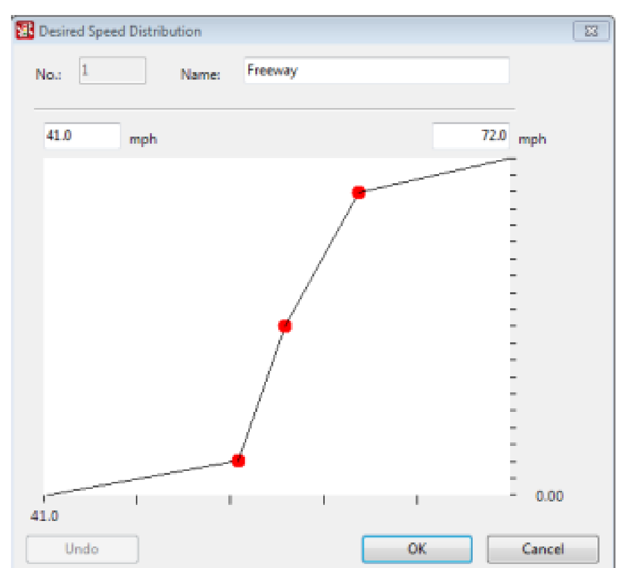
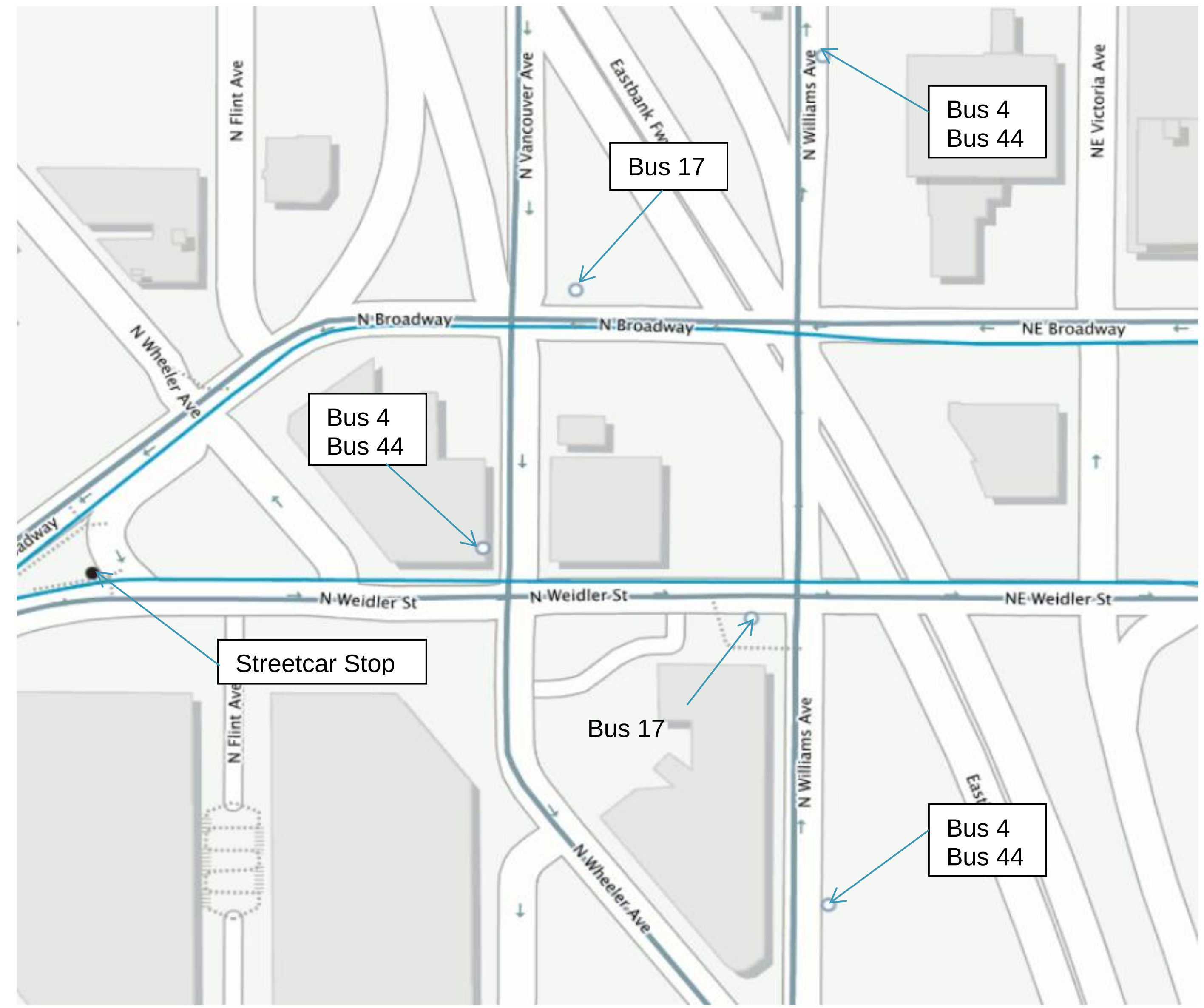


Figure 2 – I-5 Speed Distribution Profile

Figure 3 – Transit Stop Locations within the Study Area



[6]http://www.westernite.org/datacollectionfund/2005/psu_ped_summary.pdf

[7]http://web.cecs.pdx.edu/~maf/Conference_Proceedings/A%20Statistical%20Analysis%20of%20Bicycle%20Rider%20Performance.pdf

[8]Average speeds of 12.7, 12.0 and 9.1 ft/s for advanced, basic/beginner and child cyclist are specified, respectively from AASHTO, *Guide for the Development of Bicycle Facilities*. 4th ed. 1999, Washington, D.C.: American Association of State Highway and Transportation Officials, U.S. Department of Transportation.

Calibration

This section summarizes the methods the HDR Team used to calibrate the a.m., p.m., and mid-day peak hour VISSIM models, with a final summary of calibration results. This section includes a brief summary of the *VISSIM Model Calibration Methodology and Results* Memo. The full Memo is included in Appendix B. The Team calibrated freeway speed data to fall within 10% (10 mph) of the field speeds, as per ODOT's VISSIM Protocol. Traffic throughputs were calibrated on both the arterials and freeways using the same ODOT guidelines.

Error Checking

The Team checked data for coding errors before the calibration process began. This included reviewing data inputs such as network geometry, traffic volumes, signal timing and route choices; checking VISSIM error reports such as vehicle removal, signal issues, and end of link errors; and fine-tuning model animations such as checking for abnormal driving behavior or irregular queuing within the network and identifying coding parameters that may have been overlooked or incorrect.

Field Visits

Prior to calibration, the Team conducted field visits to observe operations within the Study Area. The field observations helped identify major lane imbalances, downstream or upstream bottlenecks, major queuing locations and overall driving behaviors the Team had to consider for the models to reflect real world conditions.

Calibration Targets

In order to meet calibration targets the Team used an iterative process of comparing VISSIM data outputs to field-collected data and adjusting the model accordingly. The Team calibrated the I-5 Broadway/Weidler VISSIM model for both traffic volumes and spot speeds. The targets set for calibration were:

- Speeds to be within +/- 10 miles per hour on at least 85% of all freeway links
- Volumes to be within a GEH value of 5.0 for 85% of freeway links
- Volumes to be within a GEH value of 5.0 for all entry and exit locations, all entrance and exit ramps and all intersection turn movements greater than 100 vehicles per hour

As part of the calibration process, adjustments included changes to the driver parameters and lane change distances. These changes were based on field observed vehicle operations. For example, the Team adjusted connector lane change distances to achieve appropriate lane utilization observed in the field and to mimic critical merging and weaving behaviors in congested areas. Driver behavior parameters were adjusted to replicate the less aggressive Oregon drivers, who typically maintain larger gaps between vehicles and operate with more of a "zipper effect".

Speed Calibration

The Team developed spot speed data for comparison against the VISSIM model from INRIX data. The INRIX speed data is based on average weekdays (Tuesdays, Wednesdays, and Thursdays) in 2013. Because the model is not large enough to capture all bottlenecks that affect the Study Area, the INRIX data was also used in calibration to set bottlenecks outside of the calibration area. Table 3 displays the all-day VISSIM model results compared to INRIX data in 15-minute increments along the corridor, broken down by direction. The colors represent speed variations, with green being the greatest speed (over 50 mph) and red being the slowest speed (less than 20 mph).

Volume Calibration

As per ODOT's guidelines the volume output from the model was compared to the traffic volumes using the GEH calculation. GEH is calculated using the following formula[9]:

$$GEH = \sqrt{\frac{2(m-c)^2}{m+c}}$$

Notes:
m = output traffic volume from the simulation model (vph)
c = input traffic volume (vph)

The GEH is scored using the following classification, provided in Table 2[10]

Table 2 – GEH Scoring

GEH < 5.0	**Acceptable fit**
5.0 <= GEH <= 10.0	Caution: possible model error or bad data
GEH > 10.0	Unacceptable

The Team collected model volumes at all entry and exit locations as well as for intersection turn movements and at all freeway locations between ramps in the Study Area. The entry and exit volumes and the freeway volumes were obtained using data collection points, and turn movements were based on the nodal analysis. The Team averaged all modeled volumes over 10 simulation runs, as outlined in the calibration memo in Appendix B.

[9] ODOT VISSIM Protocol, June 2011
[10] ODOT VISSIM Protocol, June 2011

Table 3 – All-Day Speed Comparison Chart

I-5 Broadway/Weidler Existing Scenario Spot Speed Chart

NB Location	6:00 AM	6:15 AM	6:30 AM	6:45 AM	7:00 AM	7:15 AM	7:30 AM	7:45 AM	8:00 AM	8:15 AM	8:30 AM	8:45 AM	9:00 AM	9:15 AM	9:30 AM	9:45 AM
	AM - Northbound Average Speeds - (VISSIM Data)															
I-5 NB 114+04454 Near 84	54.2	52.3	47.5	44.4	45.7	41.6	37.1	33.7	32.1	36.1	38.5	42.5	47.0	47.4	47.8	49.2
I-5 NB 114P04454 Near 84	55.4	54.1	52.3	49.9	50.6	48.2	39.6	33.8	30.9	36.7	42.1	42.6	49.7	51.8	52.4	53.1
I-5 NB 114+04455 Near Multnomah	55.1	52.4	45.5	37.7	34.7	33.6	27.8	26.7	25.3	28.3	32.2	33.8	41.7	49.3	50.2	49.2
I-5 NB 114P04455 Near Weidler	52.7	48.2	44.1	41.2	40.4	41.2	39.6	38.8	39.2	42.0	41.8	42.1	42.2	45.4	46.7	46.1
I-5 NB 114+4456 Bt Broadway/Weidler	53.5	51.0	49.3	47.1	43.0	46.5	46.4	44.5	43.7	47.2	46.7	47.2	44.8	48.7	50.1	49.8
I-5 NB 114P04456 Near Broadway	52.3	48.9	46.1	42.5	40.9	42.9	44.1	41.0	40.9	43.7	43.0	44.7	41.9	46.6	48.2	47.8
I-5 NB 114+04457 BT 405/Weidler	54.9	53.1	52.2	49.3	48.4	47.3	46.7	42.5	42.8	45.1	44.9	47.0	45.3	48.4	48.9	49.4
I-5 NB 114P04457 Near 405	56.2	55.8	55.6	54.9	55.0	55.0	54.8	54.6	54.7	54.8	54.5	54.9	54.0	54.2	54.2	54.5
I-5 NB 114+04458 Near Going	55.6	54.7	53.0	52.0	51.0	50.8	50.1	50.0	50.4	49.7	49.8	50.4	50.8	51.2	52.0	52.0
NB Location	AM - Northbound Average Speeds - (INRIX Data)															
I-5 NB 114+04454 Near 84	55.3	55.3	54.2	49.7	45.4	44.0	40.4	36.3	34.3	38.0	40.2	41.6	42.8	45.3	47.9	50.3
I-5 NB 114P04454 Near 84	52.4	52.4	50.9	46.1	42.2	42.1	39.5	36.7	35.2	37.6	39.4	40.6	41.4	42.7	45.5	47.4
I-5 NB 114+04455 Near Multnomah	53.9	52.8	50.2	46.6	45.1	45.3	44.7	44.0	43.8	44.5	45.2	45.3	44.6	44.5	46.3	47.2
I-5 NB 114P04455 Near Weidler	56.0	55.4	53.1	50.8	50.6	50.4	50.1	50.4	50.2	50.4	50.5	50.1	49.4	48.8	50.3	50.7
I-5 NB 114+4456 Bt Broadway/Weidler	56.6	56.0	53.8	51.6	51.5	51.3	51.1	51.5	51.2	51.2	51.2	51.0	49.5	48.4	50.0	51.2
I-5 NB 114P04456 Near Broadway	56.2	55.5	53.0	50.8	50.8	50.7	50.6	50.9	50.7	50.7	50.6	50.4	50.0	49.2	50.4	51.1
I-5 NB 114+04457 BT 405/Weidler	55.8	55.3	53.1	51.3	51.4	51.6	51.3	51.3	51.4	51.2	51.2	50.9	51.3	50.7	51.5	52.0
I-5 NB 114P04457 Near 405	57.0	56.9	56.3	55.6	55.6	55.8	55.7	55.5	55.7	55.6	55.4	55.2	55.4	55.1	55.3	55.7
I-5 NB 114+04458 Near Going	58.9	58.5	58.2	57.9	57.8	57.7	57.7	57.4	57.5	57.1	56.8	56.6	56.8	56.6	56.4	57.0
NB Location	AM - Northbound Speed Difference															
I-5 NB 114+04454 Near 84	1.1	3.1	6.6	5.4	-0.3	2.4	3.4	2.6	2.3	1.9	1.6	-0.9	-4.2	-2.1	0.0	1.1
I-5 NB 114P04454 Near 84	-3.1	-1.6	-1.3	-3.8	-8.4	-6.1	-0.1	2.9	4.3	1.0	-2.7	-2.0	-8.4	-9.1	-6.9	-5.7
I-5 NB 114+04455 Near Multnomah	-1.2	0.3	4.7	8.9	10.4	11.7	16.9	17.3	18.4	16.3	13.1	11.4	3.0	-4.7	-4.0	-2.0
I-5 NB 114P04455 Near Weidler	3.3	7.3	9.1	9.5	10.2	9.2	10.5	11.5	11.0	8.4	8.7	8.0	7.2	3.4	3.6	4.7
I-5 NB 114+4456 Bt Broadway/Weidler	3.1	5.0	4.4	4.5	8.5	4.8	4.7	7.0	7.5	4.0	4.4	3.8	4.8	-0.3	-0.1	1.4
I-5 NB 114P04456 Near Broadway	3.9	6.6	6.9	8.2	9.9	7.8	6.5	9.9	9.8	7.0	7.7	5.7	8.1	2.6	2.2	3.3
I-5 NB 114+04457 BT 405/Weidler	0.9	2.2	0.9	1.9	3.0	4.3	4.6	8.8	8.6	6.1	6.3	3.9	6.0	2.2	2.7	2.6
I-5 NB 114P04457 Near 405	0.8	1.1	0.7	0.7	0.6	0.8	0.9	0.9	1.0	0.8	0.9	0.3	1.4	0.9	1.1	1.2
I-5 NB 114+04458 Near Going	3.3	3.8	5.1	5.9	6.8	7.0	7.6	7.4	7.1	7.3	7.0	6.2	6.1	5.4	4.4	4.9
SB Location	AM - Southbound Average Speeds - (VISSIM Data)															
I-5 SB 114-04457 Near Going	54.2	52.1	51.2	50.7	49.9	49.7	46.0	43.8	36.7	34.5	31.3	30.6	30.1	39.9	43.9	41.5
I-5 SB 114N04457 Near 405	54.4	53.4	52.8	53.3	52.6	52.2	52.1	41.0	29.7	31.6	28.3	25.1	24.5	35.2	42.5	41.2
I-5 SB 114-04456 Bt 405/Broadway	56.1	55.6	55.1	55.2	55.1	54.5	35.2	17.1	16.0	16.6	16.2	16.3	16.5	15.7	18.3	23.1
I-5 SB 114N04456 Near Broadway	53.2	51.1	46.8	46.3	42.4	39.0	29.8	28.6	29.1	28.7	29.1	29.3	29.3	28.4	29.1	29.3
I-5 SB 114-04455 Near Broadway	53.0	52.0	49.5	49.6	48.4	47.0	42.8	40.9	41.1	41.1	42.4	42.4	42.7	39.0	41.4	42.0
I-5 SB 114N04455 Near Moda Center	53.0	51.7	49.4	49.6	48.4	47.1	42.4	40.3	39.1	40.0	41.8	41.3	41.1	37.6	40.2	39.4
I-5 SB 114-04454 Near Multnomah	54.0	52.1	50.4	49.9	45.8	41.8	39.2	38.0	36.7	37.1	39.4	37.6	38.2	38.4	39.3	39.4
I-5 SB 114N04454 Near 84	53.6	52.1	50.3	50.2	46.6	38.4	36.8	36.5	38.4	37.5	36.2	38.5	38.3	43.2	44.6	43.1
I-5 SB 114-04452 Near Morrison	56.5	56.2	55.8	55.9	55.3	54.3	54.4	54.2	54.6	54.5	54.1	54.6	54.7	55.4	55.1	55.0
SB Location	AM - Southbound Average Speeds - (INRIX Data)															
I-5 SB 114-04457 Near Going	57.1	55.7	52.9	50.9	50.2	48.0	44.3	36.7	34.5	35.4	34.0	32.0	33.6	43.6	46.3	47.7
I-5 SB 114N04457 Near 405	55.3	55.7	54.4	54.2	54.0	52.6	50.5	43.6	40.7	40.7	40.2	34.4	29.9	40.5	44.4	45.8
I-5 SB 114-04456 Bt 405/Broadway	55.8	55.0	53.1	52.7	52.0	50.6	48.1	39.4	36.8	37.1	37.4	31.4	27.0	34.8	40.5	41.0
I-5 SB 114N04456 Near Broadway	57.4	55.9	53.7	53.0	52.0	50.7	48.2	40.2	37.8	37.7	38.5	33.9	30.5	35.8	41.1	41.6
I-5 SB 114-04455 Near Broadway	57.0	55.3	53.1	52.6	51.7	50.5	48.5	43.8	42.0	41.7	41.6	39.1	37.1	40.0	43.6	43.9
I-5 SB 114N04455 Near Moda Center	57.0	55.4	53.2	52.6	51.8	50.4	48.8	45.5	44.1	43.6	43.7	42.3	41.8	43.2	45.5	45.7
I-5 SB 114-04454 Near Multnomah	56.7	55.2	53.2	52.8	52.1	50.8	49.5	47.0	46.0	45.2	44.8	44.2	44.6	45.6	47.1	47.4
I-5 SB 114N04454 Near 84	57.3	56.4	54.5	54.5	54.0	53.3	52.1	50.1	49.4	48.2	48.0	48.0	49.5	49.6	50.6	51.3
I-5 SB 114-04452 Near Morrison	57.2	56.8	55.7	55.7	55.1	54.9	54.3	53.9	54.0	52.9	53.0	53.1	54.0	54.1	54.2	54.2
SB Location	AM - Southbound Speed Difference															
I-5 SB 114-04457 Near Going	2.9	3.6	1.7	0.2	0.3	-1.7	-1.8	-7.1	-2.1	0.9	2.7	1.3	3.4	3.7	2.3	6.2
I-5 SB 114N04457 Near 405	0.9	2.4	1.6	0.9	1.4	0.3	-1.5	2.5	11.0	9.2	11.9	9.3	5.4	5.4	1.9	4.6
I-5 SB 114-04456 Bt 405/Broadway	-0.3	-0.5	-2.0	-2.5	-3.1	-3.8	12.9	22.4	20.9	20.5	21.2	15.1	10.4	19.1	22.2	17.9
I-5 SB 114N04456 Near Broadway	4.2	4.8	6.9	6.8	9.7	11.7	18.4	11.6	8.7	9.0	9.4	4.6	1.2	7.4	12.0	12.3
I-5 SB 114-04455 Near Broadway	4.0	3.3	3.7	3.0	3.3	3.5	5.7	2.9	0.9	0.6	-0.7	-3.2	-5.7	1.0	2.2	2.0
I-5 SB 114N04455 Near Moda Center	4.0	3.7	3.8	3.1	3.5	3.4	6.4	5.2	5.0	3.6	1.9	1.0	0.7	5.6	5.3	6.2
I-5 SB 114-04454 Near Multnomah	2.7	3.1	2.8	2.9	6.2	9.1	10.3	9.0	9.3	8.1	5.5	6.5	6.4	7.2	7.7	8.0
I-5 SB 114N04454 Near 84	3.7	4.3	4.1	4.4	7.4	14.9	15.3	13.6	11.0	10.7	11.8	9.5	11.2	6.3	6.0	8.2
I-5 SB 114-04452 Near Morrison	0.7	0.7	-0.1	-0.2	-0.2	0.6	-0.1	-0.4	-0.6	-1.6	-1.1	-1.5	-0.7	-1.4	-1.0	-0.8

