

BUS ON SHOULDER FEASIBILITY STUDY:

Final Report

Prepared for: Southwest Washington Regional Transportation Council

May 2017



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EXECUTIVE SUMMARY

STUDY PURPOSE AND GOALS

The region has a growing travel demand challenge crossing the Columbia River. The Bus on Shoulder (BOS) Feasibility Study is one of several strategies that the Southwest Washington Regional Transportation Council (RTC) is studying to manage congestion. The I-205 Access and Operations Study recommendations called for examining the potential of buses using the freeway shoulder during times of heavy congestion. The purpose of the BOS Feasibility Study is to provide an evaluation on the application of BOS in the study corridors and potentially identify a BOS pilot project for implementation.

EVALUATION PROCESS

The primary focus of this BOS Feasibility Study's screening and evaluation strategies is to: (1) evaluate potential geometric and operational constraints, (2) identify opportunities (locations and time periods) for implementing BOS, and (3) develop planning-level estimates of potential benefits to understand fatal flaws and overall feasibility to determine whether more detailed considerations are warranted.



BOS EXAMPLES AND REQUIREMENTS

Several examples of BOS pilot projects are listed below; they provide valuable insights and lessons learned that have been incorporated into the BOS concepts for the I-205 and SR-14 corridors. These initial base assumptions and requirements are the principles that guided the BOS concept development. Examples are shown below:

BOS Pilot Project Examples to Reference

State	Location	Duration of Pilot	Legislation Required	Outcome of Pilot
Illinois	Chicago	3 years	Yes	BOS expanded
Virginia	Northern Virginia/DC	2 years	No	Results pending
Ohio	Columbus	2 years	No	BOS expanded
Florida	Miami	3 years	Yes	BOS expanded
California	San Diego	2 years	No	BOS expanded
Washington	Seattle	Sept. 2015	No	Results pending

Sample Base Assumptions/Requirements

Category	Recommendation
Operating Speeds	<ul style="list-style-type: none"> 35 mph maximum speed 15 mph maximum speed differential Buses can enter shoulder when speeds are < 35 mph
Geometric	<ul style="list-style-type: none"> Right shoulder widths (preferably 10 ft. or wider) Pavement depths within the shoulders are > 7 in. Vertical clearance within the shoulders is > 14 ft.
Operating Hours	<ul style="list-style-type: none"> No restrictions—available during any time transit service is in operation
Ramp Volumes	<ul style="list-style-type: none"> Ramp volume less than 1,500 vph
Merging	<ul style="list-style-type: none"> Bus drivers must yield to all traffic when entering the shoulder and when exiting the highway Specific merging requirements for project limits should be described No BOS on two-lane ramps
Incidents	<ul style="list-style-type: none"> Shoulders retain their priority purpose for stalled vehicles, crashes, and other incidents Buses should merge into general traffic at least 1,000' prior to any blockage of the bus shoulder by stopped vehicles
Safety	<ul style="list-style-type: none"> Bus drivers must be professional drivers with sufficient training in how to operate on a BOS

Learning from those regions that have already implemented BOS, it is important to emphasize these key areas in the community outreach and engagement:

- Education – explain the concept and provide resources
- Clarify the benefits to transit riders
- Illustrate the nuts and bolts of the pilot project (location, eligible users, operational rules, start date, and evaluation methods)
- Discuss the next steps for BOS in the region
- Highlight the cost-effectiveness of the strategy (both low infrastructure cost and reduced transit operating cost)
- Emphasize that BOS has proven to be safe
- Emphasize how BOS will be enforced
- Understand unique concerns of users and

EXISTING BUS ROUTES AND TRAVEL SPEEDS

Currently, C-TRAN operates four routes that use SR-14 and/or I-205: Route #41 SR-14 Limited, Route #65 Parkrose Limited, Route #164 Fisher's Landing Express, and Route #177 Evergreen Express. The Routes #164 and #177 afternoon peak service uses northbound I-5 to SR-14 in order to take advantage of the PM peak High Occupancy Vehicle (HOV) lane on I-5. Existing bus speeds are shown on the figure on the following page, with speeds at or below 35 miles per hour (mph) shown in red, indicating speeds when bus drivers could use the shoulder for BOS operations.



RECOMMENDATIONS

Based on the BOS operating protocols, existing geometry, and traffic conditions, BOS operations are recommended on SR-14 from I-205 to 164th Avenue and on segments of I-205 from SR-14 to I-84. The recommended segments require relatively little modification of the exiting roadway and fall within the minimal or low cost parameters of the study, which are defined as follows:

- **Minimal Cost Concepts:** Use of existing roadway width with improvements limited to signing and striping changes. Segments generally meet minimum screening requirements.
- **Low Cost Concepts:** Widening/strengthening of roadway surface for short segments, minor adjustments to ramp merge/diverge points, queue jumps on ramps and signing and striping changes. Segments generally meet minimum screening requirements with the exception of shoulder width.

The BOS design and bus operating parameters for all recommended segments allow the bus to merge onto the shoulder at any point past the beginning of the BOS designation, when the operating speeds of the general purpose lane drop below 35 mph and there are no obstructions on the shoulder. Bus drivers will merge out of the shoulder to maintain shoulder priority for breakdowns and emergency response.

SR-14 BOS

Both the minimal and the low cost BOS concepts were evaluated for SR-14 between I-205 and 164th Avenue. For SR-14 westbound, the low cost option is recommended, because it provides better transit operations and additional travel time savings with only minor restriping in the corridor.

- **Minimal Cost Concept**
 - SR-14 westbound from west of the 164th Avenue entrance ramp lane to gore area next to I-205 northbound exit.
 - SR-14 eastbound from acceleration lane of the I-205 entrance ramp to 1,000 feet before the 164th Avenue exit ramp.
- **Low Cost Concept**
 - Restripe the 164th Avenue entrance ramp to allow buses to travel from the existing bus only lane directly into the SR-14 BOS lane and extend the westbound BOS approximately 1,000 feet to the west by restriping lanes on the collector-distributor (C-D) lane to allow for BOS on the C-D shoulder between the I-205 northbound exit and entrance ramps to SR-14 westbound.

I-205 BOS

Due to geometric constraints, only portions of I-205 are recommended for BOS operations. The recommended BOS corridor for I-205 northbound has one segment from Airport Way to SR-14. The BOS corridor for I-205 Southbound extends from SR-14 to I-84, with BOS operations recommended on four segments. All the I-205 recommended segments are minimal cost segments.

- Southbound I-205 BOS corridor from SR-14 entrance to Westbound I-84 exist with four operating segments
 1. SR-14 entrance to 1,000 feet before Airport Way exit
 2. Airport Way exit to Airport Way eastbound entrance
 3. I-84 eastbound exit to I-84 westbound entrance
 4. I-84 westbound entrance to I-84 westbound exit
- Northbound I-205 BOS corridor has one segment from Airport Way entrance to 1,000 feet before SR-14 exit

COSTS

The recommended BOS corridors are relatively low cost; they consist primarily of signing and striping improvements with some strengthening of drainage structures where needed. Planning-level cost estimates are under \$100,000 for constructing all of the recommended segments on both SR-14 and I-205.

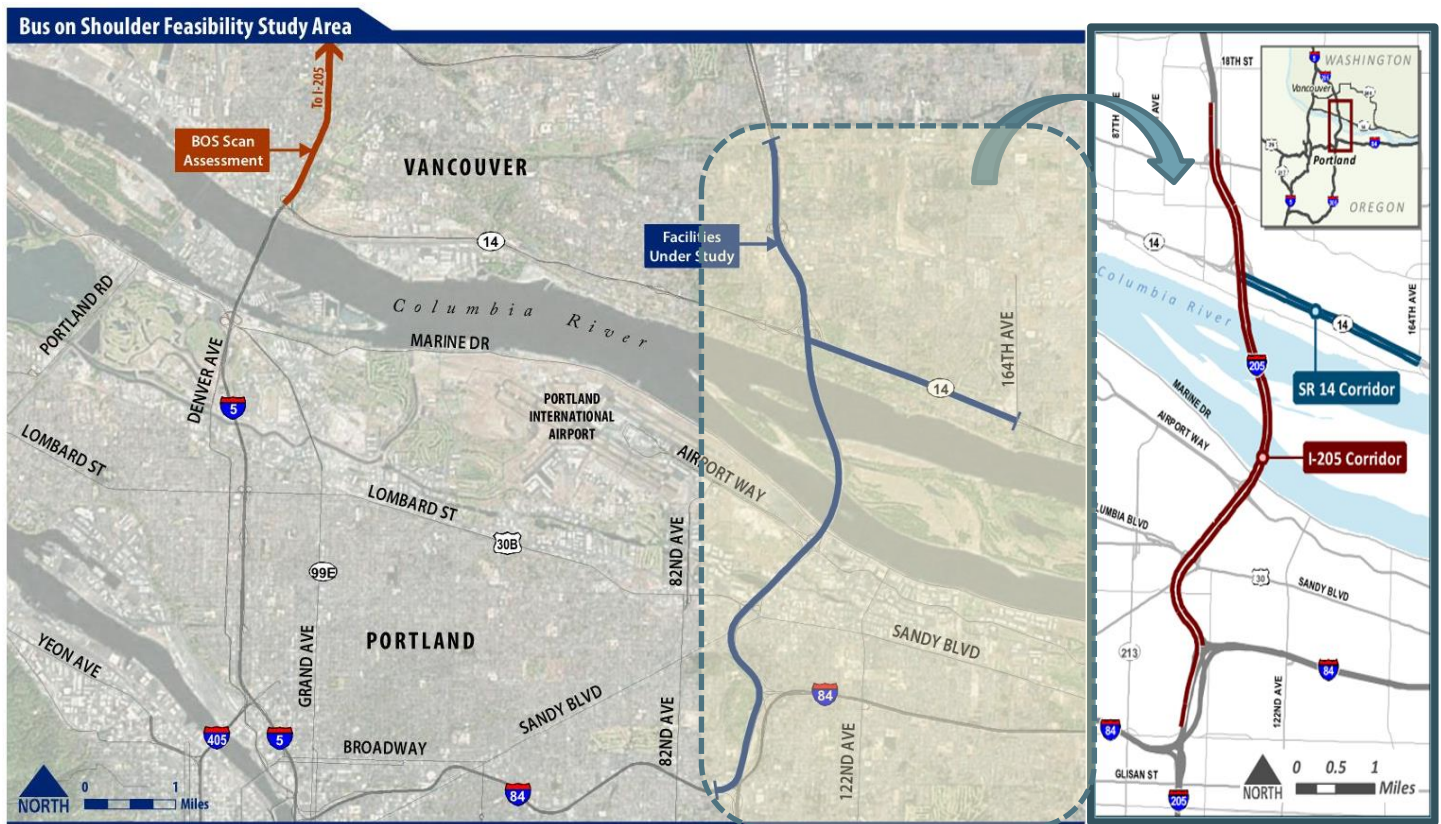
PROJECT BACKGROUND

PROJECT BACKGROUND AND STUDY AREA

As a response to growing congestion and in recognition of the need to develop multi-modal approaches to address the issue, regions throughout the U.S. are looking for low-cost and innovative transportation solutions that can provide real options for commuters seeking relief from congestion. The bus on shoulder (BOS) concept is one key strategy that is beginning to be adopted in several states. First started in Minnesota 25 years ago, the concept has since been deployed in 11 states including California, Colorado, Delaware, Florida, Georgia, Illinois, Kansas, Maryland, New Jersey, Virginia, and recently in Washington in the Seattle region.

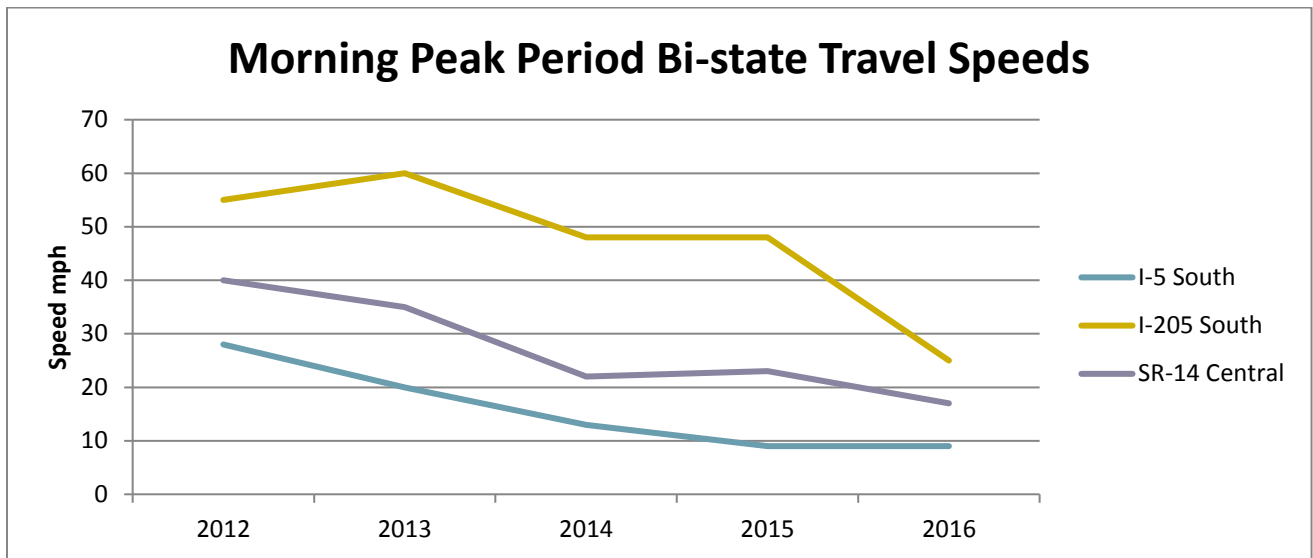
As shown in Figure 1, the study area encompasses the I-205 corridor from the 18th Street interchange south through the I-84 interchange to Glisan Street and on SR-14 from I 205 to the 164th Avenue interchange. SR-14 is included because of its high congestion levels and the significant number of buses traveling between the Fisher’s Landing Park and Ride and Portland that use SR-14. Lessons learned from this feasibility study area will be used to conduct a higher level scan assessment of the technical issues and physical characteristics associated with potential BOS operations on southbound I-5 from 99th Street to SR-14. The findings of the scan assessment are in Appendix A of the report.

FIGURE 1: STUDY AREA



Crossing the Columbia River has been a regional transportation challenge for many years. Over the last five years bi-state travel demand and associated congestion has been increasing resulting in higher travel times and reduced travel speeds, as shown in Figure 2. Regional population grew by approximately 41,000 between 2014 and 2015, indicating the travel demand across the river is going to continue to increase.

FIGURE 2: MORNING PEAK PERIOD BI-STATE TRAVEL SPEEDS



With no current major investments planned for the I-5 or I-205 Columbia River crossings, the region is conducting several studies to identify strategies to improve the efficiency of the existing transportation system to move people across the river:

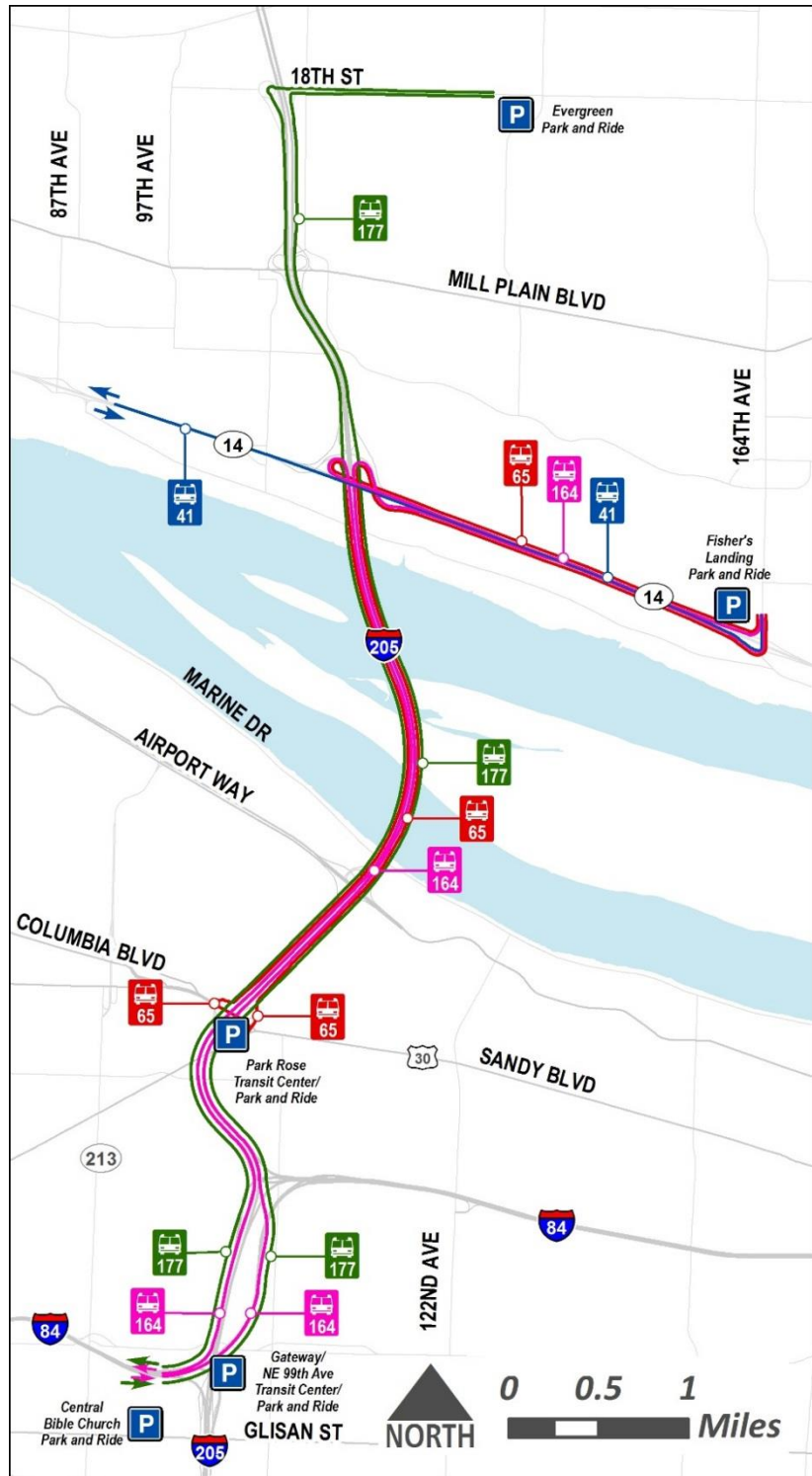
- The Washington State Department of Transportation is leading a study to analyze the benefits and impacts of ramp metering on Clark County freeways.
- RTC has funds programmed for an operations study that would look at ways to manage the region’s urban freeways more effectively that would incorporate results of the ramp metering study, and evaluate advanced traffic management, variable speeds, incident management, and other operational and high tech strategies.
- The Oregon Department of Transportation (ODOT) has a project programmed for construction in 2018 to add northbound auxiliary lanes on I-205 between I-84 and Killingsworth.
- Finally, a BOS Feasibility Study is to examine a transit option that can offer improved mobility and efficiency for transit.

