BUS ON SHOULDER FEASIBILITY STUDY:

Workshop Packet – Session 1

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Workshop Executive Summary

Context and Background

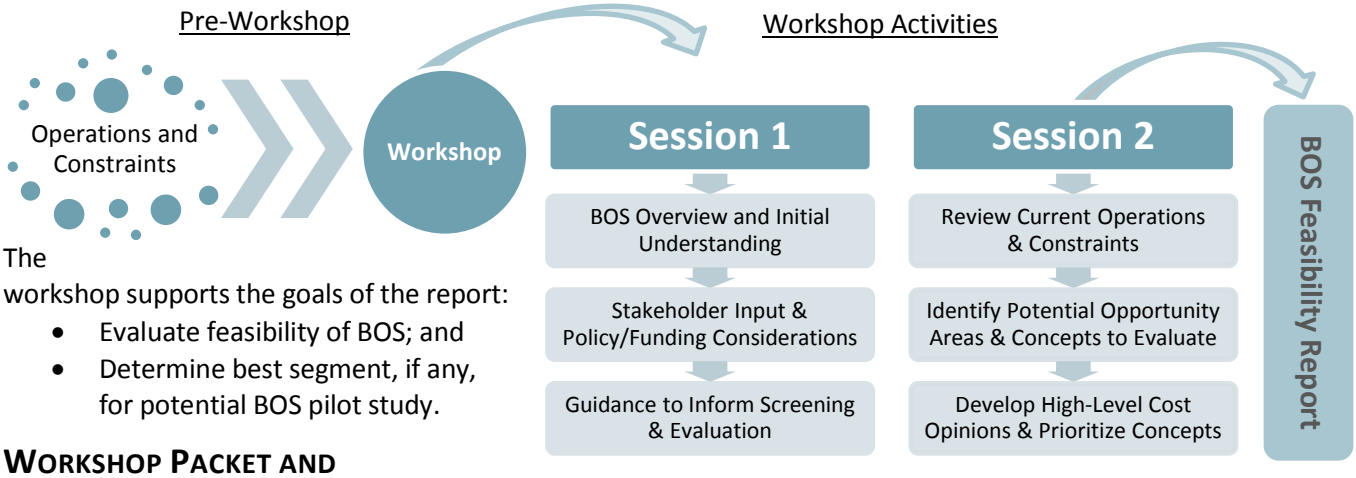
The region has a growing travel demand challenge crossing the Columbia River. The Bus on Shoulder (BOS) Feasibility Study is being initiated as one of several strategies that the Southwest Washington Regional Transportation Council (RTC) is studying to manage congestion. The I-205 Access and Operations Study recommendations called for examining the potential of buses using the freeway shoulder during times of heavy congestion. This BOS Feasibility Study will provide a proof of concept evaluation to identify one BOS strategy for the corridor and potentially identify a pilot project for BOS operations.

Workshop Purpose and Goals

This multidisciplinary strategy workshop will engage a wide range of technical and policy-level staff to help develop strategies that inform the screening, evaluation, and recommendations for this BOS Feasibility Study. This workshop is intended to provide a collaborative, challenging, and creative environment that supports the rapid identification and screening of feasible BOS concepts, development of initial cost opinions, as well as policy/funding considerations. The workshop is designed to engage advisory committee members in two half-day sessions with separate focus areas:

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

Session 2: Technical focus with technical and operations staff and other stakeholders potentially affected by any proposed system.



The workshop supports the goals of the report:

- Evaluate feasibility of BOS; and
- Determine best segment, if any, for potential BOS pilot study.

Workshop Packet and Supporting Information

Pre-workshop data collection, analysis, mapping, and synthesis of related policy and funding examples are included in this Workshop Packet. The packet also includes operational, geometric, and supporting implementation guidelines. This information is intended to help the workshop participants:

- Understand the location, duration, and extents of potential BOS opportunities (based on speed/delay)
- Consider operational/design constraints (shoulder width, structures, pavement depth, merge, etc.)
- Evaluate the potential influence of incidents and law enforcement/public safety needs.