NB Location	12:00 PM	12:15 PM	12:30 PM	12:45 PM	1:00 PM	1:15 PM	1:30 PM	1:45 PM
	MD - Northbound Average Speeds - (VISSIM Data)							
I-5 NB 114+04454 Near 84	47.4	46.5	47.5	47.6	48.4	46.6	46.7	47.8
I-5 NB 114P04454 Near 84	52.3	51.7	52.7	52.3	52.9	52.6	51.6	50.2
I-5 NB 114+04455 Near Multnomah	49.5	49.0	50.9	47.2	52.7	50.8	47.8	43.5
I-5 NB 114P04455 Near Weidler	44.2	44.2	44.6	43.2	45.5	44.0	43.1	43.3
I-5 NB 114+4456 Bt Broadway/Weidler	49.3	47.7	47.8	47.5	47.9	48.6	47.4	48.3
I-5 NB 114P04456 Near Broadway	48.0	45.8	45.3	45.2	44.6	45.5	45.2	46.5
I-5 NB 114+04457 BT 405/Weidler	44.1	42.7	42.7	42.6	41.8	41.6	42.1	43.7
I-5 NB 114P04457 Near 405	53.1	53.2	53.1	53.4	53.7	53.6	53.5	53.6
I-5 NB 114+04458 Near Going	50.0	49.9	48.6	48.9	49.2	47.7	47.7	47.9
NB Location	MD - Northbound Average Speeds - (INRIX Data)							
I-5 NB 114+04454 Near 84	48.9	49.0	48.5	47.6	46.6	45.7	43.3	43.1
I-5 NB 114P04454 Near 84	46.7	46.6	46.1	45.1	43.8	43.2	41.0	40.5
I-5 NB 114+04455 Near Multnomah	47.1	46.8	46.3	45.6	45.3	43.5	41.9	41.5
I-5 NB 114P04455 Near Weidler	50.4	50.0	49.4	48.6	48.4	46.8	45.6	44.9
I-5 NB 114+4456 Bt Broadway/Weidler	50.1	49.9	49.1	47.9	47.6	46.2	44.8	43.9
I-5 NB 114P04456 Near Broadway	50.2	50.2	49.6	48.6	48.6	47.5	46.3	45.8
I-5 NB 114+04457 BT 405/Weidler	51.7	51.6	51.3	50.5	50.9	49.5	49.0	49.0
I-5 NB 114P04457 Near 405	55.1	54.8	54.8	54.5	54.5	53.7	53.5	53.3
I-5 NB 114+04458 Near Going	56.1	55.8	56.1	56.1	55.9	55.1	54.7	53.8
NB Location	MD - Northbound Speed Difference							
I-5 NB 114+04454 Near 84	1.6	2.5	1.1	0.1	-1.8	-0.8	-3.4	-4.8
I-5 NB 114P04454 Near 84	-5.5	-5.2	-6.6	-7.2	-9.1	-9.4	-10.6	-9.6
I-5 NB 114+04455 Near Multnomah	-2.4	-2.2	-4.6	-1.6	-7.4	-7.4	-5.8	-2.0
I-5 NB 114P04455 Near Weidler	6.2	5.8	4.8	5.3	2.9	2.8	2.5	1.6
I-5 NB 114+4456 Bt Broadway/Weidler	0.8	2.2	1.3	0.4	-0.3	-2.4	-2.7	-4.4
I-5 NB 114P04456 Near Broadway	2.2	4.4	4.3	3.4	3.9	2.0	1.2	-0.8
I-5 NB 114+04457 BT 405/Weidler	7.6	8.9	8.6	7.9	9.1	8.0	6.9	5.2
I-5 NB 114P04457 Near 405	2.1	1.6	1.7	1.1	0.8	0.1	0.0	-0.3
I-5 NB 114+04458 Near Going	6.2	5.9	7.5	7.2	6.7	7.4	7.0	5.9
SB Location	MD - Southbound Average Speeds - (VISSIM Data)							
I-5 SB 114-04457 Near Going	53.7	53.5	53.0	53.2	53.8	53.9	53.2	53.7
I-5 SB 114N04457 Near 405	52.7	52.9	52.1	52.4	52.2	52.6	52.6	48.1
I-5 SB 114-04456 Bt 405/Broadway	36.7	42.3	40.9	34.0	33.2	37.4	37.9	27.0
I-5 SB 114N04456 Near Broadway	23.8	26.6	26.1	24.6	28.5	29.3	25.9	21.2
I-5 SB 114-04455 Near Broadway	40.3	39.0	38.0	37.3	40.0	41.1	35.9	32.7
I-5 SB 114N04455 Near Moda Center	37.4	34.3	36.2	35.0	38.7	37.1	32.0	31.1
I-5 SB 114-04454 Near Multnomah	34.8	34.0	34.2	34.5	35.1	33.8	33.0	32.7
I-5 SB 114N04454 Near 84	47.6	44.9	48.8	47.3	50.1	49.9	49.8	48.1
I-5 SB 114-04452 Near Morrison	55.1	55.0	55.3	55.0	55.4	55.4	55.4	55.6
SB Location	MD - Southbound Average Speeds - (INRIX Data)							
I-5 SB 114-04457 Near Going	53.7	54.1	54.2	53.2	53.1	53.2	52.8	52.3
I-5 SB 114N04457 Near 405	45.1	46.4	46.2	45.6	45.2	45.8	45.1	41.7
I-5 SB 114-04456 Bt 405/Broadway	39.2	40.4	40.5	39.2	39.5	39.4	39.0	33.7
I-5 SB 114N04456 Near Broadway	39.4	39.7	39.9	39.2	39.3	39.0	38.9	33.5
I-5 SB 114-04455 Near Broadway	42.3	42.8	43.0	42.2	42.2	42.0	41.9	37.8
I-5 SB 114N04455 Near Moda Center	45.1	45.1	45.2	44.8	44.8	44.6	44.5	41.1
I-5 SB 114-04454 Near Multnomah	46.9	46.9	47.2	46.6	46.7	46.1	46.4	43.8
I-5 SB 114N04454 Near 84	51.3	51.3	51.4	51.1	50.8	50.7	51.0	50.0
I-5 SB 114-04452 Near Morrison	55.3	55.6	55.5	55.2	55.0	55.2	55.1	54.5
SB Location	MD - Southbound Speed Difference							
I-5 SB 114-04457 Near Going	0	1	1	0	-1	-1	0	-1
I-5 SB 114N04457 Near 405	-8	-7	-6	-7	-7	-7	-8	-6
I-5 SB 114-04456 Bt 405/Broadway	2	-2	0	5	6	2	1	7
I-5 SB 114N04456 Near Broadway	16	13	14	15	11	10	13	12
I-5 SB 114-04455 Near Broadway	2	4	5	5	2	1	6	5
I-5 SB 114N04455 Near Moda Center	8	11	9	10	6	8	13	10
I-5 SB 114-04454 Near Multnomah	12	13	13	12	12	12	13	11
I-5 SB 114N04454 Near 84	4	6	3	4	1	1	1	2
I-5 SB 114-04452 Near Morrison	0	1	0	0	0	0	0	-1

NB Location	2:00 PM	2:15 PM	2:30 PM	2:45 PM	3:00 PM	3:15 PM	3:30 PM	3:45 PM	4:00 PM	4:15 PM	4:30 PM	4:45 PM	5:00 PM	5:15 PM	5:30 PM	5:45 PM
	PM - Northbound Average Speeds - (VISSIM Data)															
I-5 NB 114+04454 Near 84	50.4	51.6	51.9	50.0	51.6	49.7	51.4	45.3	43.9	46.1	45.0	37.6	27.9	24.6	22.8	23.3
I-5 NB 114P04454 Near 84	53.7	54.2	54.2	53.3	54.0	52.7	53.6	51.4	50.6	51.3	50.8	43.2	29.9	24.8	25.0	24.8
I-5 NB 114+04455 Near Multnomah	54.3	54.6	54.5	54.5	54.5	54.1	54.2	49.2	50.8	48.0	47.0	39.7	25.2	22.0	22.5	22.5
I-5 NB 114P04455 Near Weidler	51.3	52.2	52.3	51.3	51.6	50.8	51.3	45.8	45.2	45.4	44.0	35.8	28.2	27.0	32.3	37.4
I-5 NB 114+4456 Bt Broadway/Weidler	52.9	53.1	53.4	52.8	52.8	52.3	52.5	49.7	50.0	50.1	48.0	37.0	27.7	27.3	31.4	37.7
I-5 NB 114P04456 Near Broadway	52.5	52.4	52.9	52.5	52.1	51.7	51.8	48.5	48.9	48.9	45.2	33.5	26.1	25.5	28.1	34.0
I-5 NB 114+04457 BT 405/Weidler	52.1	52.7	52.7	53.3	53.0	52.5	52.7	50.2	49.4	48.1	41.6	30.5	25.0	25.9	26.1	31.5
I-5 NB 114P04457 Near 405	55.0	55.0	55.1	54.7	54.9	54.8	54.7	54.1	53.1	35.9	19.3	16.0	16.1	16.3	16.8	17.3
I-5 NB 114+04458 Near Going	44.0	47.2	45.4	46.5	48.0	46.9	45.8	33.3	14.9	12.6	13.0	12.7	12.3	13.0	12.7	13.2
NB Location	PM - Northbound Average Speeds - (INRIX Data)															
I-5 NB 114+04454 Near 84	42.8	42.7	42.5	44.2	47.2	48.8	47.9	45.7	44.4	42.9	39.4	36.9	35.0	34.0	32.7	34.1
I-5 NB 114P04454 Near 84	40.4	40.6	40.3	41.5	45.0	46.5	45.4	43.4	42.3	41.3	37.7	35.5	34.3	33.1	31.6	32.8
I-5 NB 114+04455 Near Multnomah	42.0	41.8	41.1	42.0	44.5	45.6	44.4	42.5	42.0	40.3	37.5	35.1	34.1	33.2	32.0	33.2
I-5 NB 114P04455 Near Weidler	45.4	44.3	43.9	44.2	46.1	47.0	45.7	43.2	42.4	40.5	37.0	34.8	33.9	33.7	32.1	32.7
I-5 NB 114+4456 Bt Broadway/Weidler	44.3	43.2	42.5	42.8	46.1	46.9	45.4	42.9	41.9	40.2	36.8	34.5	33.2	33.4	31.8	32.0
I-5 NB 114P04456 Near Broadway	45.8	44.9	44.2	44.2	46.0	46.0	44.3	41.9	41.2	39.2	35.2	33.4	32.8	32.8	31.5	31.8
I-5 NB 114+04457 BT 405/Weidler	49.2	48.5	47.7	47.3	47.7	46.4	44.1	41.9	40.7	38.7	35.5	32.8	32.7	33.4	32.1	32.4
I-5 NB 114P04457 Near 405	52.6	51.7	50.8	49.0	45.0	37.4	32.1	29.0	28.0	25.1	22.2	20.3	20.8	20.7	20.1	21.7
I-5 NB 114+04458 Near Going	52.9	51.2	50.3	45.7	38.5	26.9	22.4	20.9	19.1	17.2	15.6	14.5	14.1	13.1	13.1	14.8
NB Location	PM - Northbound Speed Difference															
I-5 NB 114+04454 Near 84	-7.6	-8.9	-9.5	-5.8	-4.4	-0.9	-3.5	0.4	0.6	-3.2	-5.6	-0.7	7.1	9.5	9.9	10.8
I-5 NB 114P04454 Near 84	-13.3	-13.6	-13.9	-11.8	-9.1	-6.2	-8.2	-8.0	-8.3	-10.0	-13.1	-7.7	4.4	8.3	6.6	8.1
I-5 NB 114+04455 Near Multnomah	-12.3	-12.9	-13.4	-12.5	-10.0	-8.5	-9.8	-6.7	-8.8	-7.7	-9.5	-4.5	8.9	11.3	9.5	10.7
I-5 NB 114P04455 Near Weidler	-5.9	-7.9	-8.4	-7.0	-5.6	-3.8	-5.6	-2.6	-2.9	-4.9	-7.0	-1.0	5.7	6.7	-0.2	-4.7
I-5 NB 114+4456 Bt Broadway/Weidler	-8.6	-9.9	-11.0	-10.0	-6.7	-5.4	-7.1	-6.8	-8.1	-9.9	-11.3	-2.5	5.5	6.1	0.4	-5.6
I-5 NB 114P04456 Near Broadway	-6.7	-7.5	-8.8	-8.3	-6.2	-5.7	-7.5	-6.5	-7.8	-9.7	-10.0	-0.2	6.7	7.2	3.5	-2.2
I-5 NB 114+04457 BT 405/Weidler	-2.9	-4.2	-5.1	-6.0	-5.3	-6.1	-8.6	-8.3	-8.6	-9.3	-6.2	2.3	7.7	7.4	6.1	0.9
I-5 NB 114P04457 Near 405	-2.3	-3.3	-4.3	-5.7	-9.9	-17.4	-22.6	-25.1	-25.1	-10.8	2.9	4.3	4.7	4.4	3.3	4.4
I-5 NB 114+04458 Near Going	8.9	4.0	4.8	-0.8	-9.5	-20.0	-23.4	-12.4	4.2	4.6	2.6	1.8	1.8	0.1	0.3	1.6
SB Location	PM - Northbound Average Speeds - (VISSIM Data)															
I-5 SB 114-04457 Near Going	54.0	54.0	53.9	54.0	53.6	48.7	38.1	40.5	40.0	44.5	46.7	50.6	52.2	47.6	26.9	20.1
I-5 SB 114N04457 Near 405	53.2	53.1	53.3	45.7	29.6	21.7	26.8	28.0	28.3	32.1	39.6	42.1	39.6	22.0	18.8	19.0
I-5 SB 114-04456 Bt 405/Broadway	52.9	52.2	36.9	15.5	15.1	15.0	15.7	15.2	15.6	15.3	15.4	15.1	14.0	14.3	14.6	14.0
I-5 SB 114N04456 Near Broadway	39.5	33.2	22.3	19.7	18.0	18.6	19.5	18.8	19.1	19.1	18.8	18.3	15.7	15.1	15.0	14.6
I-5 SB 114-04455 Near Broadway	44.1	39.4	32.9	32.4	27.0	29.8	33.3	30.2	32.8	31.2	30.7	29.0	22.4	19.7	19.2	19.4
I-5 SB 114N04455 Near Moda Center	41.3	36.8	31.3	31.2	27.1	29.5	31.2	29.5	30.1	29.4	27.9	27.8	21.1	19.5	18.8	19.7
I-5 SB 114-04454 Near Multnomah	36.7	35.1	33.5	33.1	33.5	34.3	34.5	34.1	34.0	34.4	33.9	32.9	30.6	29.9	30.4	29.9
I-5 SB 114N04454 Near 84	51.0	50.7	51.2	50.3	49.3	45.4	46.3	46.7	47.0	47.6	47.8	47.9	40.7	50.9	52.6	51.6
I-5 SB 114-04452 Near Morrison	55.7	55.4	55.6	55.5	55.4	55.0	55.1	54.9	54.7	55.1	47.8	43.8	41.4	39.8	40.3	40.5
SB Location	PM - Northbound Average Speeds - (INRIX Data)															
I-5 SB 114-04457 Near Going	53.0	53.9	53.5	49.8	41.4	38.2	40.3	42.7	42.1	43.9	41.3	41.4	40.9	40.1	37.0	39.4
I-5 SB 114N04457 Near 405	41.1	41.1	40.9	26.7	18.3	18.2	22.2	21.7	22.5	25.0	23.0	25.0	25.9	25.1	21.8	25.5
I-5 SB 114-04456 Bt 405/Broadway	33.3	32.9	33.1	18.4	14.6	15.2	18.6	16.0	17.4	19.3	18.2	19.4	20.8	20.0	17.0	20.5
I-5 SB 114N04456 Near Broadway	33.9	32.7	33.2	20.4	17.3	17.7	20.3	18.1	19.4	21.1	19.6	20.3	21.3	20.7	17.7	21.0
I-5 SB 114-04455 Near Broadway	38.1	36.9	37.1	27.1	23.3	23.0	25.7	23.8	25.4	26.6	24.8	25.3	26.0	25.2	21.4	25.0
I-5 SB 114N04455 Near Moda Center	41.6	40.5	40.5	30.7	26.9	26.1	28.6	26.7	28.3	29.2	27.1	27.5	28.3	27.3	22.5	26.4
I-5 SB 114-04454 Near Multnomah	44.4	43.5	43.0	36.5	32.6	32.1	33.5	32.5	33.2	33.1	31.0	30.5	30.6	29.5	25.0	28.2
I-5 SB 114N04454 Near 84	50.5	50.3	49.9	47.0	46.0	45.6	46.4	46.1	47.0	45.7	44.0	43.0	40.9	39.7	34.7	36.9
I-5 SB 114-04452 Near Morrison	54.8	55.1	54.8	54.5	54.9	54.9	53.8	53.4	52.5	49.9	46.2	43.3	41.9	39.7	38.3	38.9
SB Location	PM - Northbound Speed Difference															
I-5 SB 114-04457 Near Going	-1.0	-0.1	-0.4	-4.2	-12.2	-10.5	2.2	2.3	2.1	-0.6	-5.4	-9.2	-11.4	-7.4	10.1	19.3
I-5 SB 114N04457 Near 405	-12.2	-12.0	-12.4	-18.9	-11.3	-3.5	-4.6	-6.3	-5.8	-7.1	-16.5	-17.0	-13.7	3.1	3.0	6.4
I-5 SB 114-04456 Bt 405/Broadway	-19.6	-19.3	-3.8	2.9	-0.4	0.3	2.9	0.8	1.8	4.0	2.9	4.3	6.8	5.6	2.4	6.6
I-5 SB 114N04456 Near Broadway	-5.6	-0.5	10.9	0.8	-0.6	-0.9	0.8	-0.7	0.3	2.0	0.8	2.0	5.6	5.6	2.7	6.4
I-5 SB 114-04455 Near Broadway	-6.0	-2.4	4.2	-5.3	-3.7	-6.8	-7.6	-6.4	-7.3	-4.6	-5.9	-3.6	3.7	5.5	2.2	5.6
I-5 SB 114N04455 Near Moda Center	0.3	3.7	9.2	-0.5	-0.1	-3.5	-2.6	-2.8	-1.8	-0.2	-0.7	-0.2	7.2	7.7	3.8	6.8
I-5 SB 114-04454 Near Multnomah	7.7	8.4	9.4	3.4	-1.0	-2.1	-1.0	-1.6	-0.8	-1.3	-2.9	-2.4	0.0	-0.5	-5.3	-1.7
I-5 SB 114N04454 Near 84	-0.5	-0.4	-1.4	-3.2	-3.3	0.2	0.2	-0.6	0.0	-1.9	-3.8	-5.0	0.2	-11.2	-17.8	-14.6
I-5 SB 114-04452 Near Morrison	-0.9	-0.3	-0.8	-1.0	-0.6	-0.1	-1.3	-1.4	-2.2	-5.2	-1.6	-0.5	0.5	-0.1	-2.1	-1.6