CORRIDOR BUS SERVICE

As shown in Figure 3, C-TRAN operates four routes in the study area. The ridership on these routes is heaviest westbound on SR-14 and southbound on I-205 in the morning and northbound on I-205 and eastbound on SR-14 in the afternoon. The four routes are:

- Route #41 SR-14 Limited.** This route operates between Fisher's Landing Transit Center (TC) and downtown Vancouver. There are three westbound and eastbound trips per weekday.
- Route #65 Parkrose Limited.** This route operates daily between the Fisher's Landing and Parkrose TCs. Service is all day with 15-min frequencies during the weekday peak and 30-min frequency middays and weekends.
- Route #164 Fisher's Landing Express.** This route operates peak hours on weekdays between the Fisher's Landing Transit Center and downtown Portland. There are 24 southbound and 30 northbound trips per day. The afternoon peak service uses I-5 to SR-14 to take advantage of the PM peak HOV lane on I-5 northbound.
- Route #177 Evergreen Express.** This peak hour route operates 4 southbound and 4 northbound trips on weekdays. Service is between the Evergreen Park and Ride and downtown Portland. The afternoon peak service uses I-5 to SR-14 to take advantage of the PM peak HOV lane on I-5 northbound.

FIGURE 3: EXISTING C-TRAN BUS ROUTES



NATIONAL EXPERIENCE WITH BOS

Bus on Shoulder utilizes existing infrastructure to create a new transitway on shoulders of congested highways. The driver of the bus utilizes the shoulder whenever the speed of the general lanes drops below a threshold set by the operating policy. Often, only minimal infrastructure investment is required to implement a BOS facility. Coupled with policy and necessary legal frameworks, the BOS concept can be developed and deployed relatively quickly. It should be noted that BOS facilities can be deployed more rapidly than the broader hard shoulder running (HSR) concept, because HSR allows a broader set of vehicles to use the facility, and added safety features, such as wider shoulders, intelligent transportation systems, and signing are required for safe operations of HSR.

The concept of BOS has been around for more than two decades; however, most BOS facilities are relatively new. This slow adoption of the BOS concept nationwide is often attributed to concerns with the perceived safety of repurposing a shoulder for use by buses. The concerns with BOS are typically centered on the narrow width of shoulders, the need for using the shoulder for breakdowns or incidents, and the safety of merging at ramps and interchanges. The safety of BOS operation has already been demonstrated in several regions; Minnesota recorded less than 20 crashes over 10 years on system of nearly 200 BOS lane miles; a three year evaluation in Miami showed no increase in crashes with BOS; and Puget Sound has had 3 and a half miles of BOS in operation on I-405 since September 2015 and reported no changes to safety.

As regions begin to consider BOS facilities, experience throughout the country indicates that a BOS facility should first be implemented as a pilot project in order to build public knowledge and understanding. A pilot project communicates to stakeholders and the public that the concept is new, that the concept will be tested and evaluated, and that the results of the evaluation will determine whether the concept becomes a permanent feature. The results of the evaluation determine whether the BOS concept, as designed and operated, requires modification and whether it merits expansion to other areas. Summaries of some of the pilot project implementations around the country are described in Table 1 and the following paragraphs below. All pilot BOS projects have the following common elements:

- They were developed by a multi-agency stakeholder group including operators and facility owners, Metropolitan Planning Organizations, and the Federal Highway Administration (FHWA);
- They had a set time frame for implementation and evaluation;
- They used the pilot project as the mechanism for developing common operating procedures;
- They utilized the pilot project to develop communications for introducing the concept to the region;
- The pilot project did not lead to any safety issues that required changes; and
- The pilot project led to BOS becoming a permanent part of the pilot corridor infrastructure and led to expansion of the BOS program to more facilities.

TABLE 1: CHARACTERISTICS OF PILOT PROJECTS

State	Location	Duration of Pilot	Legislation Required	Outcome of Pilot
Illinois	Chicago	3 years	Yes	BOS expanded
Virginia	Northern Virginia/DC	2 years	No	Results pending
Ohio	Columbus	2 years	No	BOS expanded
Florida	Miami	3 years	Yes	BOS expanded
California	San Diego	2 years	No	BOS expanded
Washington	Seattle	Since Sept. 2015	No	Pending

ILLINOIS PILOT

The Illinois Department of Transportation (IDOT), in partnership with the transit operator PACE, created a pilot BOS project on I-55 in the Chicago region. The pilot project lasted three years and was comprehensively evaluated. To support the BOS Pilot Concept, IDOT invested \$9.5 million to enhance the shoulders to handle heavy coach buses operated by PACE. Results of the pilot included an improvement in on-time performance from 68% to 93% and an increase in ridership of 226%. The pilot was initiated through adoption of a state statute that defined the duration of the pilot project and the authority of agencies to develop rules for operation of the pilot. Based on the success of the pilot, the BOS statute was modified to make the program permanent and expand the areas that could have BOS facilities.

VIRGINIA PILOT

The Virginia DOT (VDOT) began a pilot BOS program in March 2015. This pilot operation started after a three-year planning and project development process. The planning process reviewed regional highway operations and identified locations where reoccurring congestion was causing delays for buses and impacting the ability of buses to maintain their route schedules. In the planning phase, a stakeholder group consisting of members from the Metropolitan Planning Organization (MPO), FHWA, transit operators, and VDOT reviewed and prioritized locations for BOS. The prioritization process categorized segments by the cost to implement (low/medium/high). The stakeholder group also developed the policies and procedures for BOS operations.

In the spring of 2015, a one-year pilot operation was initiated on over 6 miles of I-66 in northern Virginia. The evaluation of the pilot is currently underway and will be based on results of surveys of bus operators, bus riders, VDOT staff, and police with jurisdiction on the highway.

OHIO PILOT

In 2006, a partnership of the Mid-Ohio Regional Planning Commissioner, the Ohio Department of Transportation, FHWA, local and state policy, and the Central Ohio Transit Authority developed a Bus on Shoulder Pilot Program for the Columbus region. The pilot was intended to test the feasibility of operating transit on the shoulders. The program was set up as a pilot project, and evaluated for safety, traffic impacts, operator and passenger opinions, and the overall impact on highway performance. The results from the evaluation concluded that the pilot was a success. Overall, the bus schedules were better able to be maintained, on-time performance improved, and riders had a favorable response to the program. Based on the pilot, the pilot area BOS continued, and BOS was expanded to two other corridors.

SEATTLE

The Washington DOT (WSDOT) has a BOS corridor operating along southbound I-405 in Bothell from the SR-527 on-ramp to the NE 195th Street off-ramp and from the SR-522 on-ramp to the NE 160th Street off-ramp. Planning started in 2009 with Sound Transit, King County Metro, and Community Transit on the details of the I-405 eastside express toll lanes, which encompassed 14 recommendations including shoulder transit lanes. The BOS system operates from 6 a.m. to 9 a.m. only when regular traffic is running at or below 35 mph.

BOS OPERATING CONCEPTS AND PROTOCOLS

INSIDE OR OUTSIDE SHOULDER

Bus on shoulder facilities can be located on the right or left shoulder of a highway. Factors considered in determining which shoulder to use include shoulder width, bus entry and exit locations on the facility, and interchange merging conditions. The most common application is to have the bus operate on the right shoulder. The right shoulder is preferred because buses typically enter and exit the facility on the right side. Left-hand shoulder operations require buses to weave across several lanes of traffic once entering the highway or to exit the highway. In addition, when operating on the right shoulder, the bus driver is better able to operate the bus on the narrow shoulder, because the general traffic is to the driver's immediate left side, making it easier to maintain safe separation from the traffic. Operations on the left shoulder do have the advantage of eliminating conflicts at merge points along the facility.

For SR-14, the right shoulder is the most appropriate shoulder for BOS, because the buses enter and exit on the right side of the facility and the right shoulder has sufficient width to handle buses. The left shoulder of SR-14 does not have sufficient width to accommodate buses. Even if the left shoulder were geometrically sufficient, it would require buses to weave across two lanes of traffic upon entering SR-14 and weave back across two lanes of traffic to reach the exit to I-205. These weaves would need to be accommodated in a relatively short length of the BOS, making the left shoulder use an impractical option.

For I-205, the right shoulder is also the best option for the BOS, because the buses using the facility enter and exit I-205 on the right. However, the right shoulder does have locations where it is less than 10 feet in width. If there is no option for establishing 10-foot-wide sections in these narrow shoulder areas, then the right shoulder will have some areas where buses will need to merge back into traffic. There are sufficient left shoulder widths in over half of the I-205 study corridor area to use as an option for BOS; however, because of the need for buses to weave across three or four lanes of traffic and back to use the left shoulder, the use of the left shoulder is not practical.

In locations where shoulders are too narrow for buses or there are multi-lane ramps, or other conditions that require buses to merge out of the BOS, a sign is placed at the designated merge point to help bus drivers know when they should reenter the general traffic exit lane.

CRITERIA FOR USE OF SHOULDER

PERMITTED SERVICES

As shown in Table 2, options exist for the types of bus service that can utilize BOS. The decision is defined by the facility owner and transit operators. Typical implementations of BOS restrict the use of the shoulder to fixed-route transit services only. There is no infrastructure condition that would make a privately operated bus, school bus, or para-transit bus unable to use the shoulder. However, these types of services are not typically allowed because of issues in providing driver training and implementing consistent operating procedures, and the ability to monitor operations of the service compared to what is possible with fixed-route drivers.

TABLE 2: PERMITTED TRANSIT SERVICES

	Typical BOS Criteria for Consideration	Recommended Elements for BOS Implementation
Permitted Vehicles/Services	Potential BOS vehicles: <ul style="list-style-type: none"> • Regular route buses • Privately operated uses • School buses • Para-transit 	<ul style="list-style-type: none"> • Regular route bus service only

OPERATING HOURS AND SPEEDS

Operating hours and operating speeds of BOS facilities are set by the BOS policy and are based on infrastructure and safety. Hours of operation can have fixed hours or can be allowed throughout the day based on adjacent traffic speeds. (Figure 4 provides examples of how each possibility would be signed within the corridor). If hours are not posted, then the BOS is available for bus use at any time that conditions warrant use. Facilities with fixed hours typically set the hours based on the AM and PM peak periods when reoccurring congestion exists. The most flexible option is to not limit the hours of use of the facility. This allows buses to use the shoulder in typically uncongested times if there is an incident, construction, or weather event that is causing congestion. Leaving the hours unrestricted also maintains flexibility for use as traffic congestion levels change.

The appropriate operating speeds of buses must be defined in policy, emphasized in training, and monitored in operation. National experience in BOS operations has settled on conditions that have proven safe. The policy on operating speeds includes the maximum speed a bus can operate on a shoulder (35 mph), the maximum speed differential between the bus on the shoulder and the adjacent travel lane (15 mph), and the speed of traffic when a bus should consider using the shoulder. There are examples where the maximum allowable bus speed is 45 mph; however, in those instances there have been at least 12-foot shoulders.

The maximum speed is limited to a level below posted speed, because the bus is operating on a narrow shoulder; it must be prepared to encounter and weave around stopped vehicles on the shoulder; and as a safety precaution it must be able to adjust to merging traffic from ramps. A speed of 35 mph has proven to be safe for a 10-foot shoulder, which is the most common shoulder width in the region. Limiting the speed differential between the bus and adjacent traffic is a best practice supported by experience and recommendations of traffic safety experts. It is the responsibility of the bus drivers to judge what speed is safe to operate at in the conditions and to determine if they are operating within the maximum 15 mph differential.

The final speed criterion centers on when a bus should leave the travel lane and utilize the shoulder. Typically, when conditions drop below 35 mph, bus drivers should consider use of the shoulder if it is clear of stopped vehicles and it makes sense to use the shoulder for the route the bus is on. Once on the shoulder, if traffic conditions in the adjacent lane increase above 35 mph, then the bus may reenter the regular travel lane in order to travel at a faster rate or remain on the shoulder if downstream conditions appear to be slowing or if the bus is exiting the facility within a short distance (typically 1 mile or less). Table 3 provides a summary of BOS operating speed criteria.

TABLE 3: BOS OPERATING HOURS AND SPEED CRITERIA

	Typical BOS Criteria for Consideration	Recommended Elements for BOS Implementation
Operating Hours	<ul style="list-style-type: none"> Option 1: Fixed hours Option 2: No restrictions on hours 	<ul style="list-style-type: none"> No restrictions—available during any time transit service is in operation
Operating Speeds	<ul style="list-style-type: none"> Maximum speed ranges from 25 to 45 mph Maximum speed differential between shoulder and adjacent lane is 10 to 15 mph 	<ul style="list-style-type: none"> 35 mph maximum speed 15 mph maximum speed differential Buses can enter shoulder when speeds are below 35 mph

SIGNING AND PAVEMENT MARKINGS

Signing and pavement markings are the key component of a BOS facility. Because the BOS is operating on an existing shoulder that has pavement markings indicating it is a shoulder, no added pavement markings are required to designate it as a BOS.

The BOS projects generally require the addition of regulatory and warning signs. The regulatory signs designate the areas where BOS is allowable, and can designate allowable hours and eligible users. The warning signs advise drivers that buses may be present on the shoulder, and advise drivers about merging and yielding in the BOS area.

Figure 4 provides example of some of the regulatory and warning signs that are generally used for BOS.

FIGURE 4: SIGN OPTIONS FOR BUS ON SHOULDER CORRIDORS





 <p><i>This regulatory sign is placed on the right shoulder at locations along the BOS corridor. This is one of two options that authorize buses to use the shoulder.</i></p> <p><i>Note: This sign is repeated approximately every half mile between the start and end of the BOS.</i></p>	 <p><i>This regulatory sign is placed on the right shoulder at locations along the BOS corridor. This is the second of two options that authorize buses to use the shoulder. This option is used in Seattle on I-405. AM and PM peak hours could be displayed.</i></p>
 <p><i>This regulatory sign, in combination with the Shoulder Authorization sign, is placed at the beginning of the BOS.</i></p>	 <p><i>This regulatory sign, in combination with the Shoulder Authorization sign, is placed at the end of the BOS.</i></p>

FIGURE 4: SIGN OPTIONS FOR BUS ON SHOULDER CORRIDORS (CONTINUED)



INTERCHANGE WEAVE STRATEGIES

For each BOS facility, the transit operating agency and facility owner should develop the weaving strategies for buses at each interchange. The strategy should define areas where buses need to merge back into general traffic and areas where it is safe for buses to remain on the shoulder through the entrance and exit locations.

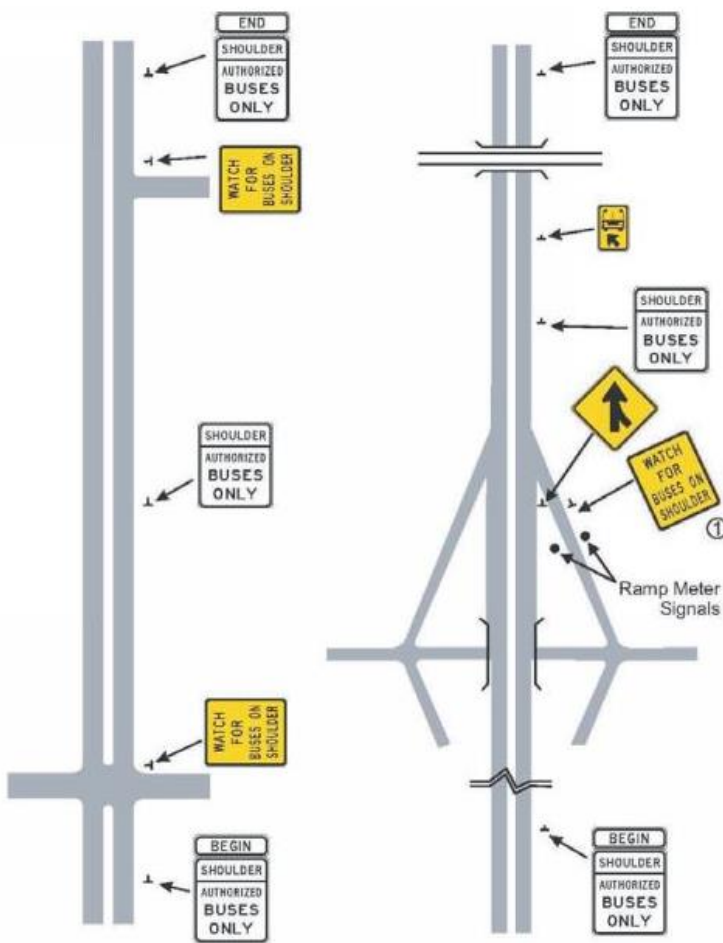
Rule-of-thumb guidelines with a foundation in the ramp volumes were developed in Minnesota and can provide guidance for the weave strategies. Bus on shoulder ramp weaves are generally not an issue for any ramp volume below 1,000 vehicles per hour (vph). Ramps with volumes of 1,000 to 1,500 vph become challenging and require a judgment on the local conditions to determine if the bus should merge back into traffic. For ramps with volume over 1,500 vph, the buses in practice do not use the shoulder in the interchange area. Because traffic volumes vary by time of day, there may be times when it is safe for buses to remain on the shoulder traveling past the higher volume ramps. The bus driver is responsible for making decisions based on what is the safest operation as merging and weaving conditions change on a ramp. Note that BOS use across double-lane on- and off-ramps is not considered a safe operation, no matter the ramp volume.

An alternative operating option for weaving area is for the standard practice to be that buses remerge into general purpose traffic lanes in advance of interchange off-ramps and do not re-enter the shoulder until after the on-ramp weave. This practice would minimize motorist surprise at these interchange weave areas, but it could also limit the travel time savings of the BOS facility.

Bus on shoulder operating policies should specify whether the bus driver is to yield to other vehicles entering or exiting the traffic. Common practice is that the buses must yield to traffic; however, some BOS implementations require entering vehicles to yield to buses on the shoulder. In general, bus drivers are in the best position to yield to other traffic, because they are seated higher than most vehicles and therefore command a better view of traffic conditions and merging and exiting traffic.

As shown in Figure 5, warning signs are posted on the entry ramp that warn motorists of buses using the highway shoulder. The warning signs state, “WATCH FOR BUSES ON SHOULDER” in black text on a yellow background. During heavy traffic periods, entry ramps may also experience high traffic volumes. The gaps available for a transit vehicle to continue its trip on the shoulder may be very small if ramp volumes are very high and traffic is entering the highway in tight platoons. In these conditions, buses can merge back into traffic or reduce speed and find a gap in the platoons of traffic. Ramp meters could also be used to help reduce platooning and increase gaps. The ability of bus drivers to see vehicles on entry ramps from the shoulder should be reviewed and stopping sight distances determined. Where adequate stopping sight distance does not exist, bus speeds should be reduced or the roadway should be modified to provide adequate sight distance for buses traveling at 35 mph.

FIGURE 5: EXAMPLE SIGNAGE FOR BOS OPERATIONS



NOTE:
 ① The WATCH FOR BUSES ON SHOULDER signs shall be located beyond the ramp meter signals.

Source TCRP Report 151: A Guide for Implementing Bus on Shoulder (BoS) Systems

GEOMETRIC DESIGN REQUIREMENTS

Table 4 below documents recommended design standards for a BOS facility. The standards are based on requirements established by the Minnesota DOT and AASTHO, and have been adopted by several other state departments of transportation for their BOS facilities.