BOS Examples & Requirements

Several examples of BOS pilot projects are listed below that provide valuable insights and lessons learned that has been built into the proposed BOS concepts for the I 205 and SR-14 Corridors. Initial base assumptions and requirements (are among the initial principals to agree on to guide and inform 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	1 year	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	Ongoing	No	Results pending

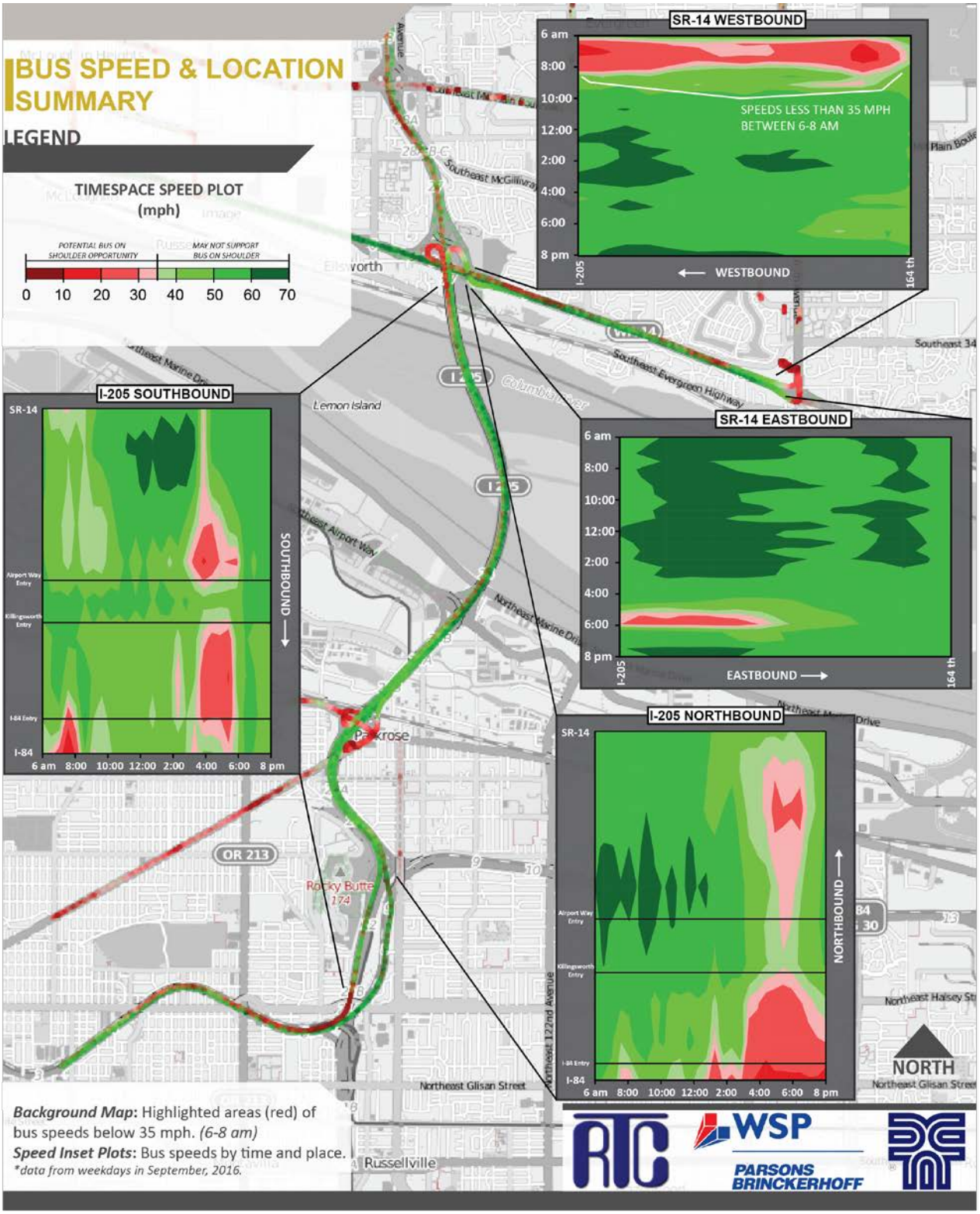
Learning from those regions that have already implemented BOS, it is important to emphasize these key areas in the community outreach and engagement:

- **Education – explain the concept & 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**

Sample Base Assumptions/Requirements

Category	Recommendation
Operating Speeds	• 35 MPH maximum speed • 15 MPH maximum speed differential • Buses can enter shoulder when speeds are < 35 MPH
Geometric	• Right shoulder widths (preferably 10' or wider) • Pavement depths within the shoulders (>7") • Vertical clearance within the shoulders >(14')
Operating Hours	• No restrictions—available during any time transit service is in operation
Ramp Volumes	• Ramp volume less than 1,500 vph
Merging	• 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	• 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	• Bus drivers must be professional drivers with sufficient training in how to operate on a BOS

FIGURE 1: BUS SPEED AND LOCATION SUMMARY



HIGH-LEVEL CONTEXT AND GUIDANCE (SESSION 1)

BOS OVERVIEW AND NATIONAL EXPERIENCE

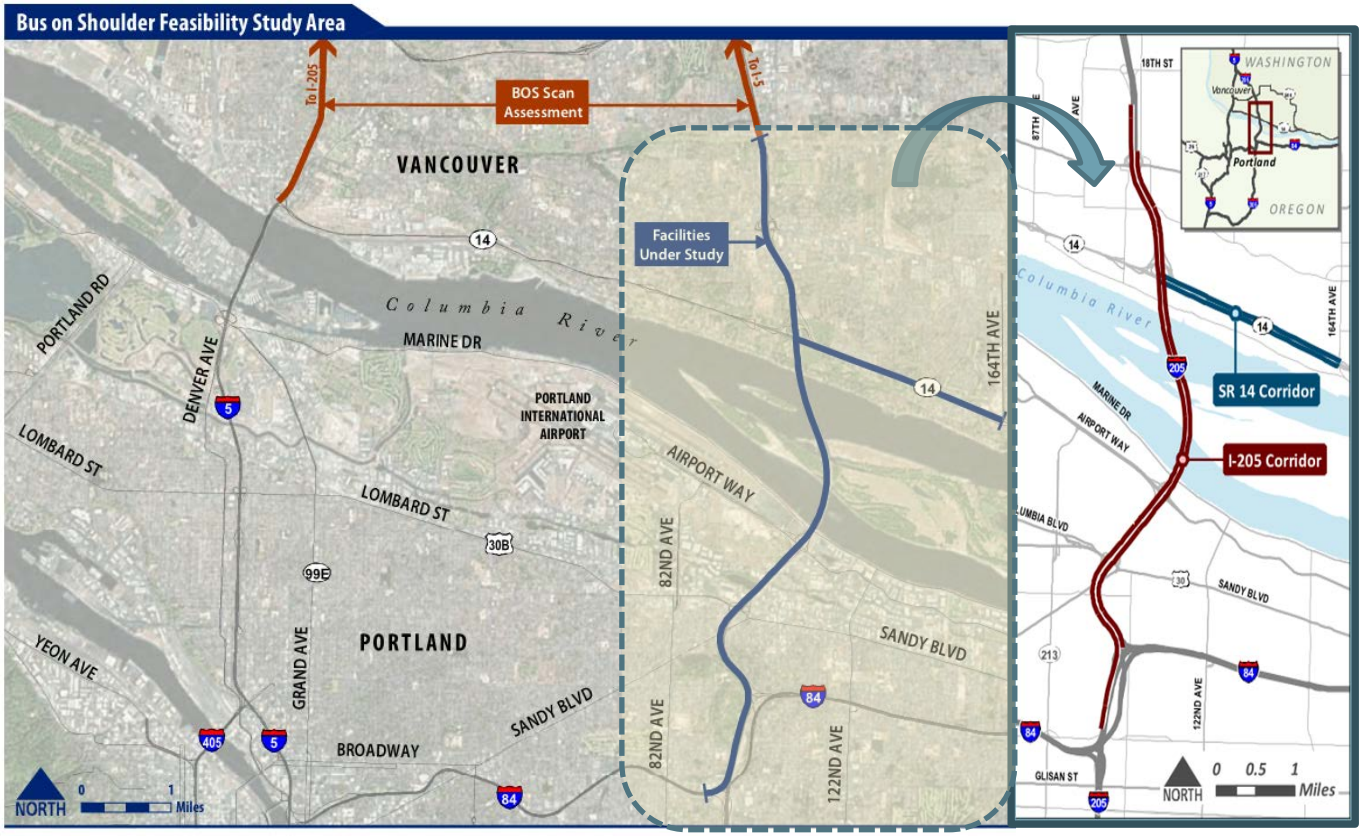
BACKGROUND & GOALS

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 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.