Speed (mph)										Difference in Speed (mph)			
< 20		20-30		30-40		40-50		>50	51.0	> 10	10.2	< -10	-10.2

Future Volume Development

The Team obtained future volumes developed for the year 2035 by disaggregating multi-hour data provided by Portland Metro into hourly volumes and then applying the National Cooperative Highway Research Program (NCHRP) Report 255 Methodology. This was accomplished by first obtaining daily profiles, aggregated by the hour from PSU Portal data. These profiles came from data taken from Tuesday, Wednesday, and Thursday from the most current three years, to provide confidence in the averages. The Team used these profiles for the entire I-5 corridor (and more specific locations within the Study Area) to compare and gain confidence in the hourly distributions. Then the Team calculated disaggregated factors for each of Metro's multi-hour models.

The Team used the NCHRP 255 Methodology to develop future traffic demand. Movements not included in the model required adjustment in the volumes through arterial balancing. These turning movements are listed below:

- Flint and Broadway WBR and SBR
- Flint and Broadway NBT, SBR and WBR
- Wheeler and Winning Way EBL, EBT and EBR

Once adjustments were made, the Team balanced the model throughout. The freeway was balanced by isolating the I-5 volumes at the Broadway and Weidler Overpasses, then adding and subtracting the ramp volumes to obtain the additional freeway volumes. The Team also used ramp volumes to balance volumes through the arterial.

Alternative Designs Development

After calibration and future model development, the Team combined data inputs to produce all subsequent models for analysis, beginning with the No Build Model. Two additional alternative designs were originally developed in the facility plan to be compared alongside the No-Build Model: Refined Auxiliary Lane and Refined Auxiliary Lane & Braided Ramps Hybrid. Further analysis showed that the two build options could be refined. Therefore, the Team expanded both to produce several more designs, all of which incorporated variations on the auxiliary lanes or the braided ramps components, and, in some cases, new design elements. The Team then compared them alongside the No Build Option for cost-to-benefit analysis. This section outlines the three-phase process through which multiple options were analyzed and refined to obtain eight final alternatives. The three phases are:

1 **Phase 1 – Facility Plan**

2 **Phase 2 – Design and Refinement/Interactive Workshop**

3 **Phase 3 – Final Options**

1 Phase 1 – Facility Plan

As determined by the traffic analysis work previously conducted and outlined in the I-5 Broadway-Weidler Facility Plan, the Team analyzed three concepts for interchange improvements along the I-5 Corridor: No-build (Option A), Refined Auxiliary Lanes (Option B), and Refined Auxiliary Lanes & Braided Ramp Hybrid (Option C).

The No Build Option does not incorporate design improvements to the freeway. The initial Option B design includes an additional auxiliary lane in the southbound direction between the NE Broadway Off-Ramp and the City Center Off-Ramp (Morrison Off-Ramp), resulting in three lanes of traffic between these ramps. An auxiliary lane would also be added in the northbound direction between the I-84 On-Ramp and the Greeley Off-Ramp resulting in three lanes of traffic between those ramps.

The initial Option C design also incorporates the auxiliary lane in the southbound direction between the NE Broadway Off-Ramp and the Morrison Off-Ramp, but with an additional braided ramp north of the Wheeler-On-Ramp for I-84 Eastbound Off-Ramp traffic. In the northbound direction, NE Weidler Off-Ramp shifts further south and meets with I-84 Westbound On-Ramp to form a Collector-Distributor (CD) Road, on which merging I-84 traffic and diverging NE Weidler traffic weave to their respective destinations.

While initial analysis showed that the two alternative options would alleviate congestion on I-5 for the current year, it also revealed that additional refinement would be necessary to mitigate congestion for the future design year 2035. This resulted in the modification of the original alternatives. The Team implemented these modifications through an iterative process by which new concepts were developed, applied, tested, and refined until the optimal design schemes were developed. This refinement process took place during the Interactive Workshop, which is detailed below.

2 Phase 2 – Design Refinement/Interactive Workshop

HDR and ODOT partnered during a week-long interactive workshop, aimed at improving the alternative design options and developing additional alternatives for final analysis. During this workshop, the Team developed two new design options, Grand Ramp Removal and Lane Comparison for I-84 Westbound On-Ramp Design. Additionally, the Team expanded Option B and Option C into one or more additional designs. All options were analyzed and compared with respect to parameters such as travel time and unserved percentage. The Team developed over ten different designs and ran VISSIM models for comparison. After testing and analyzing the benefits and drawbacks of these design elements, the Team developed eight final alternatives to be compared in the cost-to-benefit analysis. The following section details the design elements that were devised and tested during the interactive workshop.

Grand Ramp Removal

The first new scenario considered during the workshop was the removal of the Grand Ramp from I-5 Southbound to I-84 Eastbound. This scenario was chosen to provide insight into the paths of diverting traffic after removing the Grand Ramp. Table 4 below shows the results from the VISUM analysis performed on this scenario for peak p.m. hours. Figure 4 also shows the volume diversion plot for the Non-Grand Ramp VISUM model. Network label and link color are coded based on the volume differences between Non-Grand scenario and the Base scenario.

Table 4 – Grand Ramp Removal Peak PM VISUM Analysis

Future Year 2035 No Build PM Scenario (four hours)						
Location	Volumes Before Removing Grand	Volumes After Removing Grand	Capacity	Number of Lanes	Shifted Volume	Shifted volume in Percentage[1]
I-84 South Entry	5029	5711	5250	1	682	14%
I-84 North Entry	10447	11184	10500	2	737	7%
I-84 16th On-ramp	1465	2221	2853	1	756	52%
I-84 39th On-ramp	2808	2575	3324	1	230	8%
Arterial	n/a	n/a	n/a	n/a	495	17%

[1]Shifted volumes = shifted volume/volumes

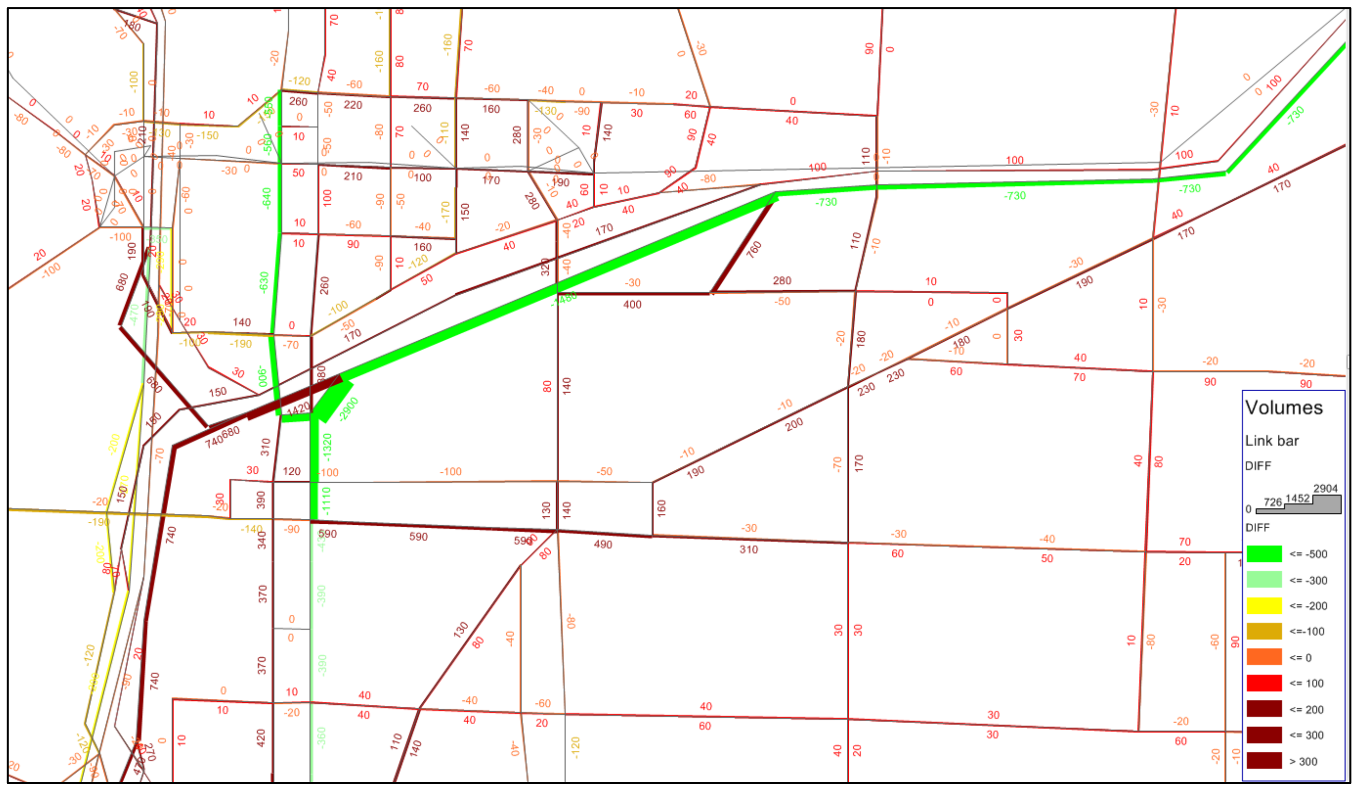


Figure 4 – Future Year 2035 Grand Volume Diversion Plot

As shown in Table 4, VISUM results showed some key shifts in traffic patterns between I-5 and I-84. Sizeable shifts in volume are detailed below:

- 14% traffic demand shifted from SB I-5 to I-84 on-ramp
- 7% traffic demand shifted from NB I-5 to I-84 on-ramp,
- 52% traffic demand shifted to NE 16th on-ramp of I-84
- 8% traffic demand shifted to NE 39th on-ramp of I-84
- 17% traffic demand stays on arterials such as NE Sandy
- I-84 North and South Entry volumes exceed the capacity

A concern with the Grand Ramp Removal was the capacity of the critical weaving section between the Weidler On-Ramp and the I-84 Off-Ramp, which would have to accommodate more than 600 additional vehicles in the southbound direction during the p.m. peak period. This would add to the queuing on the arterials a ramp meter controls the flow of these vehicles. The Grand Ramp Removal would uncork the merging situation at the Grand On-Ramp but would make the heavy weaving section worse.

After analyzing the VISUM results, the Team ruled out this option. The ramp removal caused the traffic to divert to a pre-existing heavy weaving section with Weidler and the I-84 Southbound to Eastbound Ramp, decreasing the safety and operations of the roadway section.

Two versus One Lane from I-84 Westbound to Northbound I-5

The second geometric change evaluated was a comparison of a two-lane on-ramp with a one-lane on-ramp from I-84 Westbound to I-5 Northbound. The Team created a VISSIM model to verify that the number of lanes (one versus two) for the I-84 On-Ramp to I-5 Northbound was not a critical factor in the design and that, regardless of number of lanes, the demand could still be served. Based on this analysis, the Team determined the majority of the demand could be served regardless of a one- or two-lane scenario. Further observation showed that the demand could not be met in either design during the later part of the p.m. peak hours due to congestion on I-84, which prevented access to the ramp altogether. Table 5 shows the VISSIM analysis of these two ramp scenarios:

Table 5 – Two Lane versus One Lane I-84 On-Ramp Comparison

I-84 On-Ramp Volume Comparison			
Start Time	End Time	Double Lane Volume	Single Lane Volume
2:00 PM	2:15 PM	307	304
2:15 PM	2:30 PM	312	307
2:30 PM	2:45 PM	307	313
2:45 PM	3:00 PM	313	312
3:00 PM	3:15 PM	286	291
3:15 PM	3:30 PM	289	291
3:30 PM	3:45 PM	285	278
3:45 PM	4:00 PM	255	289
4:00 PM	4:15 PM	295	309
4:15 PM	4:30 PM	313	307
4:30 PM	4:45 PM	308	293
4:45 PM	5:00 PM	319	313
5:00 PM	5:15 PM	324	300
5:15 PM	5:30 PM	333	291
5:30 PM	5:45 PM	316	301
5:45 PM	6:00 PM	334	284

Option B Refinement

The original Option B scheme included a one-lane I-84 Off-Ramp with an auxiliary lane between the Weidler On-Ramp and I-84 Off-Ramp. During the interactive workshop, the Team split Option B into two scenarios for comparison: Option B One-Lane to I-84 and Option B Two-Lanes to I-84. Once modeled, analysis of the VISSIM results provided lane-by-lane comparisons of vehicle speeds for each scheme. Figure 5 shows the comparison between the two scenarios for the p.m. peak hours of 5:00-6:00 p.m.

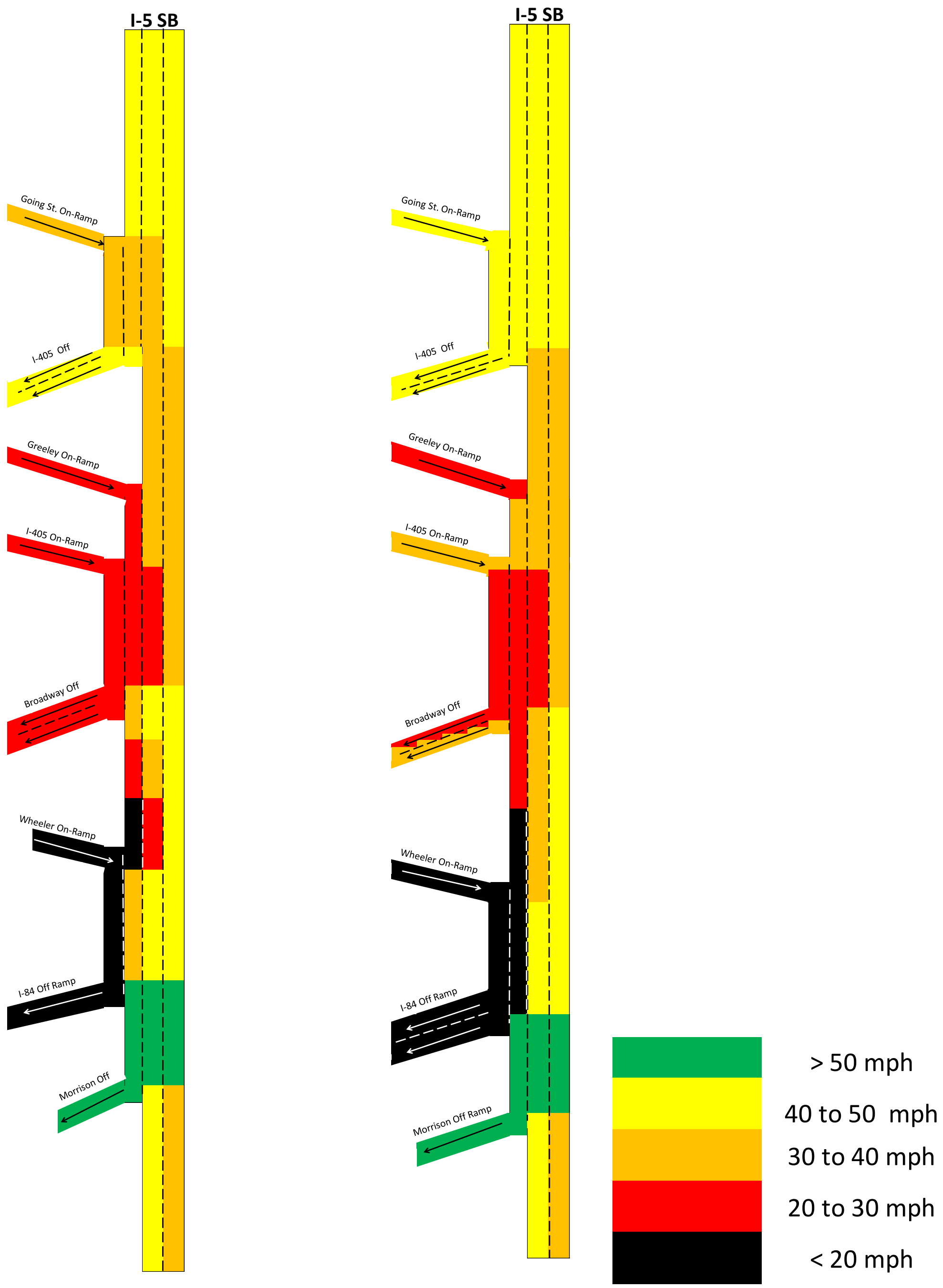


Figure 5 – Option B One Lane versus Two Lanes to I-84 (5-6 p.m.)