TABLE 4: STANDARD DESIGN CRITERIA FOR BOS FACILITY

Controlling Geometric Design Criteria	Standard	Notes:
Design Speed, mph	35	<ul style="list-style-type: none"> Maximum speed for buses traveling on shoulder, as per operational policy
Shoulder Width, ft.	10.0	<ul style="list-style-type: none"> 10.0 ft. minimum (11.5 ft. with barrier), 12.0 ft. desirable
Shoulder Depth, in.	7	<ul style="list-style-type: none"> 6 in. minimum, 7 in. desirable
Bridge Width, ft.	11.5 12.0	<ul style="list-style-type: none"> 11.5 ft. minimum, 12.0 ft. desirable 12.0 ft. required in areas of new construction or reconstruction
Grades, max. %	No Change	<ul style="list-style-type: none"> No change ; match existing roadway
Horizontal Alignment, radius, ft.	No Change	<ul style="list-style-type: none"> No change ; match existing roadway
Vertical Alignment, minimum K value	No Change	<ul style="list-style-type: none"> No change ; match existing roadway
Stopping Sight Distance, ft.	250	<ul style="list-style-type: none"> Stopping Sight Distance based on 35 mph design speed
Vertical Clearance, ft.	14	<ul style="list-style-type: none"> AASHTO's A Policy on Geometric Design of Highways & Streets, Chapter 7 Tallest design vehicle is 10 ft. 9 in.
Horizontal Clearance to Obstructions, ft.	0	<ul style="list-style-type: none"> AASHTO's A Policy on Geometric Design of Highways & Streets, Chapter 8 2 ft. beyond edge of shoulder is preferable

IDENTIFICATION OF BOS RISKS AND MITIGATION STRATEGIES

As shown in Table 5, bus on shoulder programs have few risks and these are generally known based on previous implementation experiences.

TABLE 5: RISKS AND MITIGATION STEPS FOR BOS PROJECT IMPLEMENTATION

Risk	Mitigation
Project costs are not secured	<ul style="list-style-type: none"> Identify full project costs Secure funding agreements for all elements of implementation prior to project start
Shoulder infrastructure is inadequate to handle buses	<ul style="list-style-type: none"> Conduct investigations of infrastructure to verify conditions Program infrastructure upgrades, if necessary, to sustain BOS in long term
Safety issues result in negative perception of project	<ul style="list-style-type: none"> Provide effective training of bus drivers Inform traveling public of the new service and how it operates Closely monitor BOS operations Investigate all incidents involving buses and determine if changes are needed Clearly document safety findings in evaluation and communicate these results
Expected benefits of project are not realized	<ul style="list-style-type: none"> Select a corridor that will likely have clear benefits from BOS before implementing area-wide BOS strategy Build an evaluation that includes both quantitative and qualitative data (survey data of transit riders) to clearly document benefits

EXISTING CONDITIONS

EXISTING GEOMETRY

Figure 6 and Figure 7 provide a summary of the existing geometry on the study area corridors. I-205 has multiple segments in both directions that have shoulders less than the minimum width of 10 feet and would need restriping or roadway widening for BOS operations. There are also five southbound and three northbound dual lane entry or exit ramps, which exclude BOS operations.

The majority of the shoulders on the Washington side from the Bridge to Mill Plain Blvd are constructed of asphalt paving over asphalt treated base. Little is known, by the BOS team, regarding the structural characteristics of this particular pavement section however, the pavement shows transverse cracking with grass growing in the cracks in many areas. It is very unlikely that this pavement section would be suitable for carrying bus traffic without being rebuilt. Given the geometric constraints, BOS operations are only feasible on some segments of I-205 without capital investments to meet minimum BOS operating protocols.

The geometrics on the SR-14 corridor are more favorable for BOS operations given the study area corridor is between two interchanges and there are only three small areas where the outside (right) shoulder is less than 10 feet wide. In all three cases a 10 foot shoulder, or 11.5 foot shoulder in the case of areas with guardrails, can be provided through restriping of the existing lanes.

FIGURE 6: I-205 GEOMETRICS

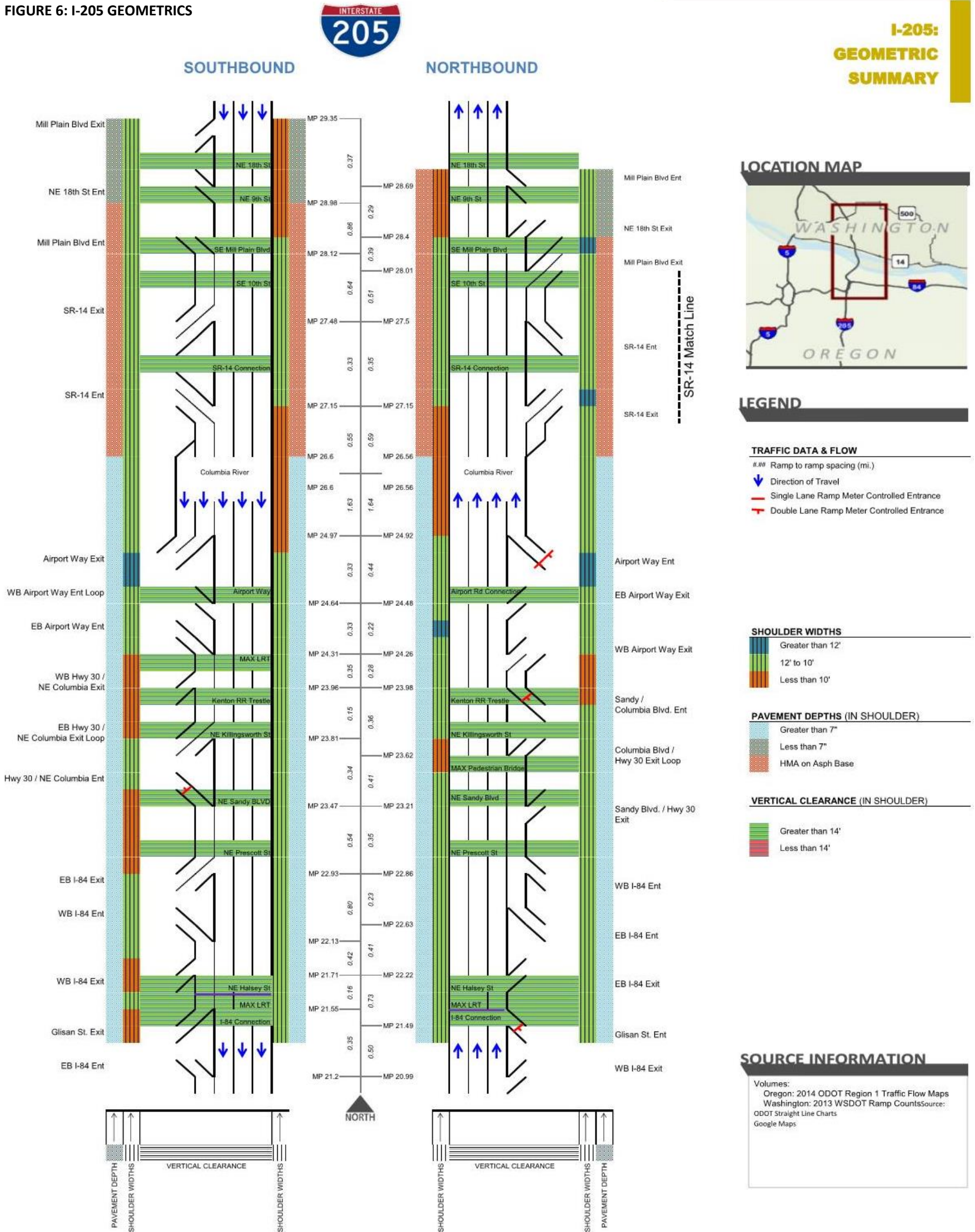
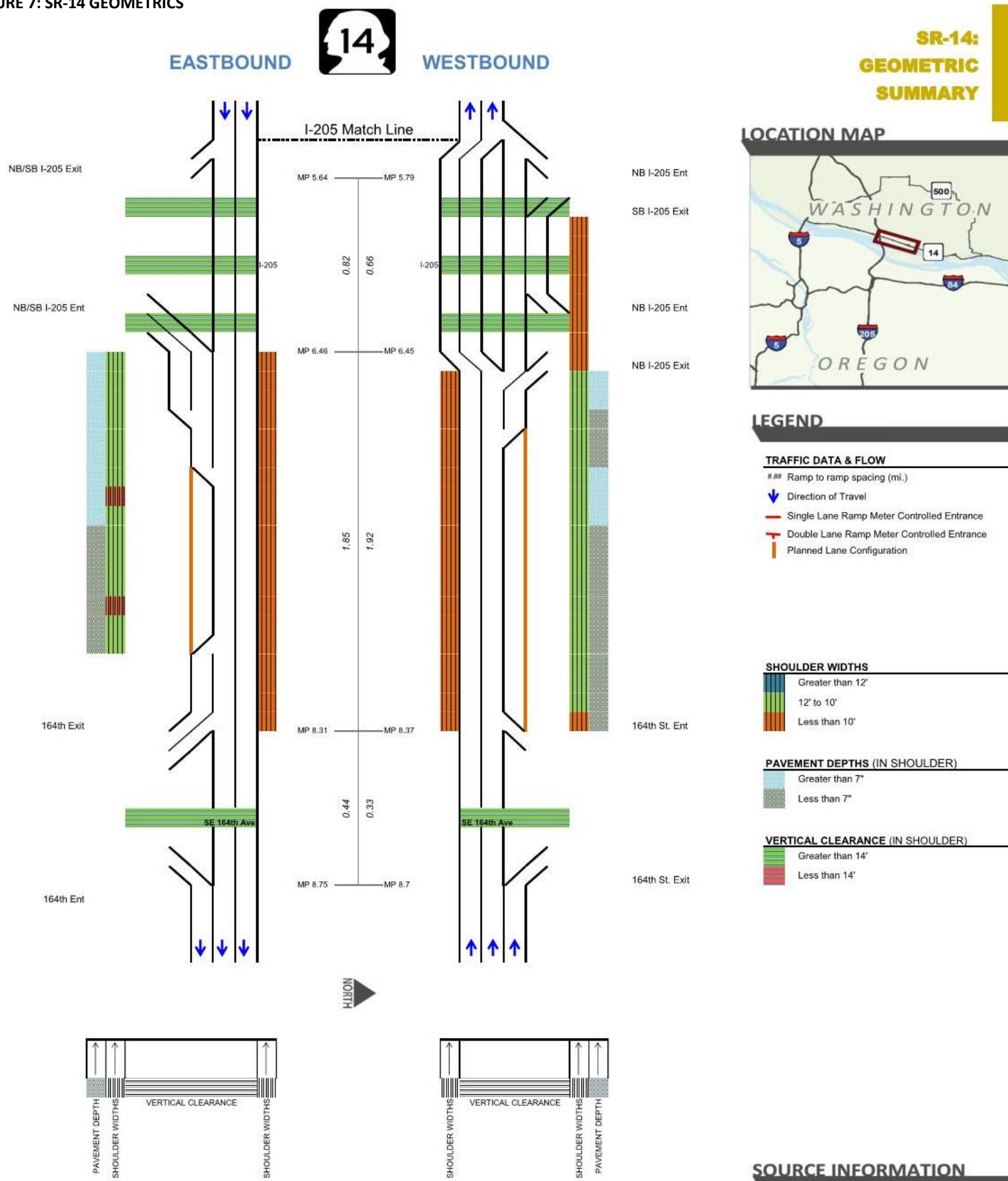


FIGURE 7: SR-14 GEOMETRICS



TRANSIT SERVICE PLAN

A BOS facility can improve the bus travel times and on-time performance of routes. In the deployment of BOS, consideration should be given to determine whether the transit service schedules for the routes that will benefit from BOS would need adjustment. If service times need adjustment, then sufficient advance notice to riders is required and could impact the schedule of the BOS start-up. The Workshop packet in Appendix B provides initial discussion of BOS impacts on Transit Service Plans, which were refined after the workshop.

CURRENT TRAVEL TIME AND SERVICE RELIABILITY

The scheduled travel time for the #65 Parkrose Limited is 12 minutes southbound and 17 minutes northbound during peak travel times, and 10 minutes for southbound and 14 minutes for northbound travel during the weekday midday. This difference in scheduled time (2 minutes southbound and 3 minutes northbound) between peak hour, peak direction flow and midday travel can be considered an estimate of the partial impact of peak period congestion on the route’s travel time. The full impact of congestion is highly variable and C-TRAN mitigates the travel variability by using an extra bus during the PM peak compared to the AM peak.

The comparison of the scheduled and actual travel times is shown in Table 6. The table also includes the standard deviation for the travel times. Standard deviation is a measure of how widely values deviate from the average, which, for travel time, makes it a measure of service reliability. In the table below, the standard deviation indicates the minutes (plus or minus) that about two-thirds of the trips are within the average travel time. For example, the average AM peak southbound travel time on the #65 Parkrose Limited is 12.1 minutes. A standard deviation of 1.9 means that about two-thirds of the trips are plus or minus 1.9 minutes from that average (between 10.2 and 14.0 minutes). The other one-third of the trips take less than 10.2 or more than 14.0 minutes.

TABLE 6. SCHEDULED AND ACTUAL TRAVEL TIME

Scheduled and Actual Travel Time (all times in minutes)	#41 SR-14 Limited	#65 Parkrose Limited	#164 Fisher's Landing Express	#177 Evergreen Express
Scheduled Travel Time AM Peak (southbound/westbound)	18.0	12.0	26.0	30.0
Average Travel Time AM Peak (southbound/westbound)	16.4	12.1	39.5	39.2
Standard Deviation	6.2	1.9	9.0	8.0
Scheduled Travel Time PM Peak (northbound/eastbound)	20.0	17.0	n/a ¹	n/a ¹
Average Travel Time PM Peak (northbound/eastbound)	14.8	21.3		
Standard Deviation	1.8	5.5		
Scheduled Travel Time Off Peak (southbound/westbound)	n/a ²	10.0	n/a ²	n/a ²
Average Travel Time Off Peak (southbound/westbound)		9.7		
Standard Deviation		0.2		
Scheduled Travel Time Off Peak (northbound/eastbound)	n/a ²	14.0	n/a ²	n/a ²
Average Travel Time Off Peak (northbound/eastbound)		12.3		
Standard Deviation		5.5		

Source: C-TRAN INIT MOBILE Statistics (all times in minutes)

¹ Routes #164 and #177 travel on I-5 during the PM peak period.

² Route #41/SR-14 Limited only travels during peak periods.

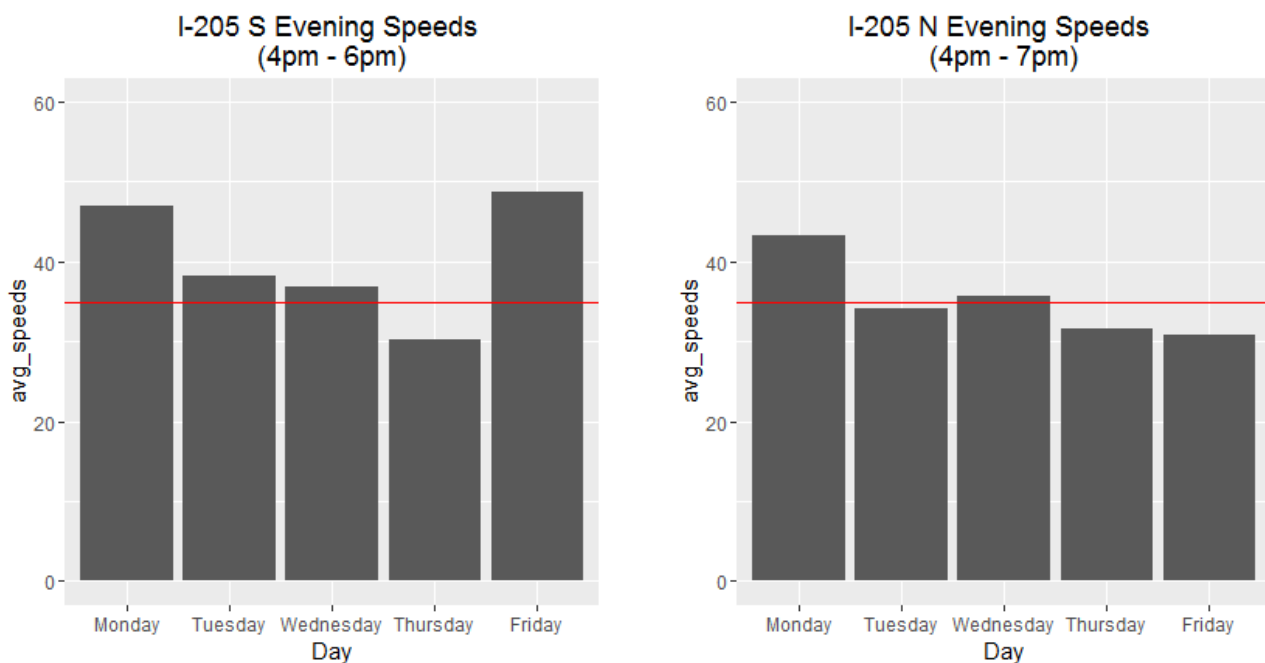
Table 6 shows that scheduled and actual running times are relatively close for the #41 SR-14 Limited and #65 Parkrose Limited. However, actual running times are significantly higher than scheduled running times for the #164 Fisher’s Landing Express and #177 Evergreen Express, the two routes that travel into downtown Portland. Those routes also have the largest standard deviation, which indicates that individual trip travel times can vary significantly from the average trip travel time. For example, one-third of the trips on the #164 Fisher’s Landing Express morning southbound service vary by more than 9 minutes from the average trip time, a situation that makes arrival times unpredictable and the service less reliable.

The data for Route #65 Parkrose Limited indicates that, based on actual travel times, midday service (which is less subject to congestion) is 2.4 minutes faster southbound and 9 minutes faster northbound than the peak hour, peak direction travel times. This is peak period travel time that a BOS project can address.

EXISTING BUS SPEEDS

The areas under the red line on the charts in Figure 8 highlight potential times when speeds are below 35 mph and buses could operate on shoulders during typical traffic conditions. This information is based on bus travel speeds collected from C-TRAN buses in 5-second increments on weekdays in September, October, and November 2016. The bus speed data was compared to fixed freeway speed detector data and general speed data, and the bus speed data was found to be also representative of general traffic speeds averaged across all travel lanes.