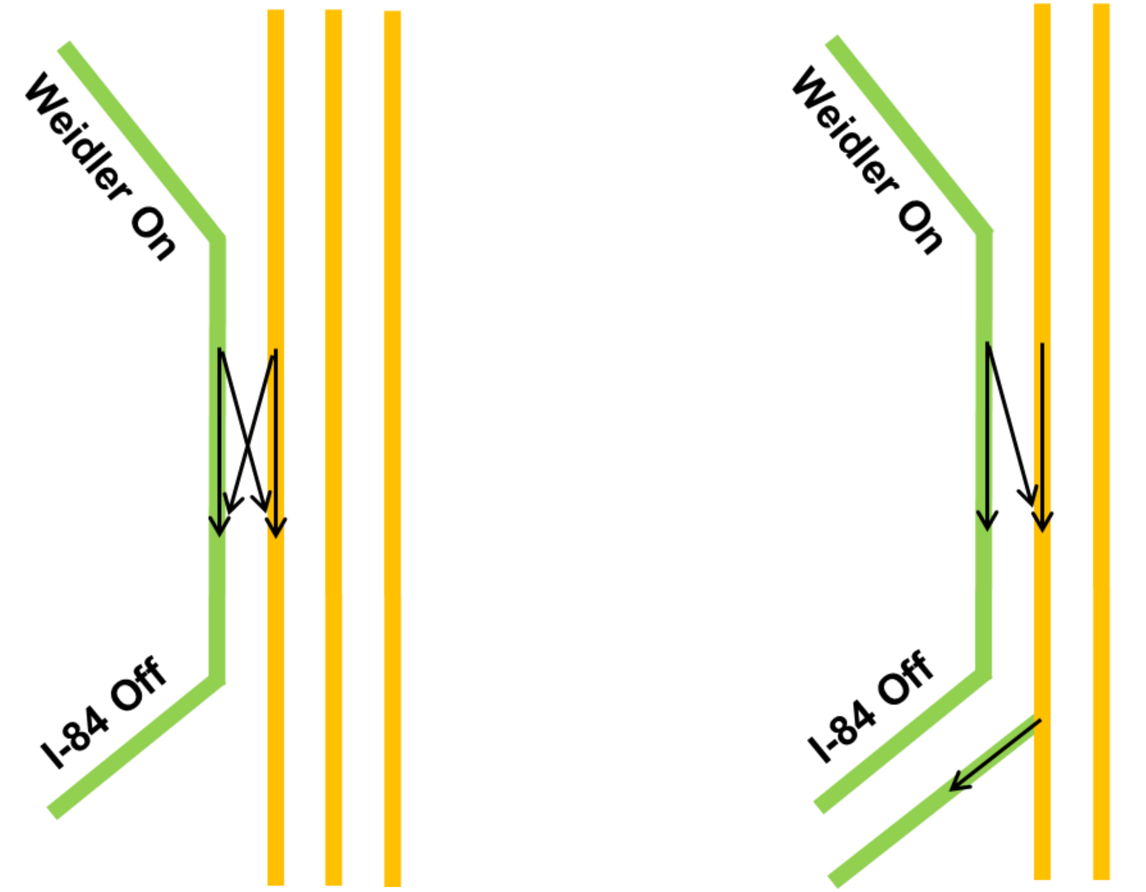


Figure 6 – Weaving Section in One Lane versus Two Lanes to I-84

The Option B Southbound speed comparisons show a range of colors that correlate with vehicle speed, as detailed in the legend. As the comparison shows, the Two-Lane to I-84 scheme has slower speeds, or greater congestion, in the third-to-right lane leading to the I-84 Off-Ramp. This can be contributed to the additional exit lane from I-5 to I-84 which more vehicles will utilize to exit. Although the speeds are lower in this lane, the speeds are gradually faster further upstream, all the way to the Greeley On-Ramp. The additional exit lane has the potential to reduce the amount of weaving in the section by eliminating the need to exit on the outside left lane, thus allowing the speeds to remain more consistent leading up to this point on the freeway. The different weaving sections are shown in Figure 6. As shown, Option B Two-Lanes to I-84 has the potential for improved safety since there are ideally fewer weaving movements required. While the VISSIM model for this option does show some weaving instances from I-5 Southbound to the auxiliary lane between Weidler On and I-84 Off, the amount is significantly reduced from the original One-Lane to I-84 design.

Option C Refinement

The original braided ramp scenario of Option C from the facility plan utilizes a braided ramp between the Weidler On-Ramp and I-84 Off-Ramp in the southbound direction. The Team evaluated this option in depth during the Interactive Workshop, to determine the potential design optimizations and improvements for this scenario. The most complex and detailed version of this option utilized a double braided scenario that included both the Morrison Off-Ramp and the Weidler On-Ramp in the braid. Additional options that the Team evaluated included one with an express lane as well as a bifurcation scenario. The bifurcation concept focused on moving all local traffic accessing the ramps to the right side of the freeway and all the through traffic traveling in the furthest left lane.

The Federal Highway Association (FHWA) defines this type of scenario as managed lanes, which are lanes controlled or managed for specific purposes.[11] These lanes can be controlled through signing, tolling, or limiting access. The VISSIM model assumed that all through traffic would stay in the left lane and would not weave into the ramp traffic lanes and vice versa. Analysis of managed lane concept showed very little improvement over a similar double braid concept.

Below is a list of the various features of braided ramps that were explored during the Interactive Workshop:

- Double Braid with two local lanes one express lane (various starting locations for the express lane)
- Double Braid with three local lanes one express lane (various starting locations for the express lane)
- Double Braid with deceleration lane to I-84
- Double Braid with I-84 drop lane
- Single Braid optimize design for ramp locations to maximize space between ramps
- Double Braid optimize design for ramp locations to maximize space between ramps
- Single Braid two lane flyover for I-84
- Double Braid two lane flyover for I-84
- Auxiliary Lane with two lane flyover for I-84

As shown in Figure 7, both the Greeley On-Ramp and I-405 On-Ramp contribute significantly to the congestion on the southbound freeway for both the Double Braid and Double Braid Express scenarios. This congestion is not alleviated through the express option any more than the original double braid. The Team determined through the analysis that an express lane option would not benefit the design as initially expected. Yet, it was determined through the workshop that certain ramp locations optimized the designs, with a potential cost to benefit improvement for a two lane flyover for I-84 for all scenarios.

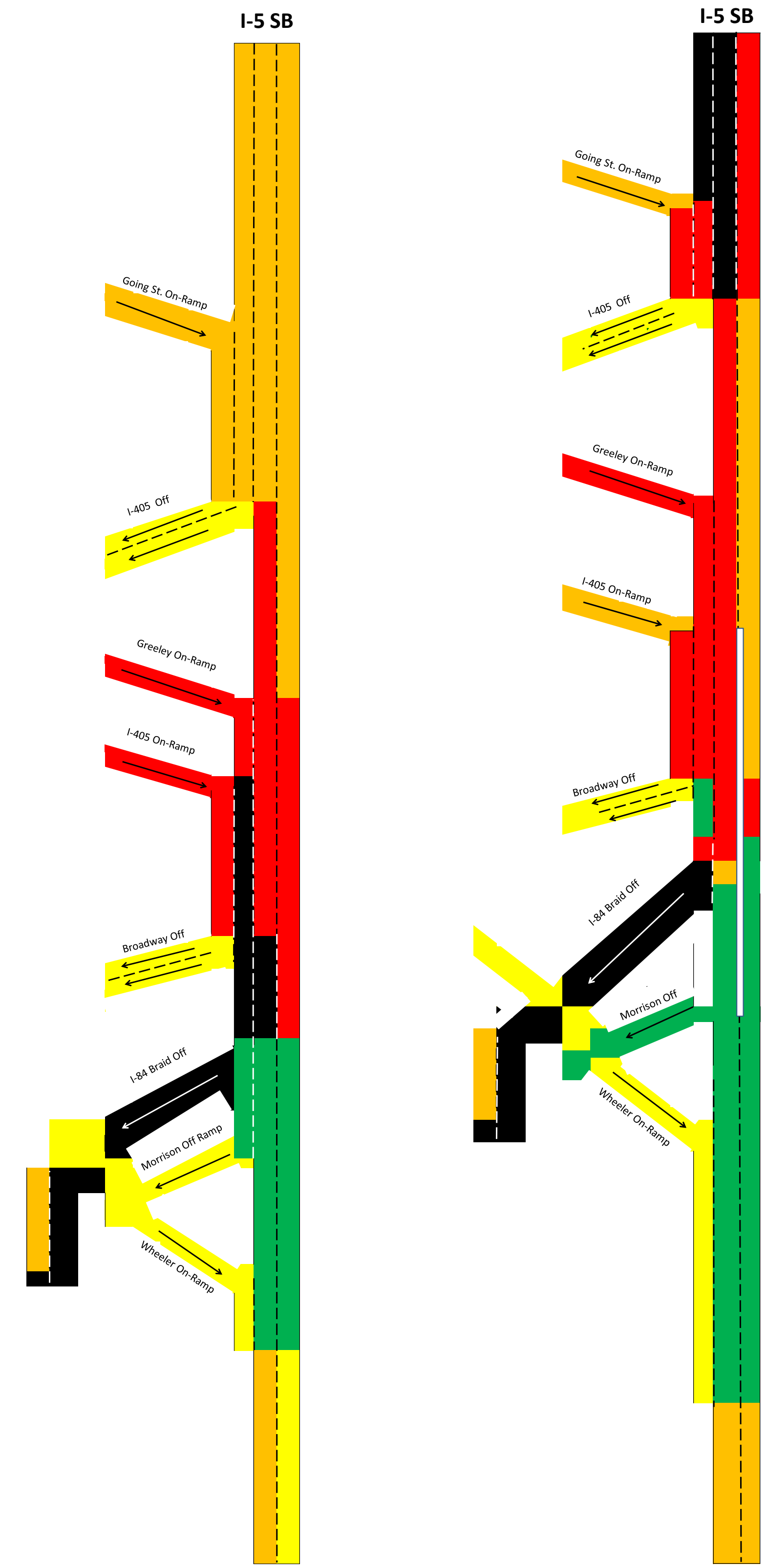


Figure 7 – Option C Double Braid versus Double Braid Express (5-6 p.m. Southbound)

[11] http://ops.fhwa.dot.gov/publications/managelanes_primer/

3 Final Options

After refinement and analysis of all the options developed during Phase 2, the Team chose eight final options to be evaluated in further detail. Option C was split into two scenarios

- Option A1: No-build
- Option A2: No-build with two lane flyover
- Option B1: Auxiliary lanes
- Option B2: Auxiliary lanes with two lane flyover
- Option C1: Single braid
- Option C2: Single braid with two lane flyover
- Option D1: Double Braid
- Option D2: Double Braid with two lane flyover

These options include optimized ramp locations for auxiliary lanes and braided ramps, as well as each design with and without a two lane flyover.

Beyond the freeway configuration, the No-Build Options (Option A1 and Option A2) include improvements of the removal of the southbound slip ramp at the I-5 southbound ramp with Vancouver/Weidler and an additional bike lane on N Williams Ave, which are both under construction or to be added in the near future. The improvements to the six Build Options have a new intersection at N Winning Way and N Vancouver Ave, as well as a change to the intersection of NE Wheeler Ave and N Williams Ave. This design extends N Vancouver further south to intersect with N Winning Way perpendicularly. NE Wheeler Ave will then begin at the intersection of N Winning Way and N Williams Ave and will travel in a SE direction and function as the On-Ramp for I-5 SB. Figure 8 shows the proposed arterial configuration. The northbound movement from Williams through Weidler and Broadway was adjusted to match the recent North Williams Bikeway project with a left side bike lane by placing the bike lane in the middle of the north bound lanes.

Figure 8 – No-Build Options Arterial Configuration

Analysis of Final Options

The Team compared the results for all eight options using the parameters of travel time, travel time reliability, speed, volume throughput, emergency braking incidents, congestion, and intersection analysis. This section details how each parameter was obtained through model outputs and the level of analysis applied to each option for comparison. All eight design options include changes to the arterials at the Broadway-Weidler Interchange. All results are based on 10 simulation runs averaged.

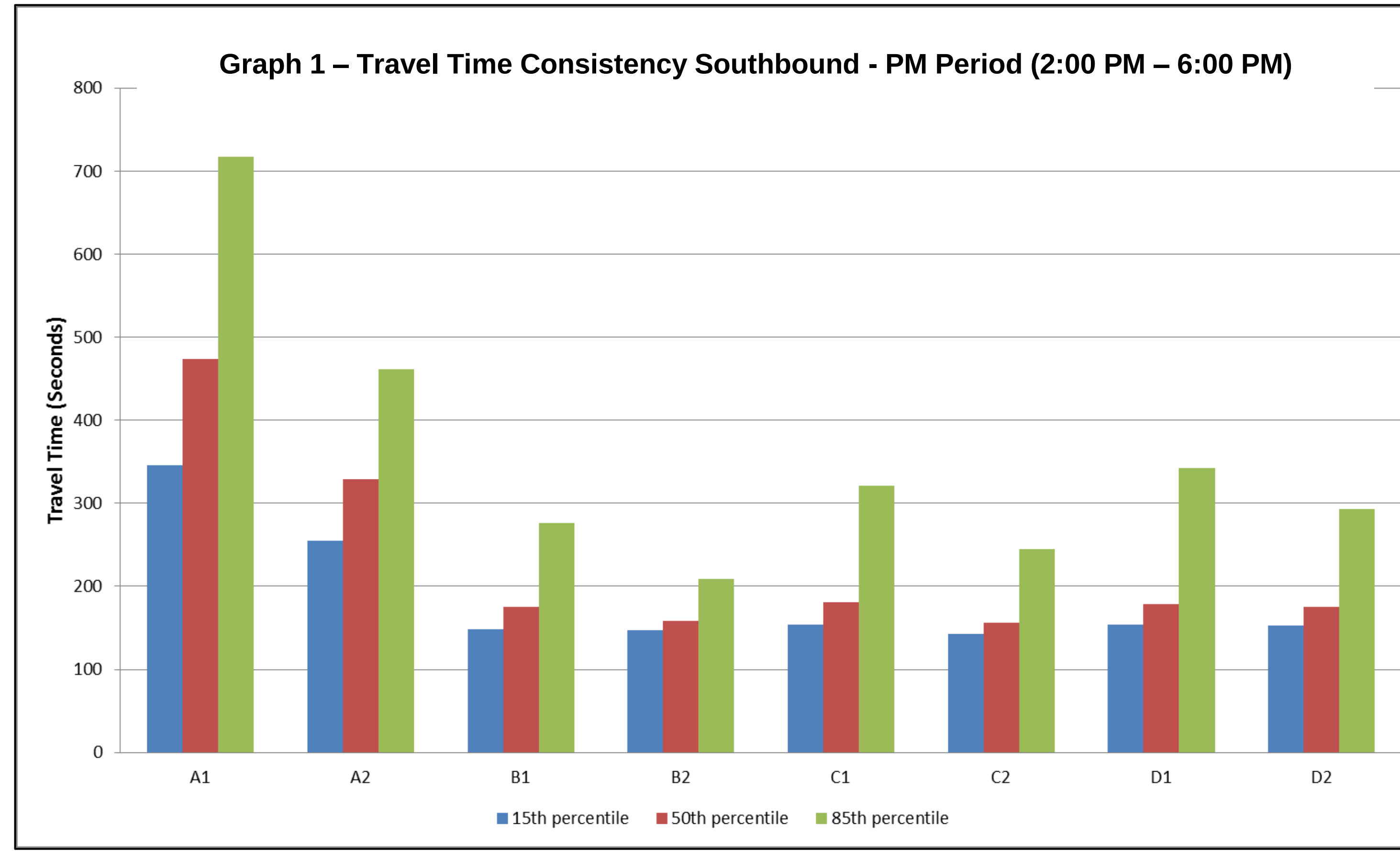
Travel Time Consistency

The Team collected second-by-second information from 10 model runs for all vehicles traveling northbound and southbound on the interstate. Travel times were recorded for these vehicles and sorted into northbound and southbound routes. Using the starting and ending time of each vehicle along a route, the Team calculated median speed (50th percentile) and standard deviations (15th and 85th percentile speeds) by hour for all the vehicles traveling either route. Graph 1 and Graph 2 show the consistency results of these routes for 10 simulation runs over 10 hours. As shown in Graph 1 for the southbound direction, Option A1 – No Build has both a long travel time and less consistency, as the 15th and 85th percentile travel times vary significantly from the median speed. This shows that there is a greater variation in the travel times throughout the p.m. peak period, thus deeming this option less reliable to drivers. For all build options, both the travel times and the consistencies show significant improvement from the No Build option. For the northbound direction in Graph 2, Option A1 – No Build also shows long travel times and less consistency. When compared to this option, all of the build options show slight improvement in travel times, yet their reliabilities do not improve significantly. This is to be expected as there will be fewer design improvements to the northbound section of I-5. More detailed travel time consistency information is provided in Appendix E.

Travel Time

The Team chose six routes to compare the travel times of vehicles for all eight options. These routes reflect common travel routes for commuter and freight traffic. Figure 9 below shows the routes that were used in the model for comparison.

The Team then compared Travel Times for each option to Option A1 – No Build in order to better understand the percentage improvement each option provided throughout the day. Table 6 shows the travel time percent differentiations from Option A1; the table is color coded; refer to the legend for details. Please note that negative values represent a percentage decrease in travel time. The table shows that the travel times are not significantly improved with Option A2, but are improved with all the build options for the majority of the routes. Both Option B1 and Option B2, however, do get worse for Route F. This is because under no-build conditions there currently is a three to two-lane drop just south of the southbound Broadway Off-Ramp. This limits the traffic that currently can access the weaving area between the Broadway-Weidler interchange area and the I-84 southbound to eastbound ramp. While this project will improve that weave by adding weaving distance, the project will also remove the three to two lane drop, allowing more vehicles to access the weave area, thus resulting in a slower travel time for southbound vehicles leaving the interchange area on the freeway.



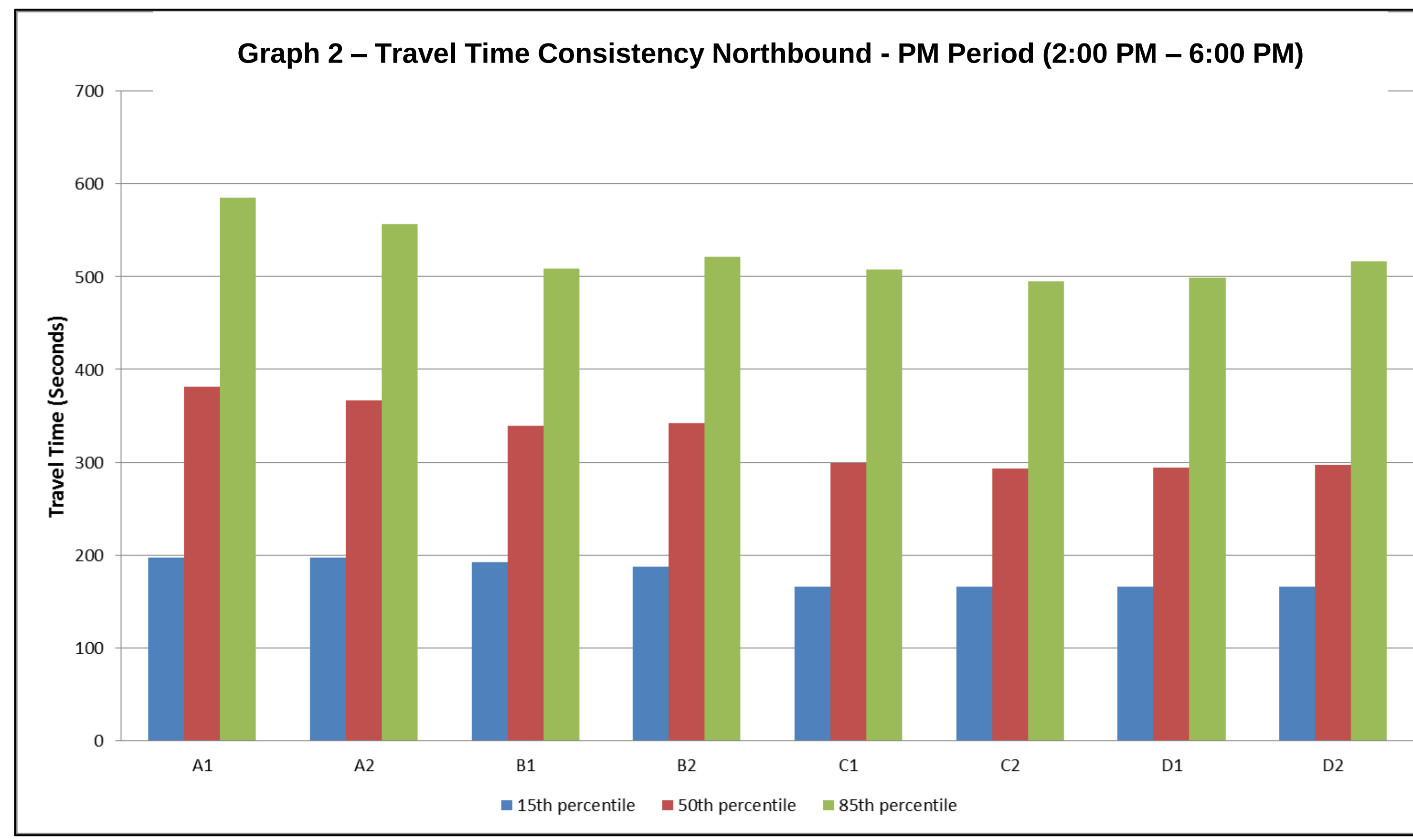


Figure 9 – Travel Time Routes

Table 6 – Travel Time Comparison to A1 No Build

Vehicular Travel Time Routes Comparison to A1 No-Build											
Route	Option	6-7 am	7-8am	8-9am	9-10am	12-1pm	1-2pm	2-3pm	3-4pm	4-5pm	5-6pm
Option A2	Route A	1%	-2%	-2%	-8%	-32%	-33%	-34%	-26%	-24%	-20%
	Route B	0%	-3%	-1%	-9%	-33%	-25%	-34%	-28%	-27%	-10%
	Route C	-3%	-3%	0%	-8%	-25%	2%	-16%	-22%	-19%	1%
	Route D	0%	-2%	-5%	-7%	-17%	14%	1%	1%	-2%	-8%
	Route E	0%	-3%	-2%	-2%	-15%	-14%	0%	-1%	-3%	-4%
	Route F	-21%	-21%	-16%	-13%	-35%	-18%	-28%	-27%	-29%	20%
Option B1	Route A	0%	-63%	-64%	-66%	-54%	-15%	-56%	-49%	-67%	-15%
	Route B	-5%	-59%	-66%	-65%	-54%	-44%	-53%	-57%	-63%	-50%
	Route C	-1%	-32%	-31%	-47%	-27%	-8%	-20%	-34%	-44%	-19%
	Route D	-11%	-35%	-40%	-36%	-41%	87%	-7%	-5%	-25%	-35%
	Route E	-6%	-22%	-24%	-23%	-29%	-31%	-4%	-3%	-7%	-12%
	Route F	-7%	-29%	16%	0%	25%	65%	151%	84%	-2%	67%
Option B2	Route A	1%	-64%	-74%	-73%	-60%	-69%	-68%	-69%	-68%	-41%
	Route B	-5%	-59%	-69%	-68%	-58%	-61%	-61%	-63%	-63%	-59%
	Route C	-5%	-37%	-30%	-45%	-32%	-3%	-14%	-16%	-42%	-12%
	Route D	-11%	-36%	-40%	-37%	-39%	67%	-7%	-7%	-26%	-42%
	Route E	-6%	-23%	-24%	-23%	-29%	-33%	-4%	-3%	-6%	-11%
	Route F	-7%	-38%	-31%	-34%	-38%	78%	51%	46%	-24%	85%
Option C1	Route A	1%	-63%	-55%	-64%	-58%	-31%	-49%	-65%	-68%	-21%
	Route B	-3%	-58%	-52%	-59%	-53%	-28%	-45%	-62%	-63%	-26%
	Route C	0%	-27%	-11%	-42%	-30%	6%	-20%	-48%	-48%	-3%
	Route D	-12%	-34%	-38%	-37%	-42%	53%	-8%	-8%	-24%	-43%
	Route E	-7%	-21%	-23%	-23%	-29%	-33%	-4%	-5%	-8%	-11%
	Route F	0%	-42%	-41%	-47%	-44%	-54%	-12%	-12%	-18%	-64%
Option C2	Route A	0%	-64%	-75%	-69%	-60%	-57%	-65%	-65%	-68%	-37%
	Route B	-4%	-58%	-68%	-64%	-57%	-51%	-58%	-61%	-63%	-42%
	Route C	-1%	-32%	-22%	-38%	-31%	3%	-14%	-16%	-41%	-6%
	Route D	-11%	-34%	-38%	-37%	-47%	33%	-7%	-6%	-24%	-46%
	Route E	-7%	-21%	-23%	-22%	-30%	-19%	-4%	-4%	-9%	-14%
	Route F	11%	-34%	-35%	-43%	-36%	-48%	-13%	-13%	-19%	-64%
Option D1	Route A	1%	-63%	-64%	-66%	-58%	-36%	-46%	-66%	-69%	-14%
	Route B	-5%	-61%	-59%	-61%	-53%	-30%	-41%	-61%	-64%	-20%
	Route C	0%	-31%	-20%	-45%	-31%	1%	-17%	-47%	-48%	1%
	Route D	-11%	-35%	-40%	-37%	-43%	74%	-7%	-9%	-24%	-44%
	Route E	-6%	-22%	-23%	-23%	-29%	-32%	-4%	-4%	-9%	-13%
	Route F	-2%	-52%	-50%	-51%	-44%	-53%	-16%	-15%	-20%	-64%
Option D2	Route A	1%	-64%	-73%	-69%	-60%	-59%	-61%	-62%	-68%	-29%
	Route B	-5%	-61%	-68%	-64%	-58%	-47%	-55%	-58%	-62%	-33%
	Route C	-1%	-30%	-17%	-32%	-29%	2%	-13%	-13%	-34%	0%
	Route D	-12%	-34%	-39%	-36%	-42%	77%	-7%	-6%	-24%	-43%
	Route E	-6%	-21%	-23%	-23%	-29%	-31%	-4%	-4%	-8%	-9%
	Route F	-2%	-52%	-50%	-51%	-44%	-56%	-16%	-15%	-20%	-64%

Legend		<-20%		-20%to -10%		-10%to 0%		0%to10%		>10%

Speed

The Team collected speed data at multiple locations along the corridor on both a segment level and a lane-by-lane level. This allowed for an evaluation of the variability of speed for each option during all model hours (a.m., p.m., & m.d.). Output from the VISSIM model also allowed the Team to develop Spot Speed comparisons (Brainscans) for all of the alternatives.

These spot speed charts show a comparison of freeway speed between each alternative and Option A1 – No Build for eighteen points throughout the length of the freeway on the northbound (nine points) and southbound sides (nine points). Tables 7 and 8 show the Spot Speed results for all eight Options. Spreadsheets with lane-by-lane speed variations are provided in Appendix F.

Table 7 – Spot Speed Data for All Options Northbound

	6:00 AM	6:15 AM	6:30 AM	6:45 AM	7:00 AM	7:15 AM	7:30 AM	7:45 AM	8:00 AM	8:15 AM	8:30 AM	8:45 AM	9:00 AM	9:15 AM	9:30 AM	9:45 AM	12:00 PM	12:15 PM	12:30 PM	12:45 PM	1:00 PM	1:15 PM	1:30 PM	1:45 PM	2:00 PM	2:15 PM	2:30 PM	2:45 PM	3:00 PM	3:15 PM	3:30 PM	3:45 PM	4:00 PM	4:15 PM	4:30 PM	4:45 PM	5:00 PM	5:15 PM	5:30 PM	5:45 PM
NB Location	**Option A1: No-build (Northbound Average Speeds)**																																							
I-5 NB Near 84	49	48	48	49	35	30	29	28	30	31	31	33	33	36	38	38	40	37	30	29	26	29	29	28	47	48	48	47	42	41	42	41	33	32	31	31	29	25	25	24
I-5 NB Near 84	53	52	53	53	44	32	30	29	29	33	33	35	32	39	43	44	51	40	28	28	27	26	27	26	53	53	53	53	51	51	51	50	47	43	40	39	33	28	27	25
I-5 NB Near Multnomah	50	48	49	49	32	25	25	25	26	25	26	28	24	24	26	27	45	29	22	24	22	22	22	22	50	53	53	53	50	52	50	46	42	37	34	32	27	24	24	24
I-5 NB Near Weidler	47	46	45	45	41	38	38	40	39	40	40	40	39	37	38	38	42	37	35	36	35	35	35	35	48	50	50	49	47	48	47	47	43	41	41	40	39	39	41	43
I-5 NB Bt Broadway/Weidler	51	50	50	50	47	43	44	46	47	47	46	47	44	41	42	44	47	38	37	39	38	37	37	38	51	52	52	52	51	51	51	50	48	47	48	46	45	43	46	47
I-5 NB Near Broadway	47	47	47	46	43	41	41	43	43	43	44	44	41	39	38	41	44	35	36	36	37	34	34	35	50	51	51	51	50	49	50	49	47	45	46	43	42	40	44	46
I-5 NB BT 405/Weidler	50	48	50	48	45	43	43	44	44	44	44	46	43	44	42	43	43	39	38	38	40	38	39	39	51	52	51	52	50	50	51	51	48	48	47	42	39	38	40	44
I-5 NB Near 405	56	55	55	55	55	54	55	55	55	55	54	55	54	54	54	54	54	53	53	53	53	54	54	53	55	55	55	55	55	55	55	55	54	44	28	18	17	20	24	26
I-5 NB Near Going	52	53	52	51	47	47	46	46	45	47	45	47	46	48	47	47	45	43	42	44	41	41	41	42	40	41	41	40	39	38	23	15	13	13	13	13	12	13	13	13
NB Location	**Option A2: No-build with two lane flyover (Northbound Average Speeds)**																																							
I-5 NB Near 84	49	48	48	48	35	31	28	29	31	32	32	32	36	38	39	40	42	36	37	35	38	35	32	28	47	48	48	47	42	41	41	41	33	32	30	30	30	26	25	25
I-5 NB Near 84	54	53	53	53	44	32	32	30	32	34	33	36	38	38	42	46	50	45	35	36	37	31	29	25	53	53	53	53	51	51	50	50	47	43	40	43	37	28	27	27
I-5 NB Near Multnomah	51	49	47	49	33	25	25	26	26	26	26	26	26	23	27	28	42	32	24	24	23	25	22	22	50	53	53	53	50	52	49	46	43	36	34	35	29	24	24	25
I-5 NB Near Weidler	47	46	46	45	42	39	40	40	40	40	40	40	39	37	38	38	42	39	38	39	39	41	41	41	48	50	50	49	47	48	47	47	43	42	42	41	40	41	39	39
I-5 NB Bt Broadway/Weidler	50	50	49	50	48	46	47	47	46	46	46	45	44	41	42	42	48	45	42	45	45	46	47	46	51	52	52	51	51	51	51	50	49	48	49	47	46	45	43	44
I-5 NB Near Broadway	48	47	47	46	45	44	45	45	43	43	43	43	40	37	38	38	46	41	40	43	43	44	46	44	50	51	51	51	50	49	49	49	47	47	47	45	44	43	41	42
I-5 NB BT 405/Weidler	50	50	50	50	47	45	46	45	45	47	45	46	43	44	42	42	45	42	45	43	45	45	47	45	51	52	51	52	51	51	51	51	48	48	48	45	43	41	42	40
I-5 NB Near 405	56	55	55	55	55	55	55	55	54	55	55	55	54	54	54	54	54	53	54	53	54	54	54	54	55	55	55	55	55	55	55	55	54	47	36	21	17	20	24	25
I-5 NB Near Going	52	52	52	52	47	47	46	47	46	47	47	47	47	47	47	46	46	43	43	44	42	42	42	44	41	40	41	40	40	38	27	15	14	13	13	13	13	13	13	14
NB Location	**Option B1: Auxiliary Lanes (Northbound Average Speeds)**																																							
I-5 NB Near 84	47	46	47	47	35	34	34	34	35	35	35	35	36	36	36	36	38	36	35	35	36	36	35	33	44	44	46	45	39	39	38	37	35	34	33	34	34	34	34	34
I-5 NB Near 84	56	55	56	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	50	46	37	56	55	56	55	55	55	55	55	55	55	55	55	55	55	53	51
I-5 NB Near Multnomah	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	52	42	37	30	56	56	56	55	56	55	55	55	55	55	55	55	55	55	52	45
I-5 NB Near Weidler	55	54	54	54	54	53	53	54	54	54	54	54	54	54	54	54	54	54	53	53	53	53	52	52	55	55	55	55	55	55	55	55	54	54	54	54	54	54	51	51
I-5 NB Bt Broadway/Weidler	55	54	55	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	53	54	54	54	54	54	55	55	55	55	55	55	55	55	54	54	54	54	55	53	52	52
I-5 NB Near Broadway	53	53	53	53	53	52	52	52	53	53	53	53	52	52	52	52	53	53	52	52	53	53	53	53	54	55	55	54	54	54	54	54	54	54	54	53	53	51	51	49
I-5 NB BT 405/Weidler	53	52	53	53	51	51	51	51	52	52	51	51	52	51	52	52	51	50	49	50	51	52	53	52	55	54	54	55	54	54	55	54	54	53	53	52	51	47	47	46
I-5 NB Near 405	56	55	55	55	55	54	54	54	55	55	55	54	54	54	54	54	53	53	53	53	53	54	54	54	55	55	55	55	55	55	55	55	54	41	29	26	18	18	19	24
I-5 NB Near Going	53	53	52	51	48	48	46	46	46	47	47	46	47	47	47	46	45	43	41	42	40	42	42	44	41	41	42	41	40	40	26	14	14	13	13	13	13	13	13	13
NB Location	**Option B2: Auxiliary lanes with two lane flyover (Northbound Average Speeds)**																																							
I-5 NB Near 84	47	45	46	46	35	34	34	34	35	35	35	36	36	37	37	36	38	36	35	35	36	37	36	35	44	44	46	45	39	39	38	37	35	34	33	34	34	34	34	34
I-5 NB Near 84	56	55	56	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	52	53	47	56	55	56	55	55	55	55	55	55	55	55	55	55	54	52	52
I-5 NB Near Multnomah	55	55	55	55	55	55	54	55	55	55	55	55	55	55	55	55	55	55	55	54	51	41	38	33	56	56	56	55	56	55	55	55	55	55	55	55	54	52	52	51
I-5 NB Near Weidler	55	54	54	54	54	54	54	54	54	54	54	54	54	54	54	53	54	54	53	53	53	53	53	52	55	55	55	55	55	55	54	55	54	54	54	53	52	51	50	49
I-5 NB Bt Broadway/Weidler	55	54	55	54	54	54	54	54	54	54	54	54	54	54	54	53	54	54	54	54	54	54	54	54	55	55	55	55	55	55	55	55	54	54	54	53	52	49	49	49
I-5 NB Near Broadway	53	53	53	53	53	52	52	53	53	53	53	53	52	52	53	52	53	53	53	52	53	53	53	53	54	55	55	54	54	54	54	54	54	54	54	51	51	48	48	47
I-5 NB BT 405/Weidler	53	53	53	53	52	51	51	52	52	51	51	51	51	51	52	51	51	50	50	50	51	52	52	53	54	55	55	54	54	55	54	54	54	54	52	50	47	44	45	44
I-5 NB Near 405	55	55	55	55	55	54	54	54	55	54	54	55	54	54	54	54	54	53	53	53	53	54	54	54	55	55	55	55	55	55	55	55	54	47	29	20	23	21	22	22
I-5 NB Near Going	52	52	52	52	48	47	46	46	47	46	46	46	47	47	48	47	45	43	42	43	41	41	42	44	41	42	42	42	40	40	25	15	14	13	13	13	13	13	12	13
NB Location	**Option C1: Single Braid (Northbound Average Speeds)**																																							
I-5 NB Near 84	48	46	47	47	35	34	33	33	34	34	34	34	35	36	37	37	39	36	36	35	37	37	36	36	44	46	46	45	40	39	39	37	34	33	33	33	33	34	33	33
I-5 NB Near 84	56	55	56	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	52	51	43	55	55	56	55	55	55	55	55	55	55	55	55	55	55	53	52
I-5 NB Near Multnomah	55	55	55	55	55	55	54	54	55	55	55	55	55	55	55	55	55	55	55	54	53	44	38	34	56	56	56	56	55	56	55	55	55	55	55	55	55	53	51	49
I-5 NB Near Weidler	55	54	55	54	54	54	53	53	54	54	54	54	54	54	54	53	54	54	53	53	53	53	53	53	55	55	55	55	55	55	55	54	54	54	54	54	53	51	51	49
I-5 NB Bt Broadway/Weidler	55	54	55	54	54	54	54	54	54	54	54	54	54	54	54	53	54	54	54	54	54	54	54	54	55	55	55	55	55	55	55	55	54	54	54	54	51	51	51	48
I-5 NB Near Broadway	53	53	53	53	53	52	53	52	53	53	53	52	52	52	52	52	53	53	52	52	53	53	53	53	54	55	55	54	54	54	54	54	53	53	53	51	50	46	46	46
I-5 NB BT 405/Weidler	53	53	53	53	51	51	51	51	52	51	51	50	51	51	51	51	51	50	50	51	51	51	51	53	55	55	55	55	54	54	54	54	53	53	52	50	46	44	44	43
I-5 NB Near 405	56	55	55	55	55	54	54	55	55	54	54	54	54	54	54	54	54	53	53	53	54	54	54	54	55	55	55	55	55	55	55	55	54	46	36	25	22	18	17	19
I-5 NB Near Going	53	52	52	51	48	46	45	47	46	47	46	45	47	47	48	47	45	42	41	43	40	42	42	44	41	42	42	41	41	39	23	15	15	13	12	13	13	13	13	13
NB Location	**Option C2: Single Braid with two lane flyover (Northbound Average Speeds)**																																							
I-5 NB Near 84	48	46	47	47	35	34	33	33	34	34	34	34	36	36	37	37	42	39	40	40	42	39	38	33	44	46	46	45	39	39	39	38	34	33	33	34	34	34	34	34
I-5 NB Near 84	56	55	56	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	49	41	32	55	55	56	55	55	55	55	55	55	55	55	55	54	55	54	54
I-5 NB Near Multnomah	56	55	55	55	55	54	54	54	55	55	55	55	55	55	55	55	55	54	55	54	51	45	31	23	56	56	56	55	56	55	55	55	55	55	55	55	55	55	53	49
I-5 NB Near Weidler	55	54	54	54	54	53	54	53	54	54	54	54	54	54	54	53	54	53	53	53	53	53	52	51	55	55	55	55	55	54	55	54	54	54	54	54	54	53	51	49
I-5 NB Bt Broadway/Weidler	55	54	54	54	54	54	54	54	54	54	54	54	54	54	54	53	54	54	53	54	54	54	53	53	55	55	55	55	55	55	55	55	54	54	54	54	54	52	51	48
I-5 NB Near Broadway	53	53	53	53	53	52	53	52	53	53	53	52	52	52	52	52	53	52	52	52	53	53	52	52	54	55	54	54	54	54	54	54	53	53	53	53	51	49	47	47
I-5 NB BT 405/Weidler	53	52	53	53	52	51	52	51	51	51	51	51	51	51	51	51	51	50	50	51	51	51	52	53	55	55	55	54	54	54	54	54	53	53	54	50	48	46	46	43
I-5 NB Near 405	56	55	55	55	54	55	54	54	55	54	55	54	54	54	54	54	54	53	53	53	53	54	53	54	55	55	55	55	55	55	55	55	54	48	32	28	21	22	22	22
I-5 NB Near Going	53	52	53	51	48	47	46	46	46	47	46	45	47	48	48	46	45	43	42	42	42	42	42	45	42	41	42	40	39	39	24	15	14	13	13	13	13	13	12	13
NB Location	**Option D1: Double Braid (Northbound Average Speeds)**																																							
I-5 NB Near 84	47	46	47	46	35	34	34	34	35	35	34	35	36	36	37	36	39	37	37	36	37	37	36	34	44	46	45	45	40	39	39	37	34	33	33	33	34	34	34	34
I-5 NB Near 84	56	55	56	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	53	52	34	55	55	56	55	55	55	55	55	55	55	55	55	55	55	54	54
I-5 NB Near Multnomah	55	55	55	55	55	55	54	54	55	55	55	54	55	55	55	55	55	55	55	55	52	45	38	29	55	55	56	55	55	55	55	55	55	55	55	55	55	54	53	49
I-5 NB Near Weidler	55	54	54	54	54	54	54	54	54	54	54	54	54	54	54	53	54	53	53	53	53	53	53	53	55	55	55	55	55	55	55	54	54	54	54	54	54	54	52	51
I-5 NB Bt Broadway/Weidler	55	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	55	55	55	55	55	55	55	55	54	54	54	54	54	53	51	50
I-5 NB Near Broadway	53	53	53	53	53	53	52	52	53	52	53	53	52	52	52	52	53	53	52	52	53	53	53	54	54	54	54	54	54	54	54	54	54	53	54	53	52	51	49	45
I-5 NB BT 405/Weidler	53	52	53	53	51	51	51	52	52	50	51	51	51	51	51	52	51	50	51	50	51	51	52	53	54	55	54	54	54	55	55	54	54	53	54	52	50	45	44	43
I-5 NB Near 405	56	55	55	55	55	54	54	54	55	54	54	54	54	54	54	54	54	53	53	53	53	54	54	54	55	55	55	55	55	55	55	55	54	46	32	24	19	21	21	20
I-5 NB Near Going	53	52	52	51	48	47	45	47	46	47	46	47	47	48	48	47	45	43	43	44	41	40	42	46	41	41	43	41	39	38	24	15	14	12	13	13	13	12	13	13
NB Location	**Option D2: Double Braid with two lane flyover (Northbound Average Speeds)**																																							
I-5 NB Near 84	48	45	47	45	36	34	34	34	35	35	34	35	36	36	36	35	39	37	36	36	38	36	35	33	44	46	46	45	39	39	38	37	34	33	34	33	34	34	34	34
I-5 NB Near 84	56	55	56	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	52	50	41	55	55	56	55	55	55	55	55	55	55	55	55	55	55	54	53
I-5 NB Near Multnomah	56	55	55	55	55	55	54	55	55	55	55	55	55	55	55	55	55	55	55	55	52	44	36	33	55	56	56	55	55	55	55	55	55	55	55	55	55	54	52	48
I-5 NB Near Weidler	55	54	54	55	54	53	54	54	54	54	54	54	54	54	54	53	54	54	53	53	53	53	54	54	55	55	55	55	55	55	55	54	54	54	54	54	54	54	51	47
I-5 NB Bt Broadway/Weidler	55	54	55	55	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	55	55	55	55	55	55	55	55	55	55	54	54	54	54	54	53	50	48
I-5 NB Near Broadway	54	53	53	53	53	52	52	53	53	53	53	52	52	52	53	52	53	53	52	52	53	53	54	54	54	54	55	54	54	54	54	54	54	54	54	53	50	49	47	45
I-5 NB BT 405/Weidler	53	52	51	54	51	50	50	51	52	51	51	51	51	52	51	52	52	51	50	50	51	52	53	54	54	55	54	54	54	55	54	54	53	53	54	50	46	41	42	39
I-5 NB Near 405	56	55	55	55	55	54	54	55	55	55	55	55	54	54	54	54	54	53	53	53	53	54	54	54	55	55	55	55	55	55	55	55	54	47	31	26	19	19	21	21
I-5 NB Near Going	53	53	52	51	49	47	45	47	47	46	47	46	47	48	49	47	45	43	42	43	41	42	43	45	41	41	41	40	39	39	25	14	14	13	13	13	13	13	12	13