FIGURE 8: BUS SPEEDS BY DAY OF WEEK



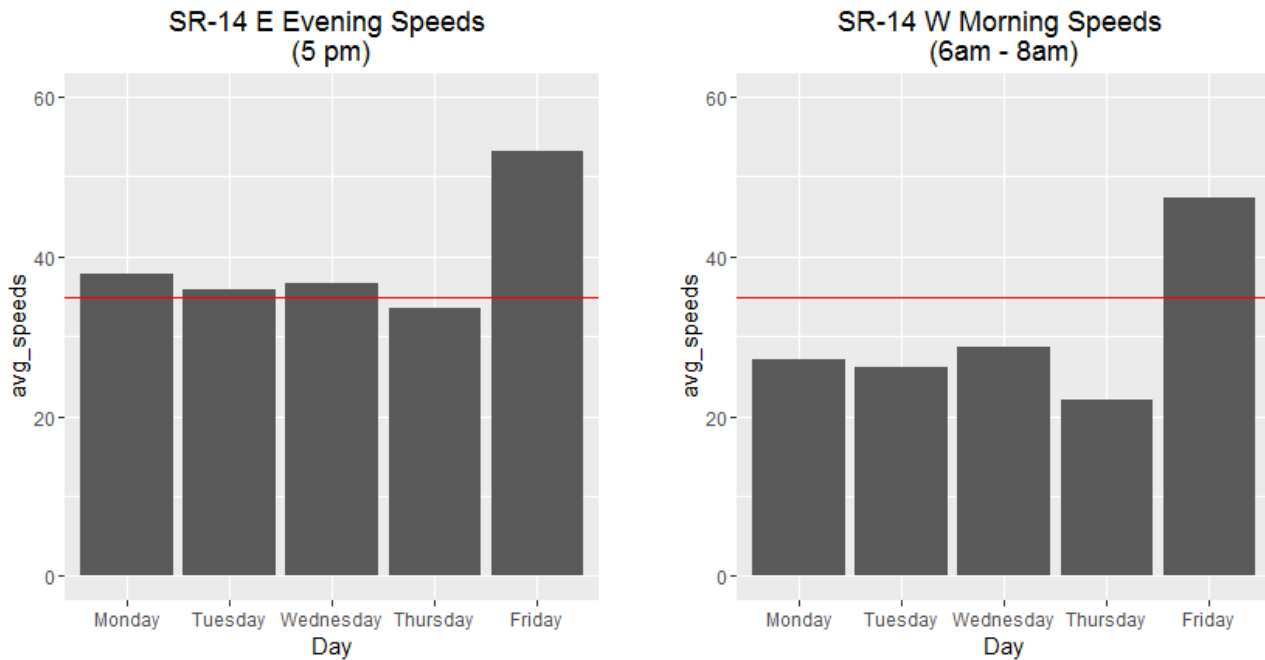


Figure 8 shows bus speeds by day of the week for slow areas to examine possible weekly variability. For SR-14 westbound, which arguably is the most appealing study area location for BOS operations, there is a two-hour window (6 a.m. to 8 a.m.) when speeds are below 35 mph, which stretches the majority of the corridor. Averaging speeds by day of week reveals that for every day except Friday, the bus, on average, travels slower than 35 mph. I-205 northbound between the hours of 4 p.m. and 7 p.m. shows similarly slow average bus speeds, especially in the later portions of the week.

The speeds shown in Figure 8 are the average bus speeds for the days observed. Traffic congestion and resulting travel speeds vary from day to day, and may be faster on some days and slower on others, especially when there are incidents.

Figure 9 and Figure 10. show the daily variability in weekday travel time on I-205 northbound over one month.

FIGURE 9: AVERAGE TRAVEL TIME ON I-205 NORTHBOUND

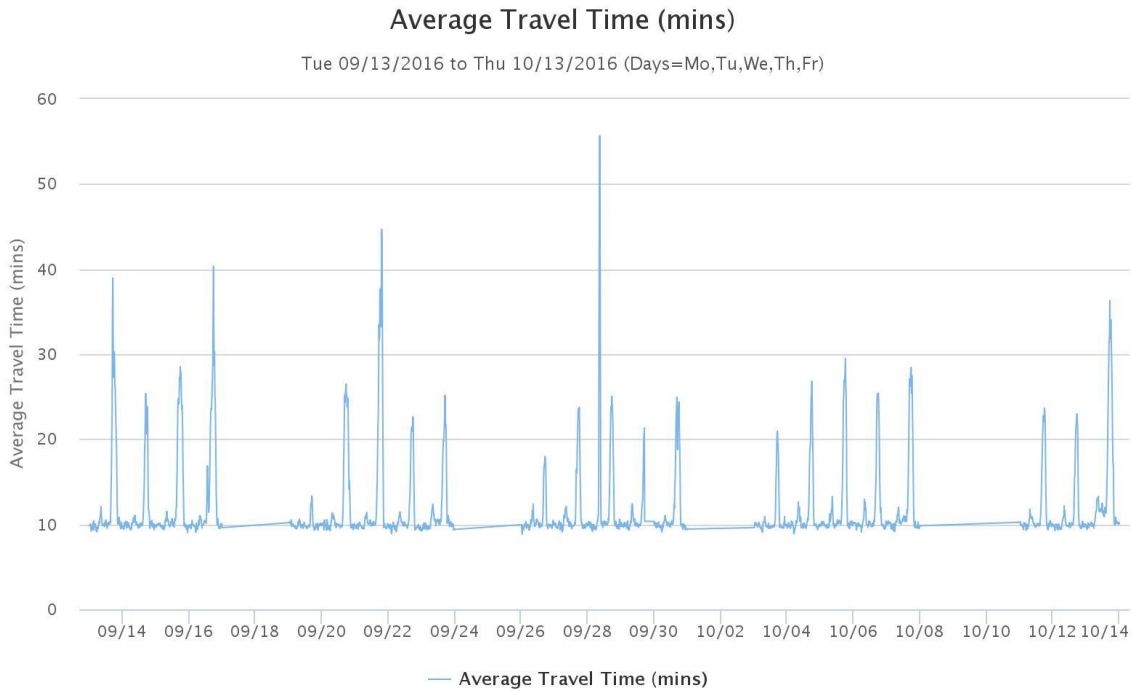
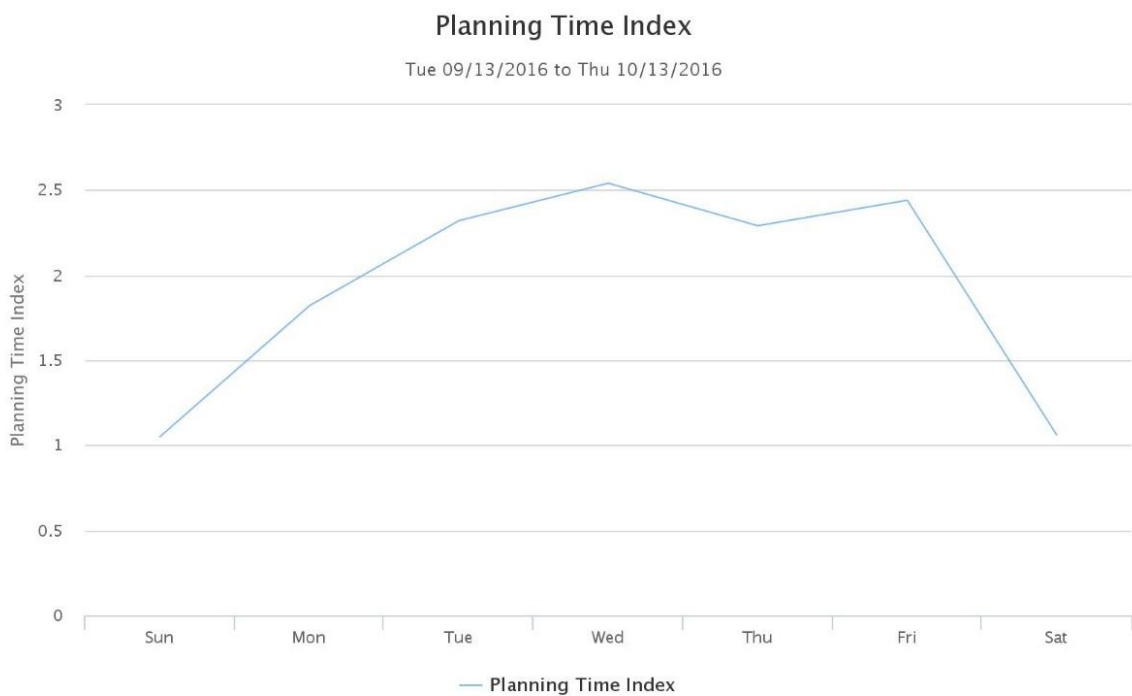


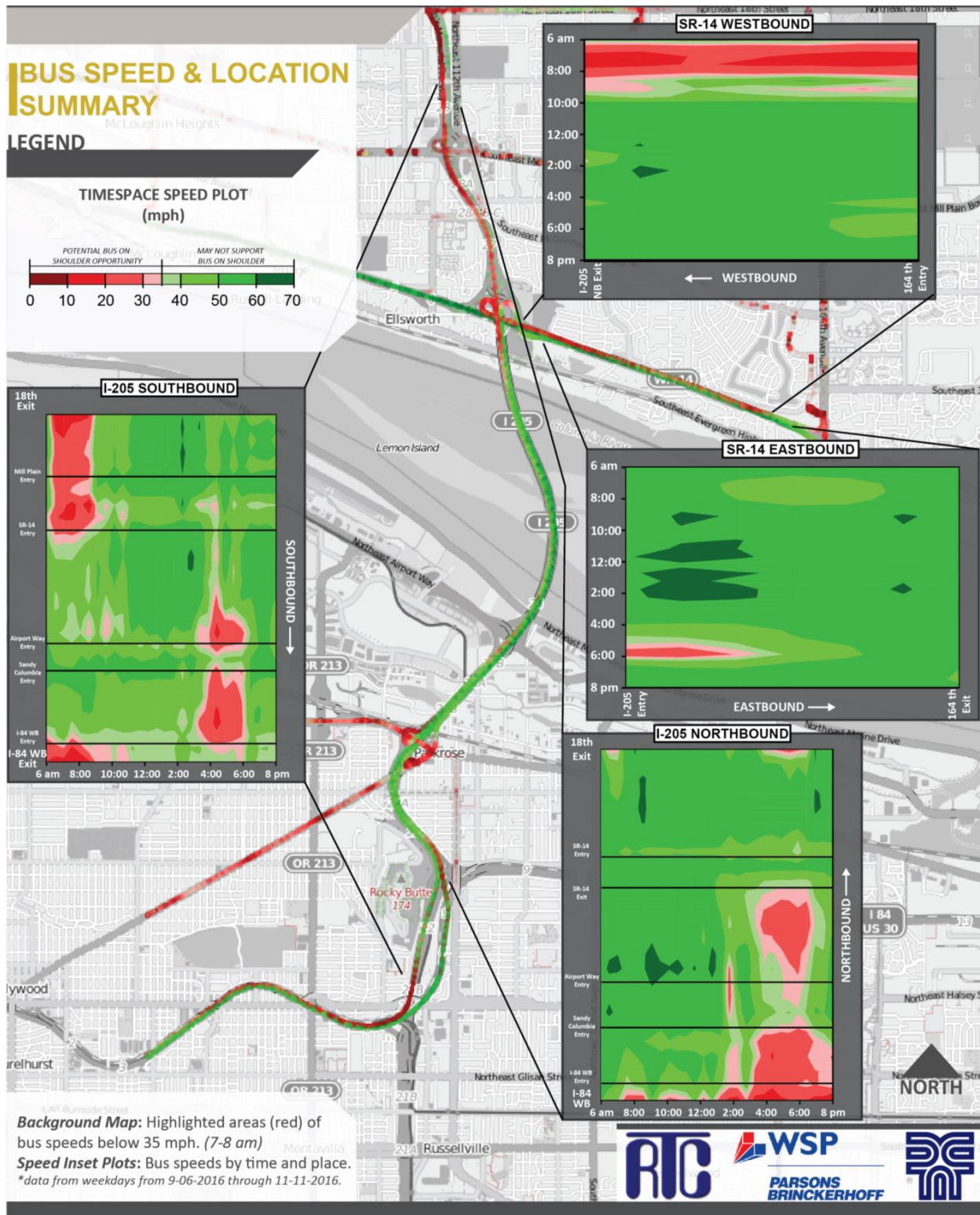
FIGURE 10: PLANNING TIME INDEX FOR I-205 NORTHBOUND



As shown in **Figure 10**, the planning time index on I-205 Northbound is over 2.5. The daily travel time variability on I-205 and SR-14 impacts the on-time reliability of the bus routes and thus requires C-TRAN to build in buffer time for the routes. Transportation professionals refer to the ratio of free-flow travel time to congested travel time as the planning time index. A value of two for this ratio means that the travel time is twice as long during the congested time as during the free-flow time. Therefore, for a free-flow travel time of 10 minutes, the driver will need to plan for a travel time of 20 minutes during the congested period in order to arrive on time.

Figure 11 shows existing average bus speeds in the study area by location and time. Speeds at or below 35 miles per hour (mph) are shown in red and indicate speeds when bus drivers could use the shoulder for BOS operations.

FIGURE 11: EXISTING BUS SPEEDS



CORRIDOR EVALUATION PROCESS

The primary focus of the screening and evaluation strategies for this BOS Feasibility Study is to: (1) evaluate potential geometric and operational constraints, (2) identify opportunities (locations and time periods) for implementing BOS, and (3) develop planning-level estimates of potential benefits to understand fatal flaws and overall feasibility to determine whether more detailed considerations are warranted. The evaluation process worked to organize the feasibility for BOS operations in the study area corridors into three categories:

- **Minimal Cost Concepts:** Use of existing roadway width, with improvements limited to signing and striping changes. Segments generally meet minimum screening requirements and were evaluated for BOS operations.
- **Low Cost Concepts:** Widening/strengthening of roadway surface for short segments, minor adjustments to ramp merge/diverge points, queue jumps on ramps, and signing and striping changes. Segments generally meet minimum screening requirements, with the exception of shoulder width, and were evaluated for BOS operations
- **Higher cost concepts:** Do not meet one or more minimum screening requirements and would require reconfiguring interchanges, moving ramps, widening structures or rebuilding shoulders to add pavement depth. While these segments may be good candidates for BOS because of operational benefits, they were outside the scope of this study are not recommended for BOS.

GEOMETRY

The existing geometric conditions (as shown in Figures 6 and 7) were reviewed to identify locations where the following minimum requirements were met:

- Shoulder widths 10 feet or wider (11.5 feet when adjacent to barriers)
- Pavement depths within the shoulders greater than 7 inches
- Vertical clearance within the shoulders greater than 14 feet

This screening provided a base for geometric review during the feasibility workshop.

CONGESTION

The existing bus speeds (as shown in Figure 8) were reviewed to identify locations and time periods that had speeds within the proposed BOS operating protocols, which allow shoulder use when speeds are below 35 mph. Segments that have bus speeds under 35 mph and meet the minimum geometric requirements have the potential to provide travel time and reliability benefits to bus operations for minimal cost.

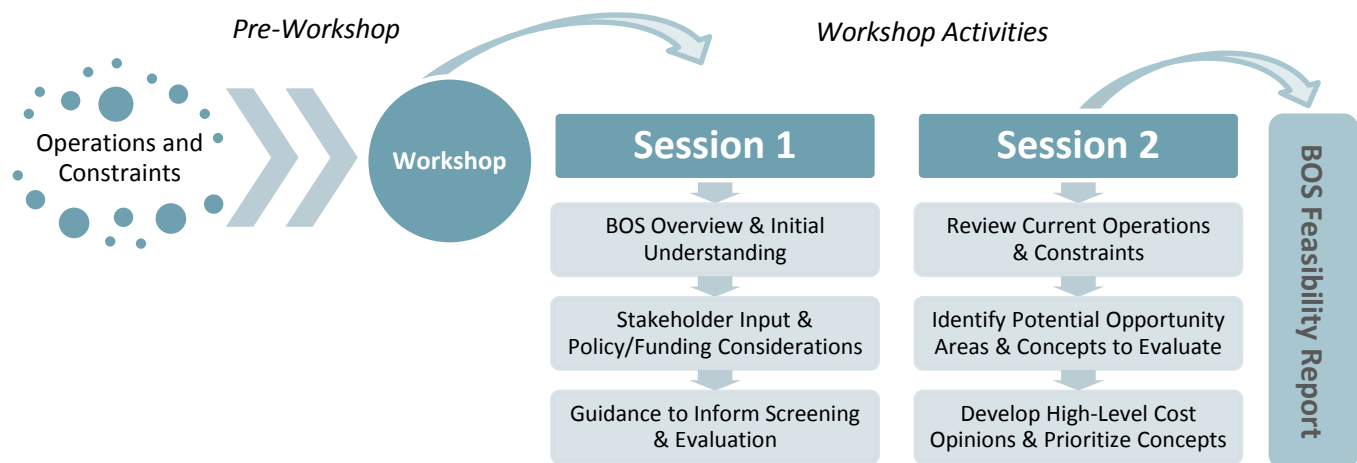
The evaluation of BOS feasibility was not limited to the locations where existing speeds were below 35 mph, because the daily variability of traffic congestion and the impact of incidents can change the location and duration of congestion from day to day. As a result, buses may benefit from use of the shoulder at different locations each time they travel the corridor. The bus speed data does, however, provide an indication of where consistent weekday travel time benefits are likely to be gained through BOS operations.

WORKSHOP

A multidisciplinary feasibility workshop was held in December 2016 to engage a wide range of technical and policy-level staff to screen segments in the corridor for their feasibility for BOS operations under the minimal cost and low cost criteria. Segments not meeting those criteria were screened out and not carried forward for further evaluation after the workshop. The workshop engaged attendees in two half-day sessions with separate focus areas:

SESSION 1: High-level focus with policy, management, and technical staff.

SESSION 2: Technical BOS feasibility focus with technical and operations staff and other stakeholders potentially affected by the proposed system.



Appendix B has the packet of materials used during the workshop and Appendix C provides a summary of the workshop, including initial workshop recommendations organized by segment for each corridor.

REFINEMENT

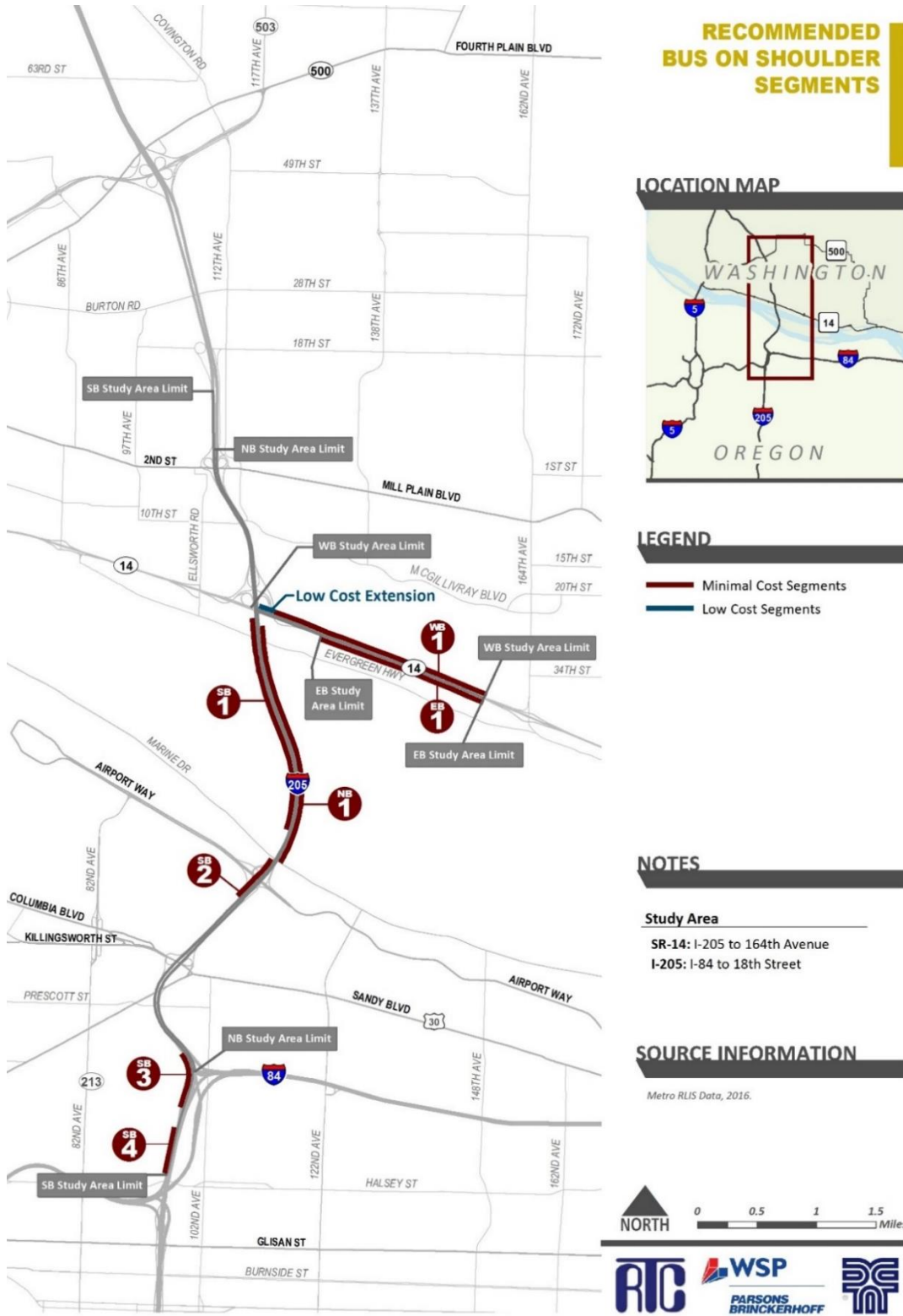
The segments that were identified for BOS operations during the feasibility workshop were further evaluated after the workshop to verify geometric conditions, finalize the recommended BOS segments for each corridor, develop the signing and striping layout, and calculate the potential bus travel time savings and planning-level cost estimate based on general material costs.