Table 8 – Spot Speed Data for All Options Southbound

I-5 Broadway/Weidler 2035 Future Options Southbound Spot Speed Chart

	6:00 AM	6:15 AM	6:30 AM	6:45 AM	7:00 AM	7:15 AM	7:30 AM	7:45 AM	8:00 AM	8:15 AM	8:30 AM	8:45 AM	9:00 AM	9:15 AM	9:30 AM	9:45 AM	12:00 PM	12:15 PM	12:30 PM	12:45 PM	1:00 PM	1:15 PM	1:30 PM	1:45 PM	2:00 PM	2:15 PM	2:30 PM	2:45 PM	3:00 PM	3:15 PM	3:30 PM	3:45 PM	4:00 PM	4:15 PM	4:30 PM	4:45 PM	5:00 PM	5:15 PM	5:30 PM	5:45 PM
SB Location	**Option A1: No-build (Southbound Average Speeds)**																																							
I-5 SB Near Going	52	50	50	48	42	41	33	25	22	23	25	26	25	24	27	29	52	49	44	33	25	25	23	21	52	50	38	26	25	28	31	31	30	31	29	29	30	22	19	19
I-5 SB Near 405	53	53	53	53	52	45	26	20	21	21	22	21	21	23	23	23	52	50	33	24	23	22	21	19	49	34	22	21	21	23	26	24	26	28	27	26	22	21	18	19
I-5 SB Bt 405/Broadway	55	54	55	55	40	19	15	14	15	15	15	15	15	16	15	16	48	23	16	15	15	15	14	14	24	16	15	15	15	17	16	16	17	16	16	16	15	14	14	15
I-5 SB Near Broadway	48	46	45	46	30	20	18	19	19	20	20	20	20	20	20	21	34	19	20	19	20	19	17	17	20	19	19	20	18	21	20	21	20	19	20	19	16	15	15	16
I-5 SB Near Broadway	50	49	49	50	44	36	31	31	33	38	39	38	38	40	37	40	44	35	38	31	34	33	28	24	36	32	30	37	32	39	38	40	38	34	34	34	24	19	18	19
I-5 SB Near Moda Center	51	49	50	50	44	34	30	29	32	37	38	36	36	37	35	39	42	34	33	29	32	29	27	23	35	30	28	35	31	38	36	38	35	33	32	32	22	19	17	18
I-5 SB Near Multnomah	52	50	50	51	39	28	27	29	29	31	31	32	32	34	35	35	38	34	33	32	33	32	32	30	34	33	33	35	34	36	35	36	36	35	34	34	31	30	30	30
I-5 SB Near 84	53	51	52	52	40	26	24	26	27	29	26	31	30	36	39	38	49	49	46	44	46	49	48	49	50	50	50	49	48	45	45	44	47	46	48	48	41	52	54	52
I-5 SB Near Morrison	56	55	55	56	54	53	53	53	54	53	53	54	54	54	54	54	55	55	54	55	55	55	55	56	55	55	56	55	55	55	55	54	55	55	47	44	40	40	41	40
SB Location	**Option A2: No-build with two lane flyover (Southbound Average Speeds)**																																							
I-5 SB Near Going	51	50	50	49	42	41	34	25	22	24	25	26	24	25	30	36	51	49	50	43	39	40	32	25	52	52	50	45	38	38	36	37	34	38	40	45	51	43	22	18
I-5 SB Near 405	53	53	53	53	52	44	28	20	20	21	22	21	20	23	26	28	52	52	44	31	27	26	24	22	53	51	38	29	25	30	28	29	33	37	41	41	42	27	18	18
I-5 SB Bt 405/Broadway	55	55	55	55	40	17	14	15	15	16	15	15	15	16	16	16	50	30	19	16	16	16	15	14	31	17	16	16	17	17	17	17	17	18	17	17	17	14	13	13
I-5 SB Near Broadway	47	45	46	46	28	20	19	19	19	20	21	21	20	21	21	21	35	22	21	21	21	21	20	17	23	22	22	22	22	22	22	22	22	22	22	22	19	14	13	13
I-5 SB Near Broadway	50	49	49	50	47	42	33	31	33	38	44	42	41	45	46	46	48	46	47	46	46	45	38	28	47	47	45	46	47	47	47	47	47	47	47	47	37	20	17	18
I-5 SB Near Moda Center	51	50	51	51	49	43	30	28	32	38	43	40	40	47	47	48	49	48	48	48	48	46	37	27	47	47	44	46	47	48	48	48	48	48	48	48	34	17	16	16
I-5 SB Near Multnomah	54	54	54	54	47	35	21	21	23	29	28	31	27	40	43	46	49	48	49	49	50	45	30	19	50	49	44	49	43	50	48	49	48	46	47	45	28	16	15	16
I-5 SB Near 84	52	51	52	52	42	28	24	25	26	30	28	31	27	30	37	39	49	49	49	48	51	50	48	50	50	52	50	50	48	49	47	48	48	46	46	45	49	52	53	52
I-5 SB Near Morrison	56	55	55	56	55	54	53	53	53	54	53	54	54	54	54	54	55	55	55	55	55	55	56	56	55	56	56	55	55	55	55	55	55	55	47	43	42	42	41	42
SB Location	**Option B1: Auxiliary Lanes (Southbound Average Speeds)**																																							
I-5 SB Near Going	52	51	50	50	40	42	41	41	35	33	32	34	36	41	39	41	51	49	50	50	47	45	34	29	52	52	52	50	47	42	44	44	42	43	45	47	52	52	34	24
I-5 SB Near 405	53	53	53	53	52	52	52	52	52	52	52	52	50	51	52	52	52	52	51	50	48	40	28	25	53	53	53	51	48	45	48	52	53	53	53	53	53	45	23	25
I-5 SB Bt 405/Broadway	54	54	54	54	53	49	52	50	48	44	43	43	46	49	50	52	52	51	51	48	38	25	18	16	50	45	29	25	25	27	31	39	45	49	49	50	47	26	15	20
I-5 SB Near Broadway	54	54	54	55	53	52	53	52	51	47	45	46	50	53	51	52	53	52	51	46	45	43	40	39	50	38	27	26	32	48	51	52	53	53	53	53	44	41	48	41
I-5 SB Near Broadway	54	54	54	54	53	52	52	51	48	44	42	44	45	49	49	50	52	47	38	34	34	36	34	34	44	31	26	24	26	40	47	49	51	51	52	50	35	29	43	36
I-5 SB Near Moda Center	54	54	54	54	53	52	51	46	43	42	40	40	42	46	47	50	51	43	34	31	32	32	32	31	40	30	27	25	27	36	43	46	50	50	51	49	33	26	38	35
I-5 SB Near Multnomah	55	55	55	55	51	48	43	49	50	51	49	46	50	53	53	53	55	54	54	53	54	54	55	55	55	55	55	54	54	53	54	54	55	55	54	54	55	56	56	56
I-5 SB Near 84	55	55	55	55	51	48	43	49	50	51	49	46	50	53	53	53	55	54	54	53	54	54	55	55	55	55	55	54	54	53	54	54	55	55	54	54	55	56	56	56
I-5 SB Near Morrison	56	56	56	56	54	54	54	54	54	54	54	54	54	55	55	55	56	55	55	55	56	56	56	56	55	55	55	55	54	54	54	54	54	54	46	42	41	41	42	41
SB Location	**Option B2: Auxiliary lanes with two lane flyover (Southbound Average Speeds)**																																							
I-5 SB Near Going	52	51	48	50	41	40	38	39	35	31	34	33	37	41	41	41	51	49	50	50	49	48	48	45	52	52	52	50	48	42	44	44	42	43	45	47	52	54	48	27
I-5 SB Near 405	53	53	53	53	52	52	52	52	52	52	52	52	52	52	52	52	52	52	51	52	52	52	50	37	53	53	53	52	53	52	53	53	53	53	53	53	53	51	34	20
I-5 SB Bt 405/Broadway	54	54	54	55	53	52	52	52	51	52	51	50	53	52	53	52	52	51	52	52	52	51	39	20	51	51	49	47	43	44	47	51	51	50	50	51	50	42	18	15
I-5 SB Near Broadway	55	54	55	55	53	53	53	53	53	53	51	52	53	54	53	54	53	53	53	53	53	51	34	19	53	52	49	45	43	49	53	54	54	53	53	53	51	37	26	42
I-5 SB Near Broadway	54	54	54	54	53	52	53	52	52	52	50	50	50	51	53	53	52	51	52	52	52	45	27	19	51	49	45	38	37	45	51	52	54	52	52	52	48	28	22	36
I-5 SB Near Moda Center	54	54	54	54	53	53	52	52	52	52	50	49	49	51	52	53	52	52	52	52	51	41	27	22	51	49	42	37	36	42	49	52	53	52	52	53	46	29	24	29
I-5 SB Near Multnomah	55	55	55	55	51	46	45	44	44	50	48	46	51	54	53	54	54	54	54	53	53	52	51	51	54	54	53	52	51	51	52	54	54	54	54	54	54	53	54	54
I-5 SB Near 84	55	55	55	55	51	46	45	44	44	50	48	46	51	54	53	54	54	54	54	53	53	52	51	51	54	54	53	52	51	51	52	54	54	54	54	54	54	53	54	54
I-5 SB Near Morrison	56	56	56	56	54	53	54	53	53	54	54	54	55	55	55	55	55	55	55	56	56	56	56	56	55	55	55	55	55	54	54	54	54	54	46	42	41	40	41	42
SB Location	**Option C1: Single Braid (Southbound Average Speeds)**																																							
I-5 SB Near Going	51	51	49	49	45	39	43	42	36	32	31	29	34	41	40	42	50	49	49	49	50	43	35	24	52	52	52	49	48	43	43	43	41	43	44	48	52	46	21	18
I-5 SB Near 405	53	53	53	53	52	52	52	52	49	43	42	41	45	49	51	52	52	52	51	52	49	36	27	23	53	52	48	49	48	53	53	53	53	53	53	54	52	28	17	18
I-5 SB Bt 405/Broadway	55	54	55	55	53	52	53	48	36	30	32	32	35	42	49	51	53	53	52	39	30	22	17	16	48	30	26	25	25	40	47	52	51	50	50	51	39	13	13	14
I-5 SB Near Broadway	55	55	55	55	53	52	51	46	36	37	38	40	38	47	52	54	54	53	47	31	27	21	19	17	41	30	28	25	33	49	52	54	53	53	53	52	30	13	13	13
I-5 SB Near Broadway	52	52	52	52	48	47	44	41	32	34	34	34	35	39	45	49	47	41	34	28	25	24	23	22	32	26	26	24	29	40	46	47	49	48	48	45	30	23	25	23
I-5 SB Near Moda Center	55	55	55	55	54	53	53	53	53	52	53	52	51	53	54	54	54	54	54	53	53	53	54	53	54	54	54	53	53	54	54	54	54	54	54	54	55	55	56	55
I-5 SB Near Multnomah	54	54	54	54	52	52	52	51	52	51	51	50	49	53	53	53	54	53	53	52	53	53	53	53	54	54	53	53	52	53	53	53	53	54	53	54	54	55	55	55
I-5 SB Near 84	54	53	53	53	45	43	43	39	45	44	42	40	42	49	51	52	53	52	52	50	51	52	53	53	53	53	53	52	51	51	52	52	52	52	52	52	53	53	54	54
I-5 SB Near Morrison	56	55	55	55	54	54	54	54	54	54	53	53	54	55	55	55	55	55	55	55	55	56	56	56	55	55	55	54	54	54	54	54	54	54	46	41	40	40	41	41
SB Location	**Option C2: Single Braid with two lane flyover (Southbound Average Speeds)**																																							
I-5 SB Near Going	52	50	50	50	44	41	44	40	37	36	34	32	37	41	38	39	49	49	50	50	50	48	47	33	52	52	52	50	48	42	44	44	42	43	45	47	52	52	37	18
I-5 SB Near 405	53	53	53	54	52	52	52	52	52	52	52	52	50	50	51	52	52	52	52	52	52	51	42	26	53	53	52	52	47	52	53	53	53	53	53	53	52	46	21	19
I-5 SB Bt 405/Broadway	55	54	55	55	53	51	53	52	51	51	51	50	49	50	50	53	53	52	52	53	52	47	25	16	52	51	43	35	28	38	45	51	52	50	51	51	47	30	13	15
I-5 SB Near Broadway	55	55	54	55	53	52	53	52	53	52	51	49	50	51	53	53	54	53	53	53	53	39	21	17	53	51	38	30	34	45	51	51	53	53	53	53	48	21	14	14
I-5 SB Near Broadway	53	52	52	53	50	50	49	49	48	48	46	45	47	47	48	49	48	46	48	48	45	37	31	31	48	44	37	35	36	41	46	48	49	49	49	49	45	33	32	32
I-5 SB Near Moda Center	55	55	55	55	54	54	54	53	53	54	53	53	54	54	54	54	54	54	54	54	54	54	54	54	54	55	54	54	53	54	54	54	54	54	54	54	55	55	55	55
I-5 SB Near Multnomah	54	54	54	54	52	52	52	48	50	52	52	51	53	53	53	53	53	53	54	53	53	53	53	53	54	54	54	53	53	52	53	53	53	53	54	54	54	54	55	55
I-5 SB Near 84	54	53	53	54	45	41	39	36	40	42	44	44	49	51	51	51	53	52	52	51	52	52	52	53	52	53	52	52	50	52	51	52	52	52	52	52	53	53	53	53
I-5 SB Near Morrison	56	56	55	56	54	53	54	54	53	54	53	54	55	55	55	55	55	55	56	55	55	56	56	56	55	55	55	55	54	54	53	54	54	54	46	42	40	40	39	40
SB Location	**Option D1: Double Braid (Southbound Average Speeds)**																																							
I-5 SB Near Going	51	50	50	49	46	41	42	37	31	32	30	32	36	39	44	45	50	49	50	50	50	47	37	24	52	52	52	50	46	40	44	44	43	44	46	47	52	45	20	19
I-5 SB Near 405	53	53	53	53	52	52	52	52	51	50	47	48	49	47	50	52	52	51	52	51	50	39	30	24	53	51	42	45	47	51	53	53	53	53	53	53	50	27	18	19
I-5 SB Bt 405/Broadway	55	54	55	55	53	52	52	49	45	41	40	37	40	46	49	53	53	53	52	41	33	24	21	18	46	31	27	27	27	43	49	52	52	52	52	52	40	15	14	16
I-5 SB Near Broadway	55	55	55	55	54	54	53	50	41	44	42	41	42	48	53	54	54	53	51	36	28	24	21	19	41	30	29	28	33	51	53	54	54	54	54	53	32	15	14	16
I-5 SB Near Broadway	52	52	52	53	49	50	47	42	28	31	31	32	31	39	44	49	46	41	30	24	18	16	13	13	26	18	18	16	21	35	45	49	50	49	50	46	21	11	11	12
I-5 SB Near Moda Center	54	54	55	55	52	52	52	51	47	48	48	48	49	51	52	53	54	52	50	47	48	48	48	48	51	50	50	50	50	51	53	54	54	54	54	54	51	51	50	50
I-5 SB Near Multnomah	56	56	56	56	55	55	55	55	54	55	54	55	55	56	55	56	56	56	56	55	55	55	55	55	55	55	55	55	54	55	55	55	55	55	55	55	56	56	56	56
I-5 SB Near 84	56	56	56	56	55	55	55	55	55	55	55	55	55	56	56	56	56	56	56	56	56	56	56	56	55	55	55	55	55	55	55	55	55	55	55	55	56	56	56	56
I-5 SB Near Morrison	56	56	55	56	54	55	54	54	53	54	53	54	54	55	55	55	55	55	55	55	55	55	56	55	55	55	55	54	53	53	54	54	54	54	46	41	40	40	42	40
SB Location	**Option D2: Double Braid with two lane flyover (Southbound Average Speeds)**																																							
I-5 SB Near Going	50	51	50	49	43	39	40	35	39	35	36	29	37	36	44	42	50	49	50	50	50	49	46	32	52	52	52	49	47	44	44	44	42	43	45	47	51	49	31	19
I-5 SB Near 405	53	53	54	53	53	52	52	52	52	52	52	52	44	41	44	45	52	51	52	52	52	51	40	23	53	53	52	51	46	51	53	53	53	53	53	54	52	41	21	21
I-5 SB Bt 405/Broadway	55	54	55	55	54	53	53	53	52	53	51	42	40	40	40	40	53	53	52	53	52	43	24	17	52	52	37	31	29	37	42	46	50	50	51	51	46	25	15	16
I-5 SB Near Broadway	55	55	55	55	54	54	54	54	54	54	49	41	39	40	48	48	54	53	54	53	51	37	24	22	54	50	34	29	34	42	48	49	51	52	54	52	44	20	14	16
I-5 SB Near Broadway	52	52	52	52	51	50	50	50	46	47	38	29	30	33	39	37	46	43	45	41	36	20	16	16	46	34	23	21	22	30	39	43	46	45	47	47	37	14	10	11
I-5 SB Near Moda Center	55	54	55	55	54	53	53	53	52	52	50	49	50	51	48	48	54	53	53	52	52	49	48	49	54	53	50	50	50	50	52	53	54	53	53	54	53	51	52	51
I-5 SB Near Multnomah	57	56	56	56	56	56	56	55	56	55	56	56	55	56	56	55	56	56	56	56	56	56	55	56	56	55	55	55	55	55	55	55	55	55	55	55	56	56	56	56
I-5 SB Near 84	56	56	56	56	56	56	55	56	55	56	56	55	56	56	56	55	56	56	56	56	56	56	56	56	55	55	55	55	55	55	55	55	55	55	55	55	56	56	57	57
I-5 SB Near Morrison	56	56	56	56	55	55	54	54	54	54	54	54	55	55	55	54	55	55	55	55	55	56	55	56	55	55	54	54	54	53	53	54	54	54	45	40	40	39	41	41