EVALUATION FINDINGS

Based on the BOS operating protocols, existing geometry, and traffic conditions, BOS operations are recommended on SR-14 from I-205 to 164th Avenue and on segments of I-205 from SR-14 to I-84, as shown on the Figure 12 overview map. The recommended segments require relatively little modification of the existing roadway and fall within the minimal or low cost criteria of the study.

The BOS design and bus operating parameters for all recommended segments allow the bus to merge onto the shoulder at any point past the beginning of the BOS designation, when the operating speeds of the general purpose lane drop below 35 mph and there are no obstructions on the shoulder. Bus drivers will merge out of the shoulder to maintain shoulder priority for breakdowns and emergency response.

FIGURE 12: RECOMMENDED BOS SEGMENTS



SR-14 WESTBOUND

Both a minimal cost BOS segment and a low cost extension are recommended for BOS operations westbound on SR-14 between I-205 and 164th Avenue.

MINIMAL COST

As shown in Figure 13, the minimal cost BOS segment for westbound SR-14 begins downstream of the on-ramp from 164th Avenue to westbound SR-14. The on-ramp is striped as a two-lane ramp with the right lane being designated as a “bus only lane.” This bus only lane begins at the Fischer’s Landing Transit Station. Eventually the bus only entrance lane ends and the on-ramp becomes a single-lane on-ramp at the merge with SR-14. The shoulder at the merge point of the ramp with SR-14 does not provide the minimum 10-foot width needed for BOS operations. To avoid the cost of restriping the ramp and mainline to provide a 10-foot shoulder, the minimal cost concept requires the buses to merge onto SR-14 from the general purpose lane and then transition into the BOS lane downstream of the ramp. Operationally, the buses traveling this segment can merge onto the shoulder at any point past the beginning of the BOS designation when the operating speeds of the general purpose lane drop below 35 mph and there are no obstructions on the shoulder.

A bus that is utilizing the shoulder, as it approaches the I-205 interchange, will need to merge back into the right lane after the lane exits from SR-14 onto the Collector-Distributor (C-D) system, but before the lane turns and becomes the entry ramp to northbound I-205. A black and yellow warning sign will be installed to designate to bus drivers where the transitioning to the right lane should occur. From there, the bus will travel in the right exit lane to northbound I-205; however, rather than exiting to I-205, the bus will transition straight into the gore area between the exit ramp and the C-D lane and then into the C-D lane at the end of the BOS segment.

Low Cost

As shown in Figure 14, the low cost concept for westbound SR-14 extends the length of the BOS segment by restriping the 164th Avenue entry ramp to allow buses to travel from the existing bus only lane on the ramp directly into the SR-14 BOS lane. Operationally, the buses traveling this segment stay in the shoulder on the ramp when the operating speeds of the general purpose lanes and/or ramp drop below 35 mph and there are no breakdowns or other obstructions on the shoulder. If operating conditions on the mainline are above 35 mph or there are obstructions, buses will merge into the general purpose ramp entrance lane and then merge onto SR-14.

The I-205 interchange C-D lane is also restriped for the low cost concept in order to allow BOS operations to extend from the northbound I-205 exit gore to the southbound entrance lane. Figure 14 provides the signing and striping layout for the low cost concept.

For the both the minimal cost and low cost concepts, buses on C-TRAN Route #41 SR-14 Limited will need to transition out of the BOS lane earlier than buses exiting to I-205 in order to stay on SR-14. A general BOS designation sign will be placed at the location for this earlier transition, and drivers should be trained to use the sign as a reference point. If drivers choose not to transition early, then they can simply use the BOS lane to the end of the segment and then use the C-D lane to enter back onto SR-14 west of I-205.

SR-14 EASTBOUND BOS

The eastbound SR-14 BOS is a simpler operation. The start of the BOS operation is at the acceleration lane of the I-205 entrance ramp to eastbound SR-14. The end of the BOS operation would be at a point near the exit gore for the exit to 164th Avenue. Operationally, the buses traveling this segment can merge onto the shoulder at any point past the beginning of the BOS designation when the operating speeds of the general purpose lane drop below 35 mph and there are no obstructions on the shoulder. As the bus approaches the exit to 164th Avenue, it should begin merging back into the exit lane approximately 1,000 feet before the exit ramp, when it is safe to merge. Eventually the bus will need to merge left an additional lane either on the exit ramp or after turning left onto 164th Avenue in order to access the Fischer's Landing Transit Station entrance.

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FIGURE 13: SR-14 BOS MINIMAL COST SIGNING AND STRIPING LAYOUT

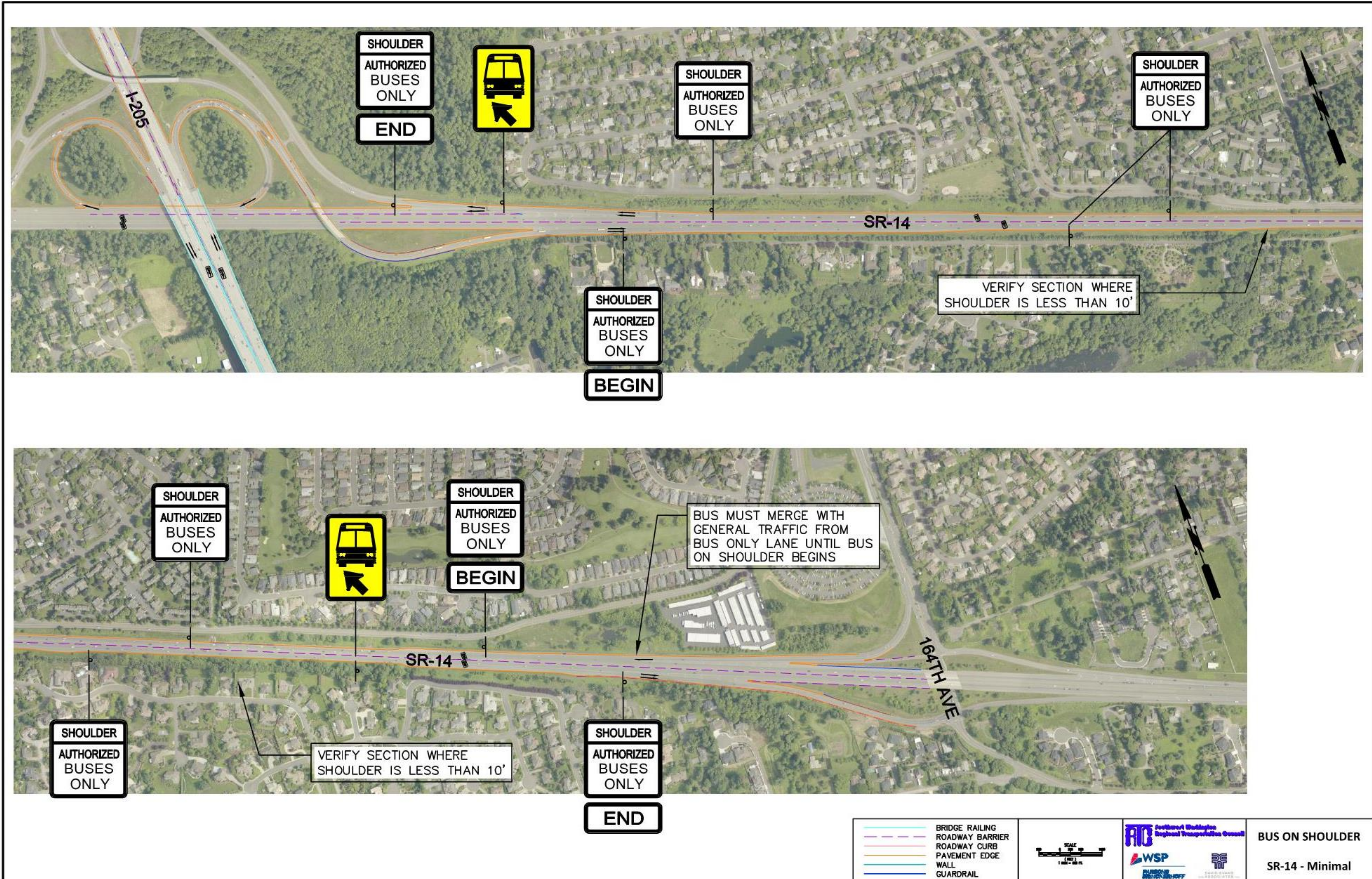
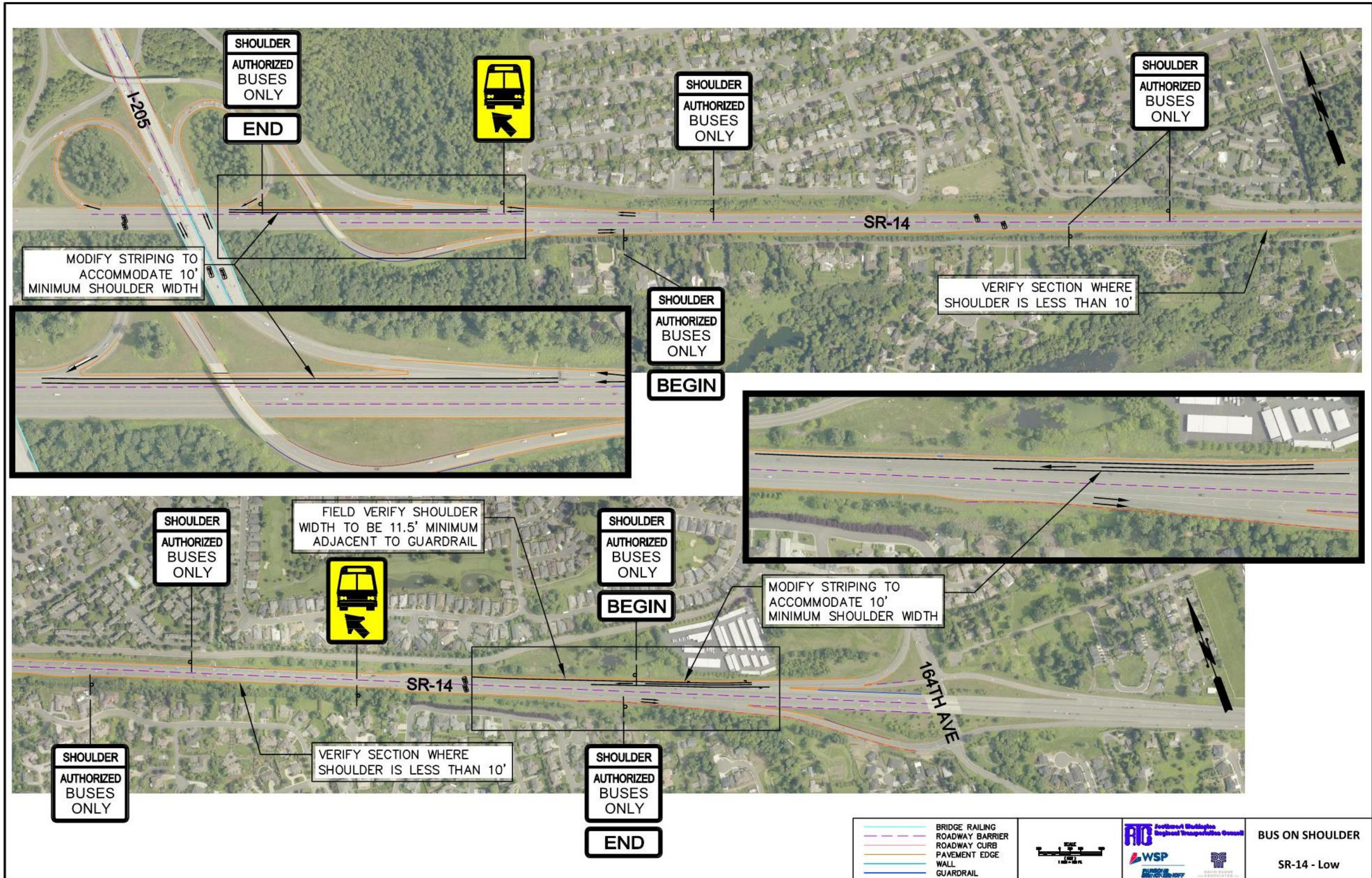


FIGURE 14: SR-14 BOS LOW COST SIGNING AND STRIPING LAYOUT



I-205 SOUTHBOUND BOS

Buses traveling on southbound I-205 enter the highway at two locations. Route 177 enters at 18th Street, and Routes 65 and 164 enter further downstream at SR-14. As shown in Figure 12, the recommended BOS corridor extends from SR-14 to I-84, with four segments authorized for BOS operations under the minimal cost criteria

Five ramps on southbound I-205 are multi-lane ramps that require buses to re-enter traffic from the shoulder in advance of the ramp. The four ramps are: exit to southbound SR-14, entrance from SR-14, exit to Airport Way, exit to eastbound Highway 30/NE Columbia Loop, and exit to eastbound I-84.

The first two ramps are successive ramps over an approximately half-mile section of the facility, thus limiting the viability of the BOS in this section. Buses approaching a two-lane exit need to begin merge at a sufficient distance in order to move over to the left-hand exit lane (two-lane weave from shoulder) or the right through travel lane (three-lane weave). From the Highway 30 /NE Columbia entrance to the exit to eastbound I-84, buses will need to re-enter the travel lane or the shoulder will need to be widened to accommodate BOS. These geometric constraints, along with the high-volume entrance ramp from eastbound Airport Way, limit the viability of BOS operations on the Oregon portion of the corridor from the eastbound Airport Way entrance to the eastbound I-84 exit.

Figure 15 and Figure 16 provide a layout of the following recommended segments on I-205. Of note, all the recommended segments on I-205 are Minimal Cost concepts and improving any of the other segments to provide a more continuous BOS corridor would require investments beyond the Minimal and Low Cost concepts evaluated in this study.

SOUTHBOUND SEGMENT 1, SR-14 ENTRANCE TO AIRPORT WAY EXIT

As shown in Figure 15, Segment 1 of the southbound I-205 BOS corridor starts immediately after the SR-14 entrance ramp merge and extends to 1,000 feet before the Airport Way exit. This is the longest BOS segment of the corridor at 1.75 miles. Average travel speeds in this segment are only below 35 mph at the south end of the segment, thus limiting the travel time and reliability benefits of BOS under average existing conditions. However, benefits are likely to increase as traffic volumes increase in the future and could be significant during heavily congested days or during incidents.

SOUTHBOUND SEGMENT 2, AIRPORT WAY EXIT TO EASTBOUND AIRPORT WAY ENTRANCE

As shown in Figure 15, Segment 2 is a short segment that extends from the Airport Way exit through the westbound Airport Way entrance, and ends before the eastbound Airport Way entrance.

SOUTHBOUND SEGMENT 3, EASTBOUND I-84 EXIT TO WESTBOUND I-84 ENTRANCE

As shown in Figure 16, Segment 3 is between the eastbound I-84 exit and the westbound I-84 entrance. This segment has speeds below 35 mph during both the AM and PM peak periods, which often extend into the midday and weekends as traffic congestion on I-84 extends back onto I-205. At times, C-TRAN buses will reroute onto Sandy Boulevard to avoid the congestion on I-84. It is recommended that additional evaluation of the travel times and reliability of the I-84 and Sandy Boulevard routing options be completed before moving forward with implementation of BOS for this segment.

SOUTHBOUND SEGMENT 4, WESTBOUND I-84 ENTRANCE TO WESTBOUND I-84 EXIT

As shown in Figure 16, Segment 4 authorizes BOS operations from a point after the westbound I-84 entrance ramp to the westbound I-84 exit ramp. Similar to Segment 3, this segment has speeds below 35 mph during both the AM and PM peak periods, which often extend into the midday and weekends as traffic congestion on I-84 extends back onto I-205. At times, C-TRAN buses will reroute onto Sandy Boulevard to avoid the congestion on I-84. It is

recommended that additional evaluation of the travel times and reliability of the I-84 and Sandy Boulevard routing options be completed before moving forward with implementation of BOS for this segment.

I-205 NORTHBOUND BOS

Routes 177 and 164 buses traveling on northbound I-205 enter the highway at the eastbound I-84 entrance. Route 65 enters the freeway at Sandy Boulevard/Highway 30 from the Parkrose Park-and-Ride. Routes 65 and 164 exit at SR-14, whereas Route 177 exits farther downstream at 18th Street. Routes 164 and 177 typically use I-5 north into Vancouver due to the availability of the HOV lane. The travel time and reliability benefits of a BOS lane on I-205 could allow northbound commuter buses to shift back to the corridor.

As shown in Figure 12, the recommended BOS corridor on northbound I-205 is limited to the segment from the Airport Way entrance to 1,000 feet before the SR-14 exit due to geometric constraints between I-84 and Airport Way.

Three ramps on northbound I-205 are multi-lane ramps that require buses to re-enter traffic from the shoulder in advance of the ramp. The three ramps are: exit to westbound Airport Way, exit to SR-14, and exit to Mill Plain Boulevard. Routes 65 and 164 exit at SR-14 and need to weave into the left exit lane to proceed onto eastbound SR-14.

NORTHBOUND SEGMENT 1, AIRPORT WAY ENTRANCE TO SR-14 EXIT

As shown in Figure 15, the recommended northbound I-205 BOS corridor starts immediately after the Airport Way entrance ramp merge and extends to 1,000 feet before the SR-14 exit. This BOS segment is longer than 1.5 miles, and average travel speeds in this segment are only below 35 mph during the PM peak period.

OPTIONS CONSIDERED BUT NOT RECOMMENDED

These segments could accommodate BOS with additional investments beyond the Minimal or Low Cost investments evaluated by the Feasibility Study.