Legend	< 20 mph	19	20-30 mph	25	30-40 mph	35	40-50 mph	45	>50 mph	51.0

Emergency Braking

HDR developed a new methodology that evaluates the correlation between "emergency braking" events and crashes on the freeway in order to analyze and compare the different options for potential safety improvements. An emergency braking instance is defined by a vehicle deceleration rate faster than 14.8 ft/s^2. *A Policy on Geometric Design of Highways and Streets*[12] notes that the majority of drivers decelerate at a rate of 11.2 ft/s^2 when confronted by an unexpected object, however, the Team chose 14.8 ft/s^2 as a more conservative threshold.

The emergency braking analysis was based on the assumption that higher frequency of emergency braking events correlates with greater likelihood of vehicle crashes. In order to capture each of these events within the models, the Team collected second-by-second data for all vehicles on the network during the a.m., m.d., and p.m. peak periods. This data captured vehicle characteristics such as location on the freeway, speed, acceleration, and various other attributes.

Once these characteristics were compiled, the Team grouped all vehicles that experienced an emergency braking event, or a deceleration rate greater than 14.8 ft/s^2, according to location and mapped the locations in GIS to generate a network-wide heat map of the freeways, highlighting the most concentrated areas of emergency braking events. The braking event data for each option was sorted by direction and segmented into two sections on the northbound and southbound directions of the freeway and then compared with Option A2 – No Build, as shown in Table 9. As shown, the emergency braking events are greatly reduced in many of the build options when compared to No Build. More emergency braking data can be found in Appendix G.

To verify that the frequency of emergency braking events correlate to a higher likelihood of crashes, the Team compared the output of the calibrated existing conditions VISSIM model to a summary of crash data in the same area over the last five years.

The Team utilized the VISSIM model to summarize the emergency braking events on I-5 between the Going Street ramps and the Morrison Bridge ramps. The Team compiled 10 hours worth of model data to determine the total number of crashes by direction for these segments. The crash data over the last five years was also sorted within the same 10-hour period and for the same locations: between the Going Street ramps and the Morrison Bridge ramps.

Graph 3 shows the comparison of the crash data with the emergency braking events observed in the VISSIM model. Based on this sample, it can be concluded there is a correlation between the emergency braking events and number of crashes; however, it should be noted that this is a small sample set.

Graph 3 – Emergency Braking and Crash Data Correlation

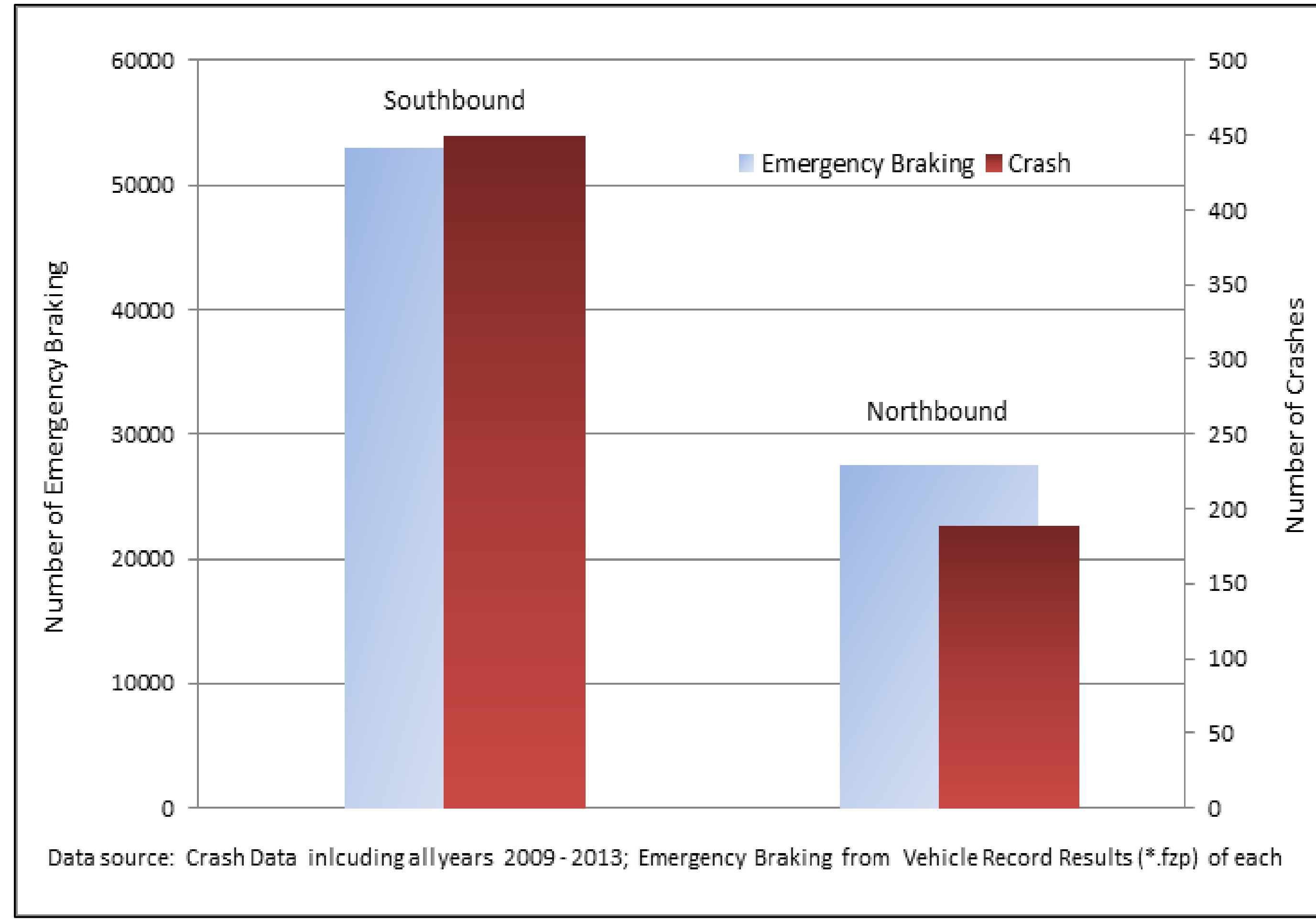


Table 9 – Emergency Braking Events

	BUILD OPTIONS EMERGENCY BRAKING REDUCTION PERCENTAGE					
Option A2: No-build	-	-	-	-	-	-
Option A1: No-build with two lane flyover	5-20%	<5%	5-20%	<5%	5-20%	5-20%
Option B1: Auxiliary lanes with two lane flyover	>60%	<5%	>60%	<5%	>60%	40-60%
Option B2: Auxiliary Lanes	>60%	<5%	>60%	<5%	>60%	40-60%
Option C1: Double Braid with two lane flyover	>60%	>60%	>60%	<5%	>60%	5-20%
Option C2: Double Braid	>60%	40-60%	>60%	<5%	>60%	40-60%
Option c1: Single Braid with two lane flyover	>60%	>60%	>60%	<5%	>60%	5-20%
Option c2: Single Braid	>60%	40-60%	>60%	<5%	>60%	40-60%

[12] AASHTO, *Policy on Geometric Design of Highways and Streets,* 6th Edition, 2011

Volume Throughput

The Team used volume output files from VISSIM to determine volume of the freeway for all peak period hours in the form of percentage of demand unserved. Table 10 and Table 11 show the Northbound and Southbound percentage of traffic that was not served at the exit points of each direction within the model compared to the demand for the freeway. The tables show that the 1:00 to 2:00 p.m. and 5:00 to 6:00 p.m. peak hours for southbound traffic and the 4:00 to 6:00 p.m. peak hours for northbound traffic are the most congested with the highest number of vehicles not being served in those hours.

The overall southbound demand is met better under Option B1, B2, C1, C2, D1, and D2 with generally more traffic being served with the two lane flyover for I-84. The overall northbound traffic did not see improvement. Unserved traffic demand in the northbound direction is caused by a bottleneck north of the Study Area.

Table 10 – Percent Unserved I-5 Southbound

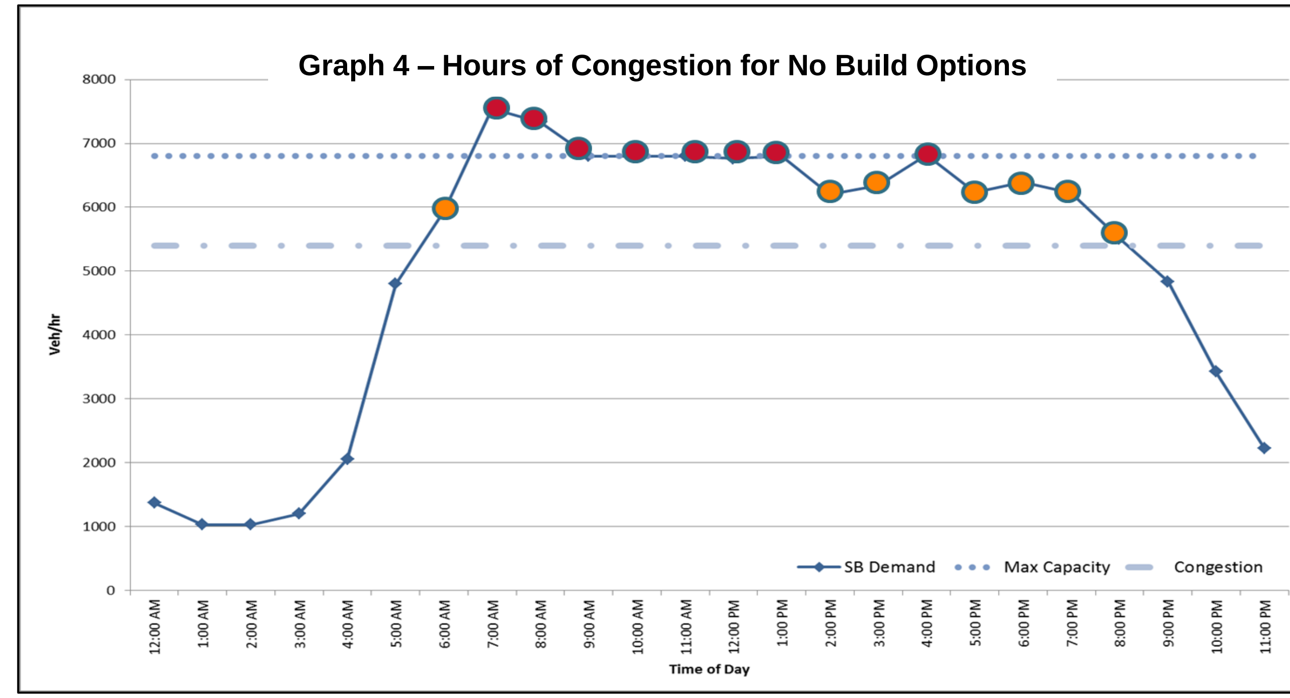
Time	Option A1 Served Vol	Option A2 Served Vol	Option B1 Served Vol	Option B2 Served Vol	Option C1 Served Vol	Option C2 Served Vol	Option c1 Served Vol	Option c2 Served Vol
6:00 AM	2%	2%	2%	2%	2%	3%	2%	2%
7:00 AM	20%	21%	8%	9%	7%	8%	8%	8%
8:00 AM	17%	18%	6%	8%	7%	8%	5%	10%
9:00 AM	3%	4%	2%	0%	2%	1%	4%	-1%
12:00 PM	9%	13%	3%	7%	4%	6%	3%	5%
1:00 PM	12%	15%	12%	15%	16%	15%	12%	15%
2:00 PM	10%	15%	6%	11%	7%	9%	6%	8%
3:00 PM	9%	13%	4%	4%	4%	3%	4%	4%
4:00 PM	4%	11%	5%	5%	3%	4%	5%	6%
5:00 PM	34%	32%	30%	35%	31%	35%	29%	34%
Total Unserved	12%	14%	7%	9%	8%	8%	7%	9%