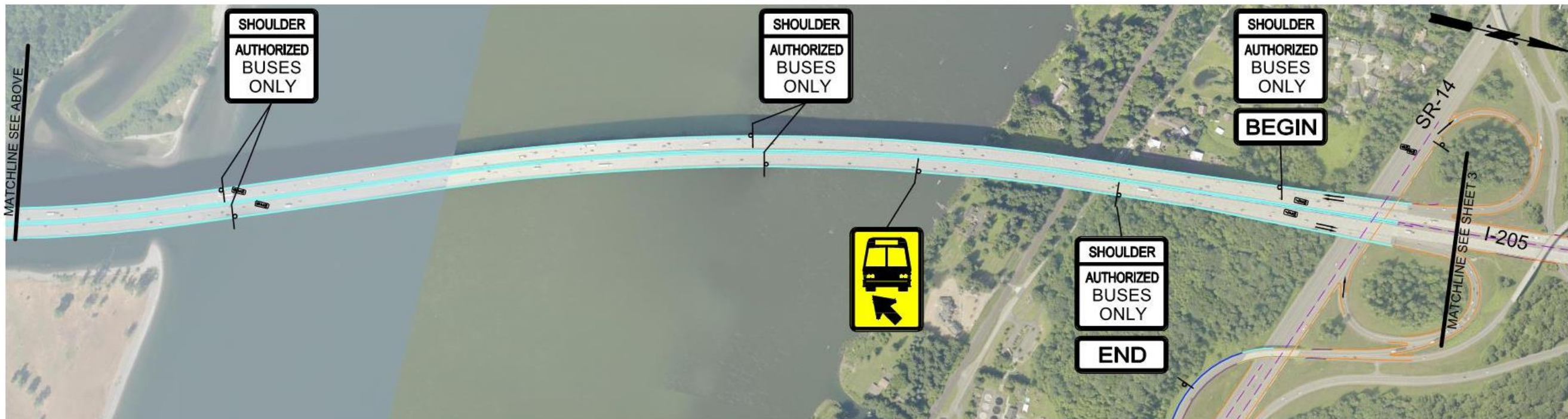
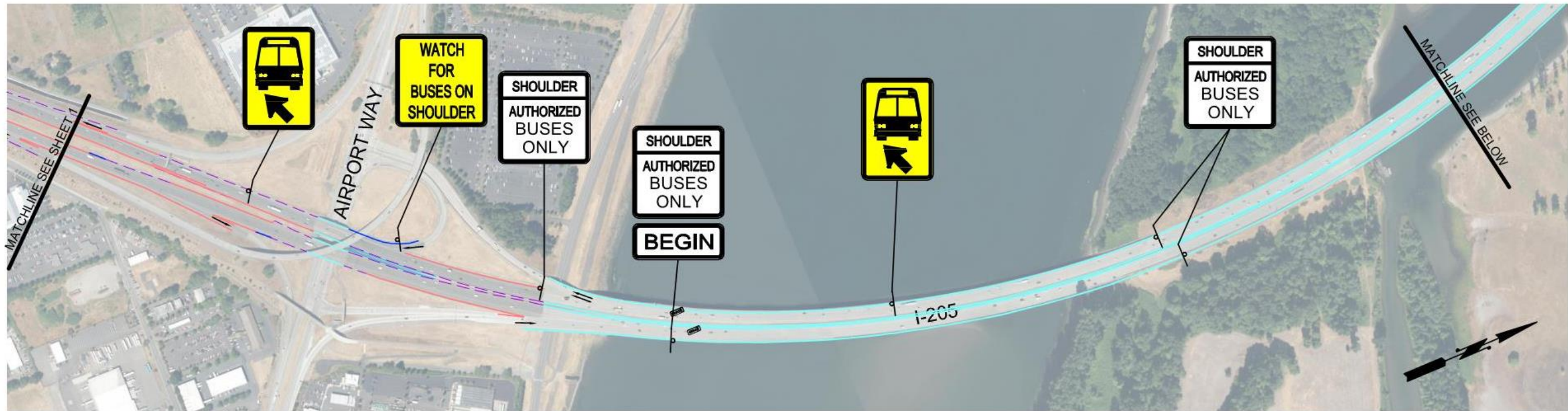
WESTBOUND SR-14 LOOP RAMP TO I-205 SOUTHBOUND

The Loop ramp from SR-14 Westbound to I-205 Southbound is congested during the AM peak period and buses would benefit from BOS on shoulder operations on the ramp to connect the recommended Westbound SR-14 BOS segment with Segment 1 of the recommended Southbound I-205 BOS. The existing ramp would require widening to provide adequate shoulder width BOS operations. Given the relatively tight horizontal and vertical curvature of the ramp the shoulder would have to be wider than 10 feet to provide adequate site distance and accommodate the wide path of long buses traversing the loop ramp. The specifics of the capital investments required is beyond the scope of this feasibility study and outside the Minimal and Low Cost concepts evaluated.

I-205 SOUTHBOUND, 18TH STREET ENTRANCE TO MILL PLAIN ENTRANCE

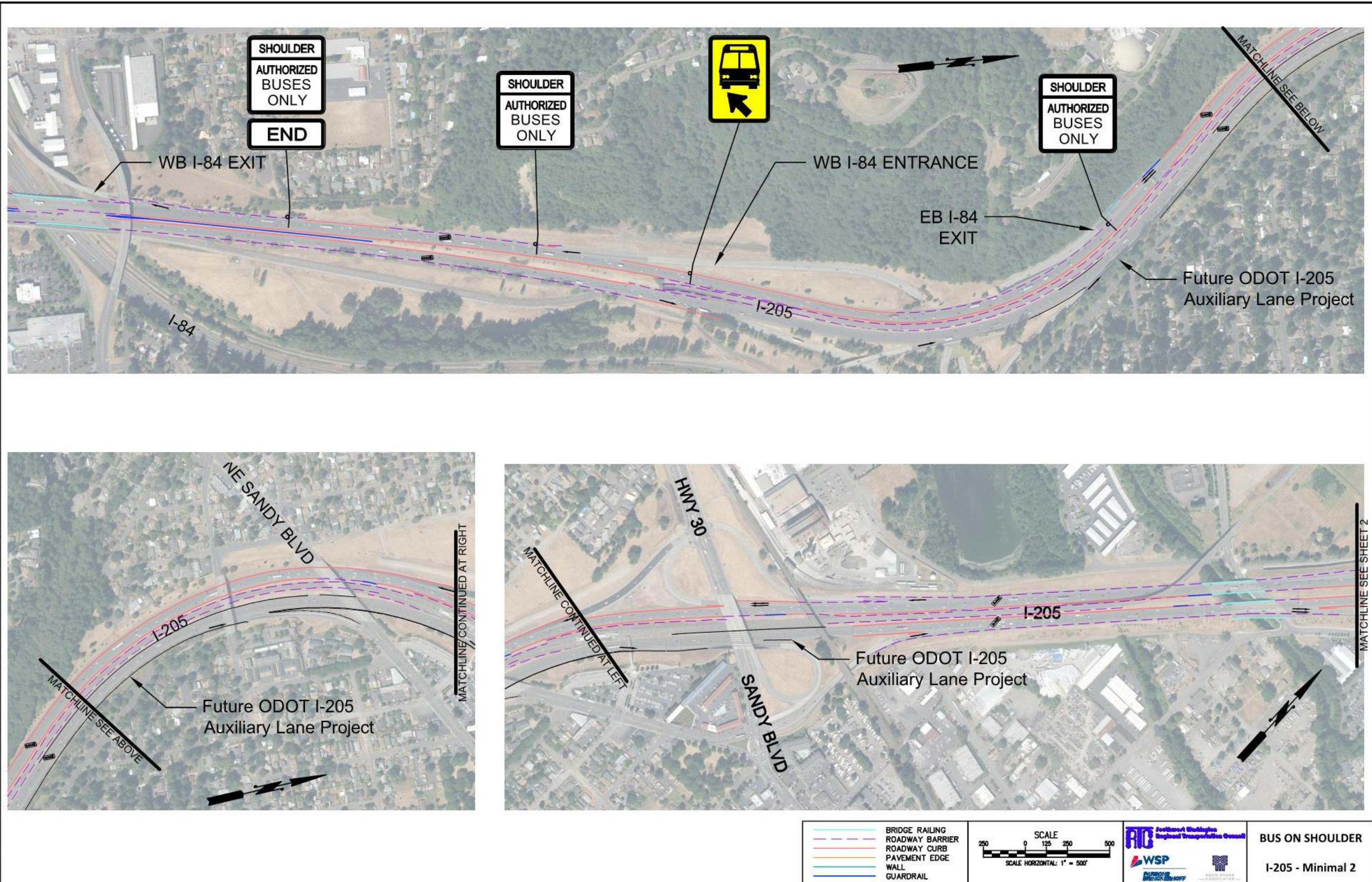
North of SR-14 to 18th Street, the shoulder is 10 feet wide; however, there is a barrier immediately adjacent to the shoulder for the majority of the segment length. Bus on shoulder operations adjacent to a barrier require a minimum 11.5-foot-wide shoulder. As a result, buses will need to re-enter the travel lane or the shoulder will need to be widened to accommodate BOS in this segment. With only one bus route (Route 177), using this segment of the corridor, along with heavy congestion on the 18th Street on-ramp limiting the reliability of the bus route, investment in BOS in this segment is not recommended as part of this initial feasibility evaluation. There is heavy congestion in this area and the potential for large travel time savings and reliability improvements through widening of the shoulders for BOS and the 18th Street ramp for a queue by-pass but those investments costs would be well above the Minimal and Low Cost concepts evaluated.

FIGURE 15: I-205 BOS SIGNING AND STRIPING LAYOUT SEGMENT 1, 2, & 4



<ul style="list-style-type: none"> — BRIDGE RAILING — ROADWAY BARRIER — ROADWAY CURB — PAVEMENT EDGE — WALL — GUARDRAIL 	<p>SCALE</p> <p>250 0 250 500</p> <p>SCALE HORIZONTAL: 1" = 500'</p>		<p>BUS ON SHOULDER</p> <p>I-205 - Minimal 1</p>
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FIGURE 16: I-205 SIGNING AND STRIPING LAYOUT SEGMENT 3



I-205 SOUTHBOUND, MILL PLAIN ENTRANCE TO SR-14 EXIT

The shoulders in this segment is constructed of asphalt paving over asphalt treated base. Little is known regarding the structural characteristics of this particular pavement section however the pavement shows transverse cracking with grass growing in the cracks in many areas. It is very unlikely that this pavement section would be suitable for carrying bus traffic without being rebuilt. In addition, this is a weaving section with a dual lane SR-14 exit ramp requiring buses to merge back into the general traffic lane and make one lane change well in advance of the two lane exit ramp limiting the effective length of BOS operations in this segment.

I-205 SOUTHBOUND, SR-14 EXIT TO SR-14 ENTRANCE

The shoulders in this segment is constructed of asphalt paving over asphalt treated base. Little is known regarding the structural characteristics of this particular pavement section however the pavement shows transverse cracking with grass growing in the cracks in many areas. It is very unlikely that this pavement section would be suitable for carrying bus traffic without being rebuilt. In addition, both the SR-14 ramps are dual lane ramps requiring buses to merge back into the general traffic lane 1,000 feet in advance of the ramps limiting the effective length of BOS operations in this segment.

I-205 SOUTHBOUND, AIRPORT WAY EASTBOUND ENTRANCE TO I-84 EASTBOUND EXIT

This segment has high volume entrance ramp from eastbound Airport Way followed by a weaving sections with narrow shoulders and a two lane exit ramp at Eastbound Sandy/US-30 and a two lane exit to I-84 Eastbound that combine to prohibit BOS without higher cost investments beyond the scope of this feasibility study and outside the Minimal and Low Cost concepts evaluated.

I-205 NORTHBOUND, I-84 EASTBOUND ENTRANCE TO AIRPORT WAY EXIT

I-84 Eastbound entrance to Airport Way entrance will have narrow shoulders once an auxiliary lane is added between I-84 Eastbound entrance and Westbound Sandy/US-30 exit, two lane exit to westbound Airport Way, high volumes at Airport Way entrance and narrow shoulder in sections combine to prohibit BOS without higher cost investments beyond the scope of this feasibility study and outside the Minimal and Low Cost concepts evaluated.

I-205 NORTHBOUND, SR-14 EXIT TO 18TH STREET EXIT

From the SR-14 exit to the 18th Street exit is constructed of asphalt paving over asphalt treated base. Little is known regarding the structural characteristics of this particular pavement section however the pavement shows transverse cracking with grass growing in the cracks in many areas. It is very unlikely that this pavement section would be suitable for carrying bus traffic without being rebuilt. Additionally, this segment is not currently congested during typical operations. Segment could be reevaluated in future as travel demands in the corridor increase.

SEGMENT COST ESTIMATES

Though BOS is a relatively low-cost transportation strategy, decisions must be made regarding the responsibility for upfront and ongoing costs. Agency staff resources at WSDOT, ODOT, and C-TRAN are needed for design and implementation of the BOS program. Project costs include developing signing plans, developing and implementing training, developing and implementing the engagement and community outreach plan, procuring and installing the BOS infrastructure, and finally conducting the evaluation. As part of BOS project designs, it is recommended that there be an agreement on responsibilities for funding and resourcing the various elements of the BOS. Appendix D provides a summary of the unit cost assumptions used to develop the segment costs estimates. The workshop packet in Appendix B provides additional discussion of financing resources.

BOS cost estimates were developed in two general cost categories:

- **Minimal Cost Concepts:** Use of existing roadway width, with improvements limited to signing and striping changes. Segments generally meet minimum screening requirements and were evaluated for BOS operations.
- **Low Cost Concepts:** Widening/strengthening of roadway surface for short segments, minor adjustments to ramp merge/diverge points, queue jumps on ramps, and signing and striping changes. Segments generally meet minimum screening requirements with the exception of shoulder width and were evaluated for BOS operations.

The costs estimates are calculated from available material capital cost on a per unit basis. The capital costs are factored up on a percentage basis to include professional design and construction service costs along with a contingency factor in order to reflect the limited (site-specific data available and the planning-level nature of this feasibility study. Table 7 provides a summary of the cost estimates for the recommended BOS segments. The total cost estimate for the all identified segments on both corridors is under \$100,000.

TABLE 7: RECOMMENDED BOS SEGMENT COST ESTIMATES BY CORRIDOR

Corridor / Segment	Minimal Cost Option	Low Cost Option
SR-14		
Westbound Segment 1: 164 th Ave. Entrance to I-205 Exit	\$8k	\$34.6
Eastbound Segment 1: I-205 Entrance to 164 th Ave. Exit	\$8k	\$8k
SR-14 Total	\$16k	\$42.6k
I-205		
Southbound Segment 1: SR-14 Entrance to Airport Way Exit	\$7.4k	
Southbound Segment 2: Airport Way Exit to Eastbound Airport Way Entrance	\$6.1k	
Southbound Segment 3: Eastbound I-84 Exit to Westbound I-84 Entrance	\$7.3k	
Southbound Segment 4: Westbound I-84 Entrance to Westbound I-84 Exit	\$4.9k	
Northbound Segment 1: Airport Way Entrance to SR-14 Exit	\$7.4k	
I-205 Total	\$33.1	
Study Area Total	\$49.1k	\$42.6k

IMPACTS TO TRANSIT PLANS

The improved travel time and reliability provided by a BOS system will impact existing C-TRAN bus schedules and ridership.

SERVICE CHANGES

Specific changes to the routes that use SR-14 and I-205 are not described in C-TRAN’s Transit Development Plan (TDP). The TDP does not typically get to this level of detail. However, C-TRAN planners indicate that continued service expansion of the routes serving SR-14 and I-205 can be expected within the next ten years and that a reasonable assumption would be an overall 25 percent increase in service. Other potential changes include:

- C-TRAN anticipates adding a bus on Routes 65 and 164 in the next couple of years (perhaps as early as September 2017). The Fisher's Landing Park-and-Ride added 198 new spaces (a 35 percent increase), leading to the need for the service increase.
- C-TRAN is considering a new park-and-ride location to replace the Evergreen location (which would be sold). C-TRAN is considering a location along I-205 between Padden Parkway and 18th Street and/or possibly having a park-and-ride in the Camas/Washougal area that would alleviate future demand out of Fisher's Landing and benefit the SR-14 corridor.

BUS ON SHOULDER PROJECT SERVICE IMPACTS

The BOS project will improve travel time and service reliability by reducing the impact of traffic congestion on transit service. In addition, the reduced travel times will provide savings in operating cost, which can be used to increase service on one or more of these three routes, or can be used elsewhere in the C-TRAN system. The reduction in travel and improved reliability will also increase ridership. The following is a limited assessment of the impact of a potential BOS project on these factors. A more detailed assessment can be undertaken if the decision to advance the BOS project to the next phase of development is made.

RELIABILITY

Reducing the impact of congestion with a BOS project can be expected to improve reliability by eliminating a portion of the route delay, especially if the extent of the delay varies from trip to trip and from day to day, as appears to be the case for the routes using SR-14 and I-205 during peak hours. Accurately predicting the impact of the BOS project on reliability requires use of a traffic model, which is beyond the scope of the project in this phase.

TRAVEL TIME SAVINGS

A prime benefit of BOS is reducing travel time for riders. In addition, reducing travel time by using BOS will result in a reduction of C-TRAN’s operating cost. The estimated travel time savings for a BOS operation have been calculated by determining current bus speeds during the peak hour, peak direction travel, and estimating potential travel time savings assuming BOS operation. The travel time savings assume the proposed operating parameters that the bus can only use the shoulders when travel speed are less than 35 miles per hour, and that travel on the shoulders cannot exceed 35 miles per hour or 15 miles per hour faster than the adjacent travel lane, whichever is less. Table 8 provides a summary of potential BOS travel time savings on each corridor under two scenarios:

- **Observed Bus Speeds:** Travel time savings for recommended segments based on observed bus speeds and the length of each segment with those speeds below 35 mph: Proposed operating protocols of shoulder use at speeds less than 35 mph with a maximum shoulder travel speed of 35 mph and a maximum speed differential of 15 mph for the bus relative to the adjacent travel lane are maintained. This represents the expect travel time savings under average weekday conditions based on observed bus speeds under existing conditions.
- **Theoretical Travel Speeds:** Travel time savings for recommended segments based on theoretical speed in adjacent travel lane of 15 mph and a BOS travel speed 15 mph faster, at 30 mph, for the full length of each segment: This represents a reasonable high-end travel time savings that is potentially representative of higher than average congestion.

TABLE 8: PEAK PERIOD TRAVEL TIME SAVINGS IN MINUTES PER SEGMENT

Corridor	Savings based on Observed bus speeds within segment	Saving based on Theoretical adjacent lane travel speed of 15 mph for full segment length	Existing Average Weekday duration of active BOS operations based on Observed Bus speeds
SR-14			
Westbound 1	2.28 min. Minimal Cost 3.08 min. Low Cost	3.00 min. Minimal Cost 4.00 min. Low Cost	4 hours (AM)
Eastbound 1	0.21 min.	2.50 min.	1 hour (PM)
I-205			
Southbound 1	0.66 min.	3.50 min.	3 hours (PM)
Southbound 2	0 min.	1.00 min.	None
Southbound 3	0.55 min. AM 0.12 min. PM	1.00 min. AM 1.00 min. PM	3 hours (AM ¹) and 3 hours (PM)
Southbound 4	1.00 min. AM 0.24 min. PM	1.00 min. AM 1.00 min. PM	3 hours (AM ¹) and 3 hours (PM)
Northbound 1	0.46 min.	3.50 min.	4 hours (PM)

Note 1: Bus service does not extend beyond 9 a.m. There is a potential for additional benefits beyond 9 a.m. if bus service times were extended.

Applying the estimated travel time savings by segment to the existing transit routes results in travel time savings for each bus trip ranging from less than a minute to over 10 minutes depending and the route as shown in Table 9.

TABLE 9: PEAK PERIOD TRAVEL TIME SAVINGS IN MINUTES PER BUS TRIP

Corridor	Savings based on Observed bus speeds within segment	Saving based on Theoretical adjacent lane speed of 15 mph for full segment length
Route #41 - SR-14 Limited		
WB AM Peak	3.08 min	4.00 min
EB PM Peak	0.21 min	2.50 min
Route #65 - Parkrose Limited		
EB/SB AM Peak	3.74 min	8.50 min
WB/NB PM Peak	0.67 min	6.00 min
Route #164 - Fisher's Landing Express		
EB/SB AM Peak	5.29 min	10.50 min
WB/NB PM Peak*	0.67 min	6.00 min
Route #177 - Evergreen Express		
EB/SB AM Peak	2.21 min	6.50 min
WB/NB PM Peak*	0.46 min	3.50 min

* Route currently uses I-5 NB to SR-14 in the PM Peak due to the travel time savings provided by the I-5 HOV Lane

A summary of the observed bus speeds is included in Appendix E.

OPERATING COST SAVINGS

Based on the estimated peak hour travel time savings attributable to the BOS project, the minimum operating cost savings are projected to be about \$90,000 (see Table 10). Operating cost savings can be realized only if C-TRAN adjusts their schedules and bus assignments to take advantage of the reduced travel time. Using the higher, more congested travel time savings calculated in Table 9 for the theoretical conditions of a 15 mph saving for the full segment of all the recommended BOS segments, a reduction in operating costs of up to \$280,000 could be realized as congestion in the corridor increases.

TABLE 10: ESTIMATED OPERATING COST IMPACT FROM THE BOS PROJECT

Route		Existing Service			With BOS Project		
		Number of Trips	Operating Cost per Hour	Travel Time (minutes)	Annual Operating Cost	Estimated Travel Time Savings (minutes)	Estimated Annual Operating Cost Savings
Southbound/ Westbound	41 SR 14 Limited	2	\$138.47	16.4	\$19,151	3.08	\$3,597
	65 Parkrose Limited	12	\$138.47	12.6	\$88,283	3.74	\$26,205
	164 Fisher's Landing Express	14	\$138.47	56.9	\$465,120	5.29	\$43,242
	177 Evergreen Express	3	\$138.47	37.6	\$65,862	2.21	\$3,871
Northbound/ Eastbound	41 SR 14 Limited	2	\$138.47	14.8	\$17,283	0.21	\$245
	65 Parkrose Limited	14	\$138.47	24.0	\$196,184	0.67	\$5,477
	163 Fisher's Landing Express	17	\$138.47	34.0	\$337,484	0.67	\$6,650
	177 Evergreen Express	3	\$138.47	39.0	\$68,314	0.46	\$806
BOS Operating Cost Savings							\$90,093
Total Operating Cost					\$1,257,681		\$1,167,589

RIDERSHIP

Reduced travel time has been shown to lead to increased ridership. The ridership elasticity with respect to travel time is assumed to be -0.6 (a generally accepted ridership elasticity for travel time). This means that a 10 percent reduction in travel time would yield a 6 percent increase in ridership. Table below estimates the ridership impact of the BOS project.

TABLE 11. ESTIMATED RIDERSHIP IMPACT FROM THE BOS PROJECT

		Pre-BOS Peak Hour Travel Time	BOS Peak Hour Travel Time	Percent Decrease with BOS	Percent Increase in Transit Ridership	Current Peak Hour Ridership	Estimated BOS Peak Hour Ridership	Weekday Ridership Increase with BOS
Route								
Southbound/ Westbound	41 SR-14 Limited	16.4	13.3	19%	11%	21	23	2
	65 Parkrose Limited	12.6	8.9	29%	18%	133	156	23
	164 Fisher's Landing Express	56.9	51.6	9%	6%	466	492	26
	177 Evergreen Express	37.6	35.4	6%	4%	43	45	2
Northbound/ Eastbound	41 SR-14 Limited	14.8	14.6	1%	1%	7	7	0
	65 Parkrose Limited	24.0	23.3	3%	2%	150	153	3
	164 Fisher's Landing Express	34.0	33.3	2%	1%	310	314	4
	177 Evergreen Express	39.0	38.5	1%	1%	34	34	0
TOTALS						1164	1224	60

The table shows an increase of approximately 60 riders per weekday (a 5.2 percent increase in peak hour, peak direction riders on these routes), which is approximately 15,000 riders annually. This estimate should be considered to be conservative since it does not account for expected improvements in service reliability, which studies show is an important factor in a person’s mode choice decision.

IMPLEMENTATION PLAN

SAFETY AND INCIDENT MANAGEMENT

The safe operations of a bus shoulder are built around the design of the shoulder, the policies for operating speeds, and the fact that the bus drivers are professional drivers who are trained how to operate in constrained geometric and traffic conditions. The bus driver's role in safety and incident management is to maintain the safe speed and to monitor downstream conditions on the shoulder to detect any stopped vehicles, debris, merging traffic or geometric pinch points.

Highway shoulders retain their priority purpose for stalled vehicles, crashes, other incidents, emergency response vehicles, and where allowed (e.g., SR-14), bicycles. Adding a BOS designation does not change this priority. Buses should merge into general traffic at least 1,000 feet prior to any blockage of the bus shoulder by stopped vehicles.

Best practices in BOS implementation include developing incident management plans between the facility owner, law enforcement, incident responders, and bus operators. These plans can result in quick clearance of incidents from shoulders through policies and communication strategies that accelerate the removal of obstructions from the shoulder and restore the full BOS facility. Examples of strategies include rapid response towing of vehicles that have stalled or been damaged in an incident, and the use of communication protocols between bus drivers and incident responders that expedite response when a bus driver detects an event that is blocking the shoulder.

By installing the appropriate signs in the corridor, the framework is set for permitting authorized buses to travel on the shoulder. Law enforcement will aid in the success of the BOS by monitoring corridor conditions, providing assistance in removing stalls and incidents quickly from shoulder lanes, and providing the incident reporting needed for accurate evaluation of the initial system or pilot. There is some slight risk that motorists will see buses traveling on the shoulder and think that the shoulder is now open as a driving lane. Though this risk is highly unlikely based on experience in other communities, both monitoring by law enforcement and communication to motorists through an engagement plan should be used to mitigate this risk.

One data point in the evaluation of BOS will be the safety of the operation. Law enforcement reports about any crashes in the corridor will be a source for this analysis. Coordination with law enforcement should include agreement on how any incident reporting and coding will occur. For incidents involving buses, follow-up interviews with bus drivers by either law enforcement or C-TRAN will provide a key source of data for the safety analysis.

The expectation is that the BOS facilities will be a success in terms of safety. This expectation is based on experiences from other regions and the fact that, with trained professional bus drivers operating within safe parameters defined by the project, the result should be no change in the safety conditions.

LEGAL FRAMEWORK AND REQUIREMENTS

Before starting a BOS program or pilot, the proper legal, policy, and operating parameters must be in place to support the BOS facilities.

In many states, the key barriers to implementation for BOS are laws that indicate it is illegal to operate a vehicle on a shoulder. For BOS operations, states often must adopt statutes that exempt buses from this restriction.

WASHINGTON

The legal framework is already established in the State of Washington for BOS operations, and this legal framework covers the SR-14 corridor and the northern portion of I-205. As determined during the implementation of BOS on I-405 in Seattle, designating a shoulder as a BOS lane is consistent with Revised Codes of Washington (RCW). Specifically, the authorization is derived from RCW 47.52.025 (Additional Powers - Controlling use of limited access facilities - High occupancy vehicle lanes - Definition) and RCW 46 61.165 (High Occupancy Vehicles lanes - Definition). The texts of RCW 47.52.025 and RCW 46 61.165 are included in the appendix of the workshop packet in Appendix B.

Vehicles in Washington are also required by law (RCW 46.61.220) to yield to transit vehicles re-entering the traffic flow.

OREGON

Oregon does not have comparable language in the Oregon Revised Statutes (ORS) that expressly permits designation of a shoulder as a BOS lane. However, the legal framework does exist for ODOT to designate exclusive use of lanes for buses. In addition, the Oregon Transportation Commission has broad authority to control operations of state highways, including use of shoulders.

If ODOT wanted to establish express legal authority for BOS, it could do so through an Oregon Administrative Rule (OAR) or by amending the ORS. The OAR process is administrative and likely faster compared to the legislative process of amending the ORS. The following example text, which is based on existing Minnesota law, could be tailored to allow for BOS in Oregon.

EXAMPLE USE OF SHOULDER TEXT BASED ON EXISTING MINNESOTA LAW

(a) The Director of Transportation is authorized to permit the use by transit buses of a shoulder, as designated by the commissioner, of a freeway or expressway, as defined.

(b) If the Director permits the use of a freeway or expressway shoulder by transit buses, the Director shall permit the use on that shoulder of a bus (1) with a seating capacity of 40 passengers or more operated by a motor carrier of passengers, as defined while operating in intrastate commerce or (2) providing regular route transit service, as defined. Drivers of these buses must have adequate training in the requirements of paragraph (c), as determined by the Director.

(c) Buses authorized to use the shoulder under this section may be operated on the shoulder only when main-line traffic speeds are less than 35 miles per hour. Drivers of buses being operated on the shoulder may not exceed the speed of main-line traffic by more than 15 miles per hour and may never exceed 35 miles per hour. Drivers of buses being operated on the shoulder must yield to merging, entering, and exiting traffic and must yield to other vehicles on the shoulder. Buses operated on the shoulder must be registered.

The current Oregon Bus Yield Law (ORS § 811.167) only applies to buses entering traffic after stopping to pick up or drop off passengers. It does not apply to buses changing lanes or entering a traffic lane from a freeway shoulder. The Oregon language would need to be modified to require a yield when the bus re-enters the traffic lane after operating on the freeway shoulder, similar to existing Washington State law.

POLICY AND DOCUMENTATION

Several policy and concurrence steps must be implemented before a BOS project can begin. These involve process within WSDOT and ODOT, creation of agreements between WSDOT/ODOT and the transit operator, and a concurrence of operations between WSDOT/ODOT and the State Patrols.

DESIGN ANALYSIS/DESIGN EXCEPTION PROCESS

A Design Analysis for WSDOT) or Design Exception for ODOT is required for the BOS projects, because they propose a design and operation that deviates from the standards for use of a shoulder. The Design Analysis/Design Exception documents the design standards, the proposed design, and the justification for deviation from the standards. Procedurally, this document/exception is approved by WSDOT/ODOT. Though the FHWA does not have a required approval for BOS, it is recommended that FHWA should receive a draft and final version of the Design Analysis/Design Exception documents for either corridor, so the agency can provide input and support for the project.

WASHINGTON

CALENDAR ACTION PROCESS

In the State of Washington, a traffic regulation may be implemented only after an official action by the appropriate jurisdictional authority. For state highways, a proposed traffic regulation (or modification) is submitted for action either to the Regional Administrator or the State Traffic Engineer, depending on the delegation of authority, and is reviewed as a “Calendar Agenda” item on the Regional Administrator’s or State Traffic Engineer’s schedule. In this process, a BOS facility is categorized as a High Occupancy Vehicle (HOV) lane designation under the WSDOT Traffic Manual (October 2009), and the State Traffic Engineer would have the delegated authority for taking official action (i.e., completing the Calendar Action Process) for approval of designation of a BOS facility.

OREGON

DESIGN APPROVAL

Similar to Washington, in Oregon ODOT’s State Traffic-Roadway Engineer would need to approve designation of a BOS facility on a state highway. Given that there currently are no BOS facilities designated in Oregon, ODOT may require approval at the Director or Deputy Director level, or may seek approval of the Oregon Transportation Commission before making any designations.

OREGON AUTHORITY TO IMPLEMENT A BOS PILOT PROJECT

Implementing a BOS pilot project in Oregon would require ODOT support at the region and headquarters levels. In addition, it is likely that ODOT would request formal approval by the Oregon Transportation Commission to authorize a pilot project. While the Oregon Transportation Commission has broad authority over the use of highways, there is no state law or administrative rule expressly authorizing the operation of buses on the shoulder of highways in Oregon. ODOT and the Oregon Transportation Commission could collectively make a determination whether a modification to allow use of the shoulder by transit vehicles may occur under Oregon Transportation Commission authority.

If ODOT or the Oregon Transportation Commission decided that specific authority was needed before approving a pilot project, they could adopt a new OAR or amend the ORS. Both of these options would take a considerable amount of time and effort. The soonest that state law could be updated would be during the 2018 Oregon legislative session. Adopting a new OAR could be completed in less than a year, but it would require reviews by the Attorney General's office and Legislative Counsel, and a public hearing. Approval by the Oregon Transportation Commission could happen in less than six months.

Action items: The project team will continue working with ODOT technical staff on identifying options for a pilot project in Oregon. Once a feasible Oregon option has been identified, the project team is available to provide support to ODOT to determine the most appropriate path to authorize a pilot project. An Oregon pilot project could take place at the same time as the Washington State pilot project or follow as a subsequent phase of work.

LETTER OF CONCURRENCE

A Letter of Concurrence is a formal agreement between WSDOT and/or ODOT and any transit operator that is permitted to use the BOS. The intent of the letter is to document the project area, operational requirements, and procedures. This letter would permit a pilot BOS facility operation to continue should it become permanent after the pilot phase, as long as the operating conditions remained in conformance with the agreement.

Table 12 provides a summary of the recommended elements that should be reviewed and agreed to by BOS operating agencies and stakeholders. Note that the recommendations below are based on best practices for operations and safety, and are in line with what is in place for the Seattle area BOS.

TABLE 12: SUMMARY OF RECOMMENDED ELEMENTS OF BOS IMPLEMENTATION

	Typical BOS Options for Consideration	Recommended Minimum Elements/Standards
BOS Project Limits	<ul style="list-style-type: none"> Left shoulder Right shoulder 	<ul style="list-style-type: none"> Right shoulder Exact start and end points of BOS project should be listed in the letter
Permitted Vehicles/Services	<ul style="list-style-type: none"> Regular route buses Privately operated uses School buses Para-transit 	<ul style="list-style-type: none"> Regular route bus service _____
Training	<ul style="list-style-type: none"> Required training on rules and procedures Field training without passengers Required for all bus operators 	<ul style="list-style-type: none"> Required training on rules and procedures Field training without passengers Required for all bus operators before their use of shoulder
Operating Hours	<ul style="list-style-type: none"> Fixed hours No restrictions on hours 	<ul style="list-style-type: none"> No restrictions—available during any time transit service is in operation
Operating Speeds	<ul style="list-style-type: none"> Maximum speed ranges from 25 to 45 mph Maximum speed differential between shoulder and adjacent lane is 10 to 15 mph 	<ul style="list-style-type: none"> 35 mph maximum speed 15 mph maximum speed differential Buses can enter shoulder when speeds are below 35 mph
Merging Requirements	<ul style="list-style-type: none"> Entering vehicles must yield to buses Buses must yield to entering vehicles 	<ul style="list-style-type: none"> Bus drivers must yield to all traffic when entering the shoulder and to all traffic when exiting the highway Specific merging requirements for project limits should be described
Infrastructure Capital and Maintenance Investments	<ul style="list-style-type: none"> Facility owner is responsible for all BOS infrastructure maintenance (signs/shoulders) Transit funding sources pay for portion of capital and/or maintenance investments 	<ul style="list-style-type: none"> Document any fiscal responsibilities of agencies for capital and ongoing costs related to the BOS operation
Incident Management	<ul style="list-style-type: none"> Shoulders are available for stalled vehicles, crashes, and other incidents 	<ul style="list-style-type: none"> Shoulders retain their priority purpose for stalled vehicles, crashes, and other incidents Buses should merge into general traffic at least 1,000 feet prior to any blockage of the bus shoulder by stopped vehicles
Safety	<ul style="list-style-type: none"> Bus drivers must be professional drivers with sufficient training in how to operate on a BOS Bus drivers and operating agencies must report and document any incident that occurs on or as a result of BOS 	<ul style="list-style-type: none"> Bus drivers must be professional drivers with sufficient training in how to operate on a BOS Bus drivers and operating agencies must report and document any incident that occurs on or as a result of BOS

COMMUNITY OUTREACH AND STAKEHOLDER ENGAGEMENT

Developing a community outreach and engagement plan is a key step in building understanding and support of corridor stakeholders and the broader regional transportation users. The community outreach and engagement plan should follow standard successful practices that the lead agencies utilize when introducing a new transportation idea, project or service.

Though the BOS concept has been utilized for a long period of time outside of the Portland/Vancouver metropolitan region, the concept will be new to most of the people who need to be engaged. Starting with a pilot project represents an opportunity to introduce the concept to the region, not just to the specific corridor users and stakeholders. Learning from those regions that have already implemented BOS, it is important to emphasize these key areas in the community outreach and engagement:

- *Explain the concept*
- *Talk about the benefits to transit riders*
- *Highlight the cost-effectiveness of the strategy (both the low infrastructure cost and the reduced transit operating cost)*
- *Describe the nuts and bolts of the pilot project (location, eligible users, operational rules, start date, and evaluation methods)*
- *Emphasize that BOS has proven to be safe*
- *Emphasize how BOS will be enforced*
- *Discuss the next steps for BOS in the region beyond the pilot*

TARGET AUDIENCES

BOS OPERATING AGENCIES

The target audience of the engagement effort includes the agencies involved in supporting, developing, and operating the BOS. This includes, but is not limited to C-TRAN, TriMet, WSDOT, ODOT, RTC, Metro, Port of Portland, Washington and Oregon State Police, and cities and counties in the study area.

BOS CORRIDOR USERS

Reaching transit riders will be relatively easy, because they are a captured audience who will directly experience the new service. Engaging these riders can occur in the weeks before start-up of the BOS and after the service is in place. The transit riders simply need to know about the new service, how it works, and the basics of when a bus driver will decide to use the shoulder or not.

Drivers traveling on the BOS corridors will need additional information about the new service, so they understand how it works and are not surprised by buses now operating on the shoulder lane. The engagement of drivers should emphasize that the shoulder is only for buses and that it is still available for emergency stopping. The basic safety messages regarding merging when buses are present should also be emphasized.

REGIONAL AUDIENCE

Implementing BOS first with a pilot project creates an opportunity to introduce BOS to the region. The materials and message that explain how BOS works and what its benefits are can be used successfully for both the pilot project audiences and the regional audience. As the pilot project engagement gets underway near the implementation date of BOS on the corridor, agencies need to have messages that indicate the next steps for BOS after the pilot. These next steps include identifying which corridors are under consideration, outlining the

potential implementation time frames, and defining the decision-making process for making the pilot permanent or expanding the concept beyond SR-14.

COMMUNITY OUTREACH MATERIALS NEEDS

There is nothing particularly unique about introducing BOS to a region that would require community outreach materials that are different from what are currently used to implement new transportation projects. The materials required include maps, images, slides, and FAQs that will support a series of news releases, media interviews, social media feeds, and community meetings.

As a starting point for development of the materials, several good examples of community outreach materials that were utilized for regional implementation of BOS are available from transit agencies and DOTs in North Carolina, Virginia, Minnesota, and the Seattle area.