Table 11 – Percent Unserved Northbound

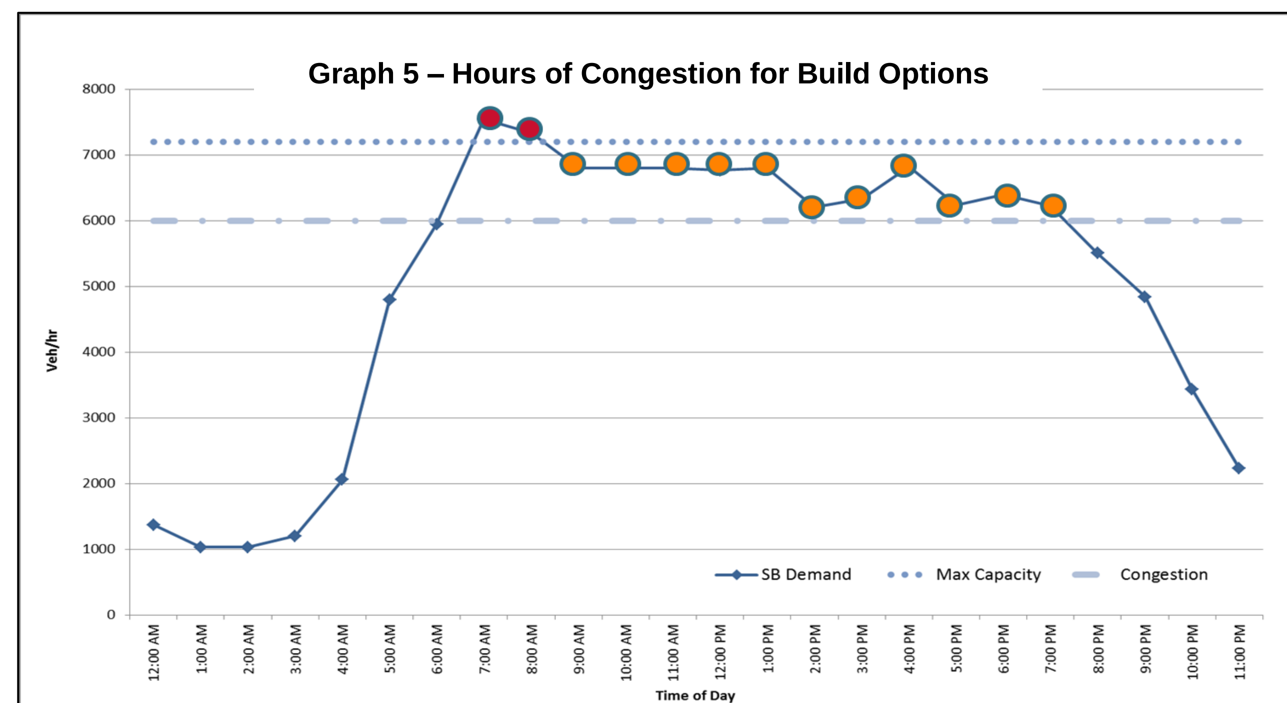
Time	Option A1 Served Vol	Option A2 Served Vol	Option B1 Served Vol	Option B2 Served Vol	Option C1 Served Vol	Option C2 Served Vol	Option c1 Served Vol	Option c2 Served Vol
6:00 AM	2%	2%	2%	2%	2%	2%	2%	2%
7:00 AM	6%	5%	5%	5%	5%	5%	5%	5%
8:00 AM	3%	3%	3%	3%	2%	2%	3%	2%
9:00 AM	0%	0%	1%	1%	1%	1%	1%	0%
12:00 PM	4%	3%	2%	2%	2%	2%	2%	2%
1:00 PM	4%	1%	2%	3%	3%	2%	4%	2%
2:00 PM	1%	1%	1%	1%	1%	1%	1%	1%
3:00 PM	8%	8%	8%	9%	8%	8%	8%	8%
4:00 PM	30%	30%	31%	31%	30%	30%	30%	30%
5:00 PM	30%	30%	30%	30%	30%	30%	30%	35%
Total Unserved	10%	9%	9%	10%	10%	9%	10%	10%

Hours of Congestion

To better understand the amount of time a vehicle would be stuck in traffic, the Team evaluated the daily Hours of Congestion for each option on I-5 near the Broadway and Weidler overpasses. This analysis was based on VISUM data to help build the demand curve and VISSIM to help identify the capacity and congestion levels. Since the freeway has similar capacities for all the build options in this location, the hours of congestion are represented as No Build and Build, with No Build representing Option A1 and Option A2, and Build representing all other options. Graph 4 and Graph 5 show that the hours of congestion do not decrease significantly, but the hours of severe congestion or traffic demand above capacity decrease under the build scenario.



Graph 4 – Hours of Congestion for No Build Options



Graph 5 – Hours of Congestion for Build Options

Intersection Analysis

The Team analyzed the arterial network at the Broadway-Weidler Interchange to determine the operational performance of each option. The criteria for the overall performance included Level-of-Service (LOS) and vehicle delay at each intersection. The Team compared the criteria at an hour-by-hour level. The build options also included signal timing improvements. Intersection reconfigurations in conjunction with the signal timing improvements will generally lead to shorter delay periods for vehicles and safer continuous connections for bicyclists and pedestrians. Appendix H provides the summary of the intersection analysis.

Shoulder Benefits

This section compiles non-simulation based analysis and research to provide an operational summary of potential improvements due to adding wider shoulders along the length of the corridor within the project area. On I-5, the shoulder widths vary greatly along the corridor. Many locations have narrow shoulders, ranging from 4-ft. to 7-ft. wide in the northbound direction and 5-ft to 7-ft. wide in the southbound direction. These locations are proposed for widening in order to improve the operations, safety, and incident recovery time on this corridor.

Safety and Incident Recovery

When traffic incidents occur on a freeway, the size of the roadway shoulder can greatly impact the freeway capacity and cause delay long after that incident has occurred. Narrow shoulders inhibit efficient accident recovery, first by preventing emergency vehicles from quickly accessing the location and second by forcing accident recovery to remain on the mainline, thus closing one or more lanes[13]. For I-5, recent incidents and their subsequent recovery periods greatly reduce the capacity and increase delay along the corridor, which reduces overall travel time reliability. From 2011 to 2013, incident data was collected from ODOT for the I-5 mainline. These incidents are reported in Tables 12 and 13 below:

Table 12 - Average Time per Year Spent with One or More Lanes Closed

Direction	Average Incidents per Year	Average Hours of Delay per Year (days)
NB	40	164 (7)
SB	71	279 (11)

Source: ODOT Incident Reporting 2011 to 2013

These reported incidents occurred between the Greeley On-Ramp and the Morrison Off-Ramp in the southbound direction and between the I-84 On-Ramp and the Greeley Off-Ramp in the northbound direction. The amount of reported delay per incident shows the average amount of time incident response vehicles needed to clear the incident after arriving and does not include wait times before the response teams arrives or wait times from the vehicles in the spillback. When looking at the average amount of time lost on I-5 from lane closures, the delay per year are significantly high, as seen in Table 14. For one or more lanes closed per incident, drivers lost an average of almost 7 and 12 days of driving per year for I-5 Northbound and Southbound, respectively. Similarly, Table 15 shows the amount of delay spent during all medium and high impact incidents for the three year period.

Table 13 – I-5 Medium or High Impact Incidents 2011-2013

Direction	Lanes Affected	Number of Incidents	Average Minutes of Delay (hours)
I-5 Northbound	Zero lanes affected	20	234 (3.9)
	One lane affected	17	249 (4.2)
	More than one lane affected	6	240 (4.0)
I-5 Southbound	Zero lanes affected	27	237 (4.0)
	One lane affected	61	236 (3.9)
	More than one lane affected	9	240 (4.0)

Source: ODOT Incident Reporting 2011 to 2013

As shown, even when zero lanes are affected (or closed) because of the incident, the average incident delay can last up to four hours minimum. These incidents occur more frequently in the southbound direction, which is to be expected, but the average delay in the northbound direction is longer. The inside shoulder in the northbound direction is particularly narrow, only 4-ft. at many points, particularly between the I-405 Off-Ramp and the Greeley On-Ramp.

The Federal Highway Administration (FHWA) recommends a minimum shoulder width of 8-ft on the mainline in order to efficiently and safely facilitate traffic during roadway incidents. Currently, the I-5 Corridor has a varying range of shoulder widths along the length of the Study Area. In certain areas, the outer (right-side) shoulders are as narrow as 5-ft.and the inner (left-side) shoulders are as narrow as 4-ft. Conversely, portions of the freeway have shoulders as wide as 15-ft. Consistent and wide shoulders along the length of the corridor would greatly benefit drivers on the freeway and allow for smoother accident recovery, thus increasing the overall reliability of travel time. As cited in the Highway Capacity Manual (HCM) 2010, not only does the blocked lane reduce capacity, it reduces a percentage of capacity greater than the proportion of the roadway that is blocked. Drivers' reactions to blocked lanes such as partaking in "rubbernecking", where drivers slow to observe the incident, contribute to this high loss of capacity. The addition of shoulders restores 45% of lost capacity for two-lane freeways and 35% of lost capacity for three-lane freeways. This increase is shown below in Figure 10.

[13] http://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3_shoulderwidth.htm

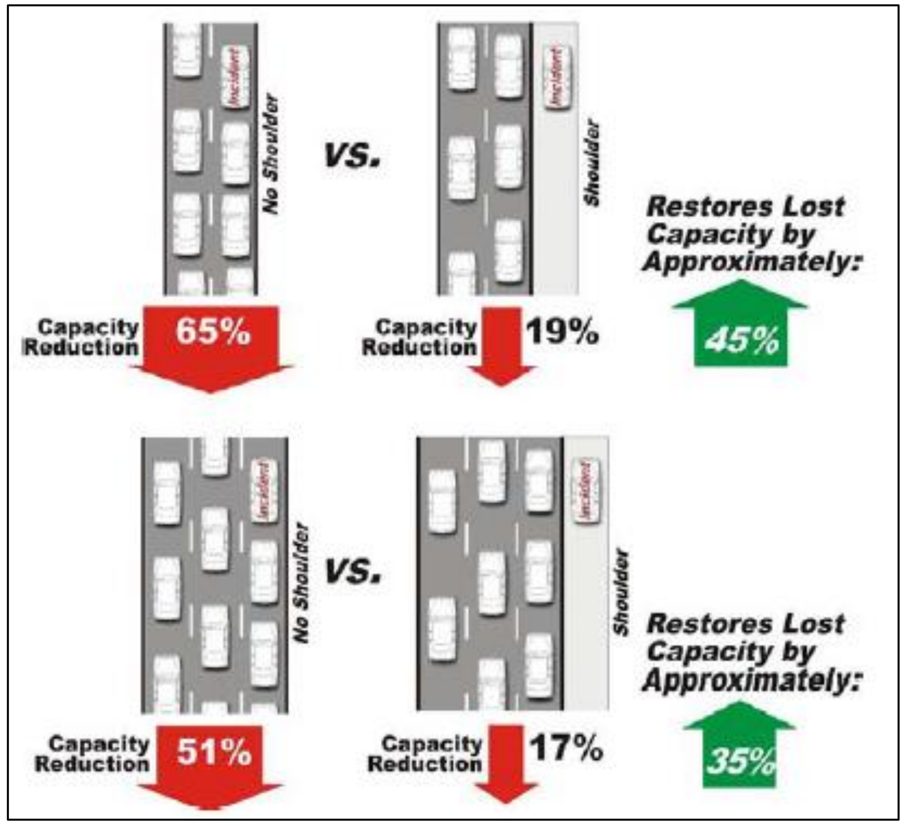
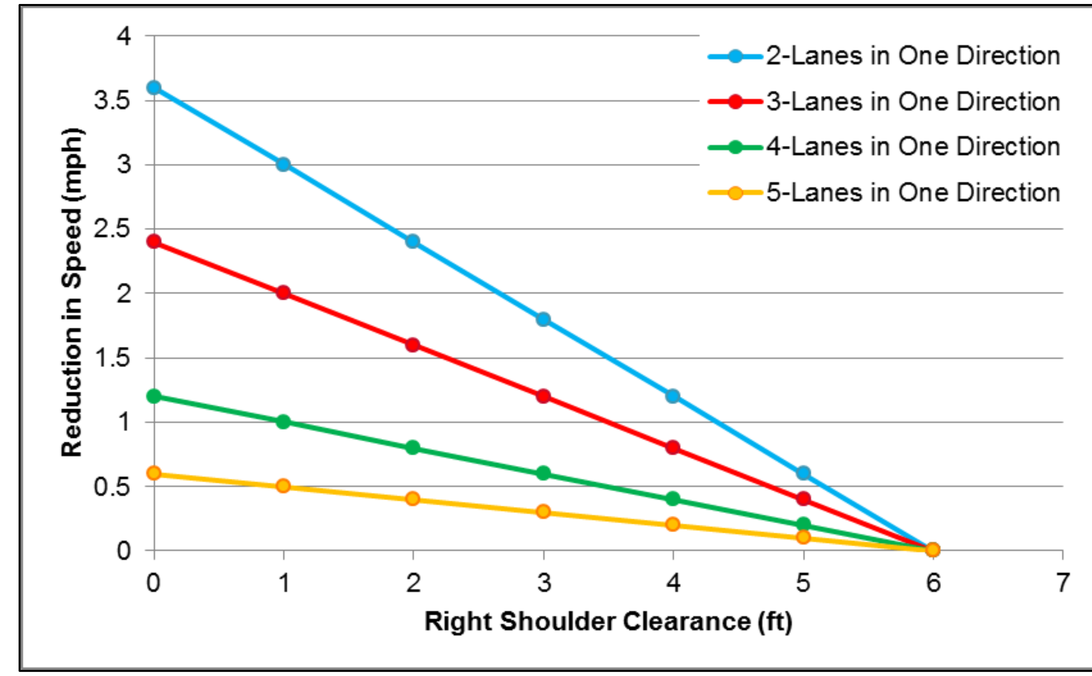


Image Source: OR 217 Interchange Management Study, DKS & Associates
Data Source: HCM 2010, Exhibit 10-17, Transportation Research Board

Figure 10 – Capacity Increase with Addition of Shoulder

Graph 6 – Linear Relationship of Free Flow Speed Reduction and Shoulder Width of Freeway



Data Source: HCM 2010, Exhibit 11-9, Transportation Research Board

Shoulder Widening

Shoulder width does not only impact the efficiency of accident recovery, but also plays a large role in the operational efficiency of a freeway during uninterrupted flow. As shown in Table 14 and Graph 6, as referenced from the HCM 2010 Manual, shoulder width greatly affects the free-flow speed of vehicles traveling on a freeway. Shoulder widths less than 6-ft. show a linear reduction in free flow speed for every foot lost of shoulder width. Based on this relationship, many sections of I-5 prevent vehicles from utilizing their maximum potential free flow speeds.

Table 14 – Operational Effects of Freeway Shoulder Widths

Right-Shoulder Lateral Clearance (ft)	Lanes in One Direction			
	2	3	4	≥5
≥6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

Data Source: HCM 2010, Exhibit 11-9, Transportation Research Board

It is recommended that wider shoulders be placed on both the right and left side of the I-5 Corridor. These shoulders will greatly improve travel time reliability, especially during incidents, and will reduce the delay across the length of the corridor.

Comparison of Alternatives

The following section provides side-by-side comparisons (Figures 11 through 14) of some key measures of effectiveness for each option with and without the two lane flyover. These measures are lane-by-lane speeds in the p.m. peak hour from 5:00 p.m. to 6:00 p.m. and the vehicle delay, emergency braking instances, and unmet demand, each for the 10-hour model period. Table 15 provides a summary of options compared with Option A1 – No-Build. These comparisons show whether each option performs worse, the same, or better than Option A2 for travel time, travel time reliability, speed, volume throughput, emergency braking incidents, congestion, and intersection analysis.

Figure 11 - Option A1 and Option A2

Figure 12 – Option B1 and Option B2

Figure 13 – Option C1 and Option C2

Figure 14 – Option D1 and Option D2

Table 15 – Design Options Summary

	Option A1	Option A2	Option B1	Option B2	Option C1	Option C2	Option D1	Option D2
Network Performance	○	◒	●	◓	◒	◒	○	◒
Travel Time	○	◓	◓	◉	◉	◉	◉	◉
Travel Time Reliability	○	○	◉	◉	◒	◒	◒	◉
Congestion	○	○	◒	◓	◓	◓	◓	◓
Spot Speed	○	◒	◓	◉	◓	◓	◓	◓
Percent Unmet Demand	○	◒	○	◉	◓	◓	◓	○
Emergency Braking	○	○	◓	○	◓	◉	◓	◉

◉ ◓ ○ ◒ ●

Better ⟷ **Worse**

Compared to Option A1 - No Build

APPENDIX A: I-5 BROADWAY WEIDLER FACILITY PLAN

APPENDIX B: VISSIM MODEL CALIBRATION METHODOLOGY AND RESULTS

APPENDIX C: EXISTING CONDITIONS DATA SUMMARY

APPENDIX D: TRAVEL TIME CONSISTENCY ANALYSIS

APPENDIX E: LANE-BY-LANE ANALYSIS

APPENDIX F: EMERGENCY BRAKING ANALYSIS

APPENDIX G: INTERSECTION ANALYSIS