TRAINING DEVELOPMENT AND IMPLEMENTATION FOR USER GROUPS

The training requirements for implementation of BOS are straightforward. The main focus of the training is the bus drivers who will be providing service on the BOS corridor. However, some minimal training is also required for C-TRAN managers, C-TRAN customer service, and law enforcement. All C-TRAN bus drivers who will operate on BOS corridors will require both classroom training and field training.

CLASSROOM TRAINING

Before the start-up of the BOS, drivers will need training on how to operate the bus on the shoulder. The training should be developed in a manner that can be easily repeated over time for any new drivers in the BOS pilot project corridor. The training topics covered in the classroom portion should include the topics listed in Table 13.

TABLE 13: CONTENT AREAS FOR BOS TRAINING

Training Topic	Content to Cover
Purpose of BOS	<ul style="list-style-type: none"> • Description of BOS concept • Overview of where it is used nationally • Expected benefits
Project Location	<ul style="list-style-type: none"> • Map of BOS area • Transit routes covered by pilot
BOS Design	<ul style="list-style-type: none"> • Signing and pavement marking design • Merge/exit locations • Constraint points (if any)
Operating Guidelines	<ul style="list-style-type: none"> • Operating speeds • Merging into/out of shoulder • Actions when encountering stalls and incidents
Operator Responsibilities	<ul style="list-style-type: none"> • Safety • Reporting incidents
Engagement with Customers	<ul style="list-style-type: none"> • Basic bus operations information to provide customers
Operating Procedures for Driving Scenarios	<ul style="list-style-type: none"> • Moving onto shoulder • Merging into traffic • Avoiding a stalled car or incident • Navigating through exit or entrance ramps

Note: The Minnesota DOT has published short instructional videos for bus drivers. These videos are intended for classroom training and cover all of the driving scenarios listed in Table 4. The videos are publicly available at <http://www.dot.state.mn.us/metro/teamtransit/documents.html>.

FIELD TRAINING



Field training should occur in the weeks immediately preceding the start of BOS operations. The training can occur once the signing is installed in a BOS corridor. The purpose of field training is to have bus drivers become familiar with each of the driving elements of operating on the shoulder. Drivers should repeat BOS trips until they are proficient in merging into and out of the shoulder, maintaining the 35 mph speed on the shoulder and maintaining the speed differential with the general purpose lane, and generally operating safely on the narrow shoulder. Field training is conducted during peak period operations with a transit supervisor/manager overseeing but with no passengers on the bus.

PILOT PROJECT

Starting a regional BOS system with a pilot project is an effective mitigation strategy overall because it: (1) limits the number of agencies involved in the project; (2) allows agencies to work through all issues in a scaled-down corridor; (3) provides for a simpler monitoring and evaluation environment; (4) minimizes implementation costs; and (5) most important, conveys to the public that the concept is being tested and will be adjusted if any issues are found.

A pilot BOS corridor is proposed by C-TRAN on SR-14 connecting the Fisher’s Landing Transit Center at the 164th Avenue interchange to the I-205 interchange. The feasibility study has shown the SR-14 segment to be suitable as a pilot BOS corridor because of the relatively simple geometry of the roadway, the presence of an existing shoulder, and the potential travel time savings to multiple transit routes. An SR-14 BOS pilot project would serve three existing transit routes: Route 41 Limited connects Downtown Vancouver to Fisher’s Landing Transit Center in the AM and PM peak periods; Route 65 provides all-day service connecting riders between Fisher’s Landing and the Parkrose/Sumner Transit Center; and finally, the express Route 164 connects riders from Fisher’s Landing to downtown Portland during the AM and PM peak periods.

EVALUATION AND MONITORING OF PILOT

The pilot project is designed to introduce the BOS concept to the Portland/Vancouver region. In addition to providing benefits to bus routes using SR-14, the pilot is intended to be a learning process to help with the rollout of BOS on other key corridors in the region. An evaluation of the pilot is an important component of the planning for a broader implementation of BOS in the region. The evaluation process should include development of a data collection and evaluation plan, execution of the data collection, and analysis of the results. The key components of these steps are listed in Table 14.

TABLE 14: BOS EVALUATION STEPS

Evaluation Actions	Evaluation Elements
Develop Evaluation Plan	<ul style="list-style-type: none"> • Time frame of evaluation (before/after) • Metrics of measurement • Quantitative and qualitative data elements
Develop Data Collection Plan	<ul style="list-style-type: none"> • Define data to collect and its format • Define responsible party for collection of data • Identify data gaps and alternative data options
Collect and Analyze Data	<ul style="list-style-type: none"> • Collect data • Analyze data • Report findings

The following data elements would provide supporting info for the evaluation:

QUANTITATIVE DATA



- Change in travel time of transit in pilot project (before/after)
- Change in on-time performance of routes (Routes 41, 65, and 164)
- Change in transit ridership (Routes 41, 65, and 164)
- Safety performance (documentation of any bus-related incidents in the pilot corridor)
- Frequency of use of BOS*

QUALITATIVE DATA

- Interviews with bus drivers, transit agency managers, DOT staff, law enforcement (after)
- Questionnaires/interviews with transit riders

*The frequency of buses using the shoulder is best determined by installing detection on the shoulder to automate the collection of the data. If detection for this purpose is not included in the pilot project, then this data may be obtained qualitatively through interviews with drivers or agency staff.

PILOT PROJECT COSTS AND RESOURCE REQUIREMENTS

Although a BOS pilot project is low-cost, decisions must be made regarding the responsibility for upfront and ongoing costs. Agency staff resources at WSDOT and C-TRAN are needed for design and implementation of the program. Pilot project costs include the cost of developing signing plans, developing and implementing training, developing and implementing the engagement and community outreach plan, procuring and installing the BOS infrastructure, and finally conducting the evaluation. As part of the pilot project design, it is recommended that there be an agreement on responsibilities for funding and resourcing the various elements of the BOS.

For the pilot project, the field infrastructure costs are relatively low, and training can be conducted with existing resources. The costs of the community outreach and evaluation elements can vary depending on the level of effort desired for the pilot.

PILOT PROJECT SCHEDULE

As shown in Table 15, the implementation of a BOS pilot project on SR-14 can be reasonably achieved within a six-month schedule, and the evaluation of BOS operations can be completed within 12 months. The schedule benefits from the fact that BOS has already been deployed in the State of Washington. The existing deployment of BOS in the state ensures that the legal framework is already in place, that the procedural steps for design and implementation on state highways are already defined, and that the general operational parameters for operating buses on the shoulder are agreed upon. It is expected that additional time could be required for regional deployment of BOS located within Oregon, because Oregon has not previously implemented BOS. Table 14 outlines a draft schedule for typical key tasks in the deployment of a BOS pilot.

It should be noted that several tasks described in the draft schedule have been completed or are partially complete through this BOS Feasibility Study; therefore, the timeline for the start of BOS operations for a pilot project could be shorter than shown in the table.

TABLE 15: DRAFT SCHEDULE FOR BOS PILOT PROJECT

BOS Pilot Project Basic Schedule by Task	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Develop Design Concept	█	█										
Identify Project Funding			█									
Develop and Secure all Project Agreements			█	█								
Develop and Conduct Stakeholder Engagement		█	█	█	█	█	█	█	█	█	█	█
Install Field Infrastructure					█	█						
Develop and Conduct Classroom/Field Training				█	█							
Start BOS Operations						█						
Plan and Conduct Pilot Evaluation			█	█	█	█	█	█	█	█	█	█
Develop Lessons Learned and Regional Plan											█	█

SCHEDULE ASSUMPTIONS

The basic schedule has several risks and opportunities that could impact it. The following assumptions are made in defining this schedule:

- The design concept will follow the BOS design implemented on I-405 in Seattle.
- The funding necessary to implement the project is available.
- The production and installation of all BOS infrastructure can be done by WSDOT or within a minimal time for design and installation of infrastructure by contract.
- The existing shoulder and drainage infrastructure can adequately support buses operating on the shoulder.
- All training can be conducted in the month prior to the start of operations.
- The evaluation time frame is three months before BOS operations and six months after.

IDENTIFICATION OF PILOT PROJECT RISKS AND MITIGATION STRATEGIES

Bus on shoulder programs have few risks, and they are generally known risks based on previous implementation experiences. Risks and mitigation strategies are included in Table 16.

TABLE 16: RISKS AND MITIGATION STEPS FOR BOS IMPLEMENTATION

Risk	Mitigation
Pilot project costs are not secured	<ul style="list-style-type: none"> • Identify full project costs • Secure funding agreements for all elements of implementation before start of project
Shoulder infrastructure is inadequate to handle buses	<ul style="list-style-type: none"> • Conduct investigations of infrastructure to verify conditions • Program infrastructure upgrades, if necessary, to sustain pilot in long term
Safety issues result in negative perception of project	<ul style="list-style-type: none"> • Provide effective training of bus drivers • Inform traveling public of the new service and how it operates • Closely monitor the operations of the pilot project • Investigate all incidents involving buses and determine if changes are needed • Clearly document safety findings in evaluation and communicate these results
Expected benefits of project are not realized	<ul style="list-style-type: none"> • Select a pilot corridor that will likely have clear benefits from BOS • Build an evaluation that includes both quantitative and qualitative data (survey data of transit riders) to clearly document benefits

STUDY RECOMMENDATIONS

This BOS Feasibility Study provides an evaluation on the application of BOS in the study corridors and potentially for a BOS pilot project for implementation. It evaluates potential geometric and operational constraints, and (2) identifies opportunities (locations and time periods) for implementing BOS. BOS operations are recommended on SR-14 from I-205 to 164th Avenue and on segments of I-205 from SR-14 to I-84. The recommended segments require relatively little modification of the exiting roadway. These recommendations provide the basis for moving forward with the implementation of BOS segments on SR-14 and I-205.

The legal framework is in place on the Washington side, making SR-14 ideal for a pilot study. BOS in Oregon does not currently have authority to operate buses in the freeway shoulder and would have to be addressed prior to implementation.

In addition, there are several segments in the corridors that have promise in showing additional operational and reliability benefits for transit by completing gaps and expanding the BOS concepts. These additional segments would require a level of investment outside the scope of this study, but should be considered for further evaluation by policy makers.

RECOMMENDED BOS CONCEPTS

The BOS workshop, held in December 2016, developed a set of BOS concepts framed within the scope of the study that focused on minimal and low cost BOS options for SR-14 and I-205. Minimal cost options, target what can be done with roadway signing and minor striping of the existing roadway. Low cost or low capital options, emphasis signing, more significant striping, merge/diverge adjustments and other minor modifications to complete gaps at key locations. The workshop outcome successfully identified bus on shoulder concepts for SR-14 and I-205 as shown on Figure 17, with implementation of the BOS concepts recommended in the following three categories:

- **Proposed Pilot Project**
 - SR-14 eastbound and westbound between 164th Ave. and I-205
- **Recommended**
 - I-205 northbound and southbound between SR-14 and Airport Way
- **Not Recommended at This Time – Subject to Further Review**
 - I-205 southbound from Airport Way exit to eastbound Airport Way entrance
 - I-205 southbound from I-84 eastbound exit to westbound entrance
 - I-205 southbound from I-84 westbound entrance to I-84 westbound exit

FIGURE 17: BOS CONCEPTS



SR-14 WESTBOUND

While both minimal and low cost options were developed for Westbound SR-14 from I-205 to 164th, the low cost option is recommended. Compared to the minimal cost options, it offers improved bus movement and reliability with minor restriping that:

- Restripes shoulder at the east end of SR-14 to allow buses to stay out of the traffic lane and move directly onto the shoulder from the bus only onramp from 164th Avenue.
- Extends westbound BOS approximately 1,000 feet to the west by restriping collector / distributor road shoulder between the I-205 NB exit and the entrance ramps to westbound SR-14.

SR-14 EASTBOUND

A minimal cost option from I-205 to 164th is recommended for SR-14 eastbound.

STUDY TEAM OBSERVATIONS

WSDOT and C-TRAN have cooperated on a thorough examination of SR-14 from I-205 to 164th and identified it as an excellent location for a BOS pilot project. The SR-14 concept:

- Has no intermediate interchanges
- Has suitable freeway shoulders
- Has an existing WB bus only on-ramp at 164th
- Serves as a queue jump to I-205 SB
- A pilot project evaluation will provide performance measurement and allow proof of concept for consideration of other corridors

The agencies are collaborating on the development of a letter of understanding for operating rules and shoulder maintenance as well as the required design analysis documentation for pilot project approval and implementation. An SR-14 pilot project can also provide insight to how BOS operation could apply to other freeway corridors in the bi-state region.

I-205 SOUTHBOUND

There are some geometric constraints on segments of I-205 southbound where shoulders are less than 10 feet or dual lane ramps prevent BOS operations. This limits recommended BOS operations to only portions of I-205. The identified BOS corridor on I-205 southbound is from SR-14 to I-84 and consists of the following segments:

RECOMMENDED

- Segment 1, SR-14 entrance to 1,000 feet before Airport Way

NOT RECOMMENDED AT THIS TIME - SUBJECT TO FURTHER REVIEW

- Segment 2, Airport Way Exit to Airport Way eastbound entrance
- Segment 3, I-84 eastbound exit to I-84 westbound entrance
- Segment 4, I-84- westbound entrance to I-84 westbound exit

I-205 NORTHBOUND

Geometric constraints and programmed construction of northbound auxiliary lanes from I-84 EB and WB to Killingsworth limit opportunities for BOS in the northbound direction to the following segment.

RECOMMENDED

- Segment 1, Airport Way Entrance to 1,000 feet before SR-14 Exit

STUDY TEAM OBSERVATIONS

The northbound and southbound segments that cross the Glenn Jackson Bridge are straightforward sections for the implementation of BOS; there are no intermediate interchanges and there are adequate freeway shoulders for the full length of the bridge. Southbound segments 2, 3 and 4 meet technical criteria established to identify feasible BOS sections. However, they are located in a more complex portion of I-205 with multiple interchanges and several two lane onramps where buses would have to leave and get back on the shoulder. While many regions have successfully operated non-continuous BOS segments with similar characteristics, the three southbound segments may need further examination of operational and safety issues as well as a more detailed policy review on the question of BOS service in the corridor.

There are currently no BOS corridors in the Portland region. The BOS Feasibility Study Report documents operational guidelines, technical criteria, safety factors, and transit benefits to guide the future consideration of other freeway corridors for BOS operations

ADDITIONAL ANALYSIS

TRAVEL TIME

While the recommended segments on I-205 have a benefit to travel time and reliability and show additional promise as congestion in the corridor increases, BOS use is not available on I-84 west of I-205 because of constrained ROW. It should be noted, that commuter buses on I-205 will frequently reroute by using Sandy Boulevard and other parallel facilities into downtown Portland during times of heavy congestion in the I-205/I-84 corridor.

A more detailed examination of bus travel times between Fisher’s Landing and downtown Portland should be conducted to better understand the tradeoffs between transit travel time to downtown via I-205/I-84 or I-205/Sandy, which is one of the alternate routes used by C-TRAN. This analysis would help guide decision-makers on the full range of routing options for commuter transit travel to Portland.

I-5 BOS SCAN ASSESSMENT FINDINGS

A high level assessment of BOS was conducted of I-5 southbound from 99th Street to the Interstate Bridge and is documented in Appendix A. The assessment focused on geometric opportunities and constraints and AM peak period travel speeds to determine the adequacy of southbound I-5 for possible BOS operations. The scan assessment found that implementing BOS on southbound I-5 would likely require investment levels beyond simple signing and striping. The following segments were identified for further feasibility evaluation. It should be noted that the corridor could accommodate improvements to either an outside or inside shoulder, but not both.

OUTSIDE (RIGHT) SHOULDER

- Segment A: 99th St. to 78th St.
- Segment B: Main St. to 39th St.

These segments would require restriping of the existing lanes to widen the outside (right) shoulder to 11.5 feet due to the adjacent barrier and over the longer term strengthening of the shoulder to increase the depth to a minimum of 7 inches.

INSIDE (LEFT) SHOULDER

- Segment C: 99th St. to SR-14

This segment would require widening and strengthening of the shoulder, along with restriping of the existing lanes to provide an inside (left) shoulder of 11.5 feet due to the adjacent barrier.

POLICY FRAMEWORK

WASHINGTON

The legal framework is already established in the State of Washington for BOS operations and this legal framework covers the SR-14 corridor. This authorization is derived from RCW 47.52.025 (Additional Powers - Controlling use of limited access facilities - High occupancy vehicle lanes - Definition) and RCW 46 61.165 (High Occupancy Vehicles lanes - Definition)

OREGON

Oregon does not have comparable language in the Oregon Revised Statutes (ORS) that expressly permits designation of a shoulder as a BOS lane. However, the legal framework does exist for ODOT to designate exclusive use of lanes for buses. It would first require ODOT support at the region and headquarters levels. If ODOT is interested in pursuing BOS, there are several possible pathways to proceed.

The Oregon Transportation Commission has broad authority to control operations of state highways, including use of shoulders. ODOT and the OTC should examine and make a determination whether a modification to allow use of the shoulder by transit vehicles may occur under Oregon Transportation Commission authority. If ODOT wanted to establish express legal authority for BOS, it could do so through: 1) an Oregon Administrative Rule or by amending the Oregon Revised Statute (ORS), which would require legislative action.

POTENTIAL NEAR TERM I-205 BOS EXTENSIONS

The following segments could accommodate BOS with additional investments beyond the Minimal or Low Cost investments evaluated by the Feasibility Study and were therefore outside the scope of this study. Although they are not recommended, they are included here because they would offer improved reliability and travel time for transit if BOS expansion in the corridor were to be considered.

I-205 (18TH STREET TO MILL PLAIN)

The shoulder is 10 feet wide; however, there is a barrier immediately adjacent to the shoulder for the majority of the segment length and bus on shoulder operations adjacent to a barrier require a minimum 11.5-foot-wide shoulder. As a result, the shoulder will need to be widened to accommodate BOS in this segment. With only one bus route (Route 177) using this segment of the corridor, along with heavy congestion on the 18th Street on-ramp limiting the reliability of the bus route, investment in BOS in this segment is not recommended as part of this initial feasibility evaluation.

SR-14 LOOP RAMP TO I-205 SOUTH

The cost of this segment to accommodate BOS was outside the scope of this study, however, the loop ramp from SR-14 Westbound to I-205 Southbound is congested during the AM peak period and buses would benefit from BOS on shoulder operations on the ramp to connect the recommended Westbound SR-14 BOS segment with Segment 1 of the recommended Southbound I-205 BOS across the Glenn Jackson Bridge.

The existing ramp would require widening to provide adequate shoulder width BOS operations. Given the relatively tight horizontal and vertical curvature of the ramp, the shoulder would have to be more than 10 feet to provide adequate site distance and accommodate the wide path of long buses traversing the loop ramp.

PROGRAMMED SR-14 IMPROVEMENT

Since the completion of the BOS Study, new funding has become available to expand SR-14 from 2 to 3 travel lanes in each direction between I-205 and 164th Avenue. Design of SR-14 improvement is programmed to occur over the next 2 years with construction in 2019 to 2021. SR-14 project design should be considered that accommodates the WB transit on ramp at 164th, the future/ongoing operation for transit use of the freeway shoulder on SR-14, the transition of BOS from SR-14 to the SB loop ramp to I-205 and widening of the ramp to accommodate use of ramp shoulder for transit vehicles. This would allow a continuous BOS lane from 164th on SR-14 west to the Airport Way Exit on I-205 south.