Session 1 Goals

- Understand BOS Strategies and Benefits
- Gather Stakeholder Input & Review Policy/Funding Considerations
- Provide Guidance to Inform Screening & Evaluation in Session 2

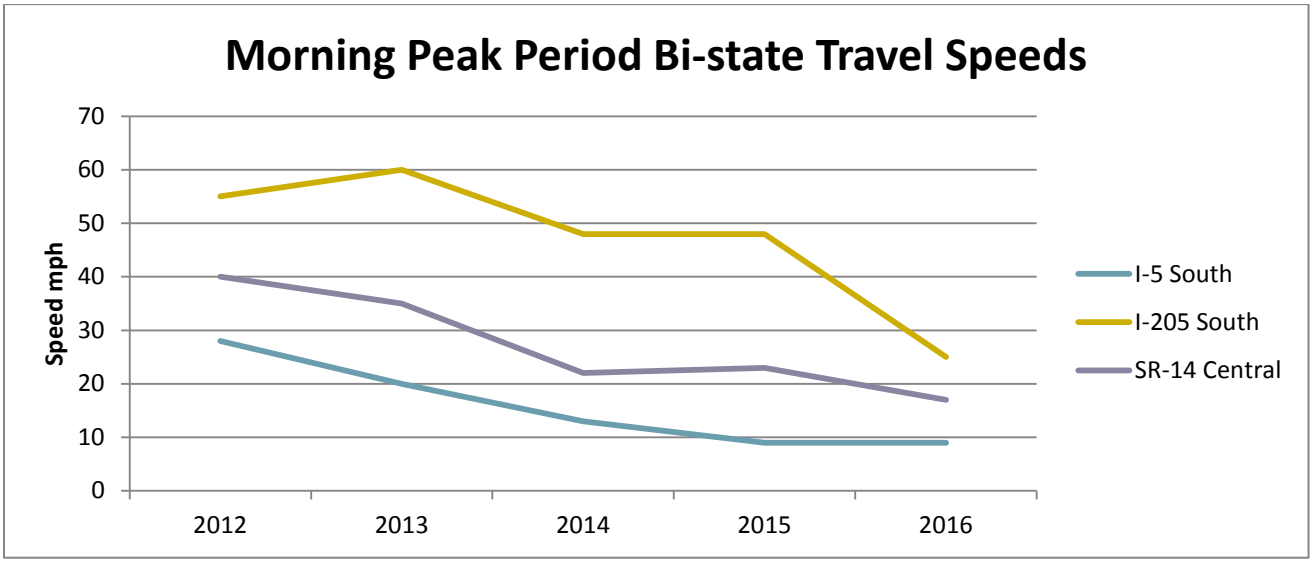
FIGURE 2: STUDY AREA



As shown in Figure 2, the study corridor 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 workshop will be used to conduct a scan assessment of the technical issues and physical characteristics associated with BOS on I-5 north of SR-14 and I-205 north of 18th Street.

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 resuling in higher travel times and reduced travel speeds, as shown in **Error! Not a valid bookmark self-reference.**. 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 3: 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 RTC is conducting several studies to identify strategies to improve the efficiency of the existing transportation system to move people across the river. In addition to this Bus on Shoulder Feasibility Study, RTC is also has funds programmed for an operations study that would look at ways to manage the region's urban freeways more effectively that would look at results of the ramp metering study, advanced traffic management, variable speeds, incident management and other operational and high tech strategies. The Washington State Department of Transportaion is aslo leading a study to analyze the benefits and impacts of ramp metering on Clark County freeways.

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.

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 considerations 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.

NATIONAL EXPERIENCE WITH BOS

As regions begin to consider BOS facilities, experience throughout the country indicates that the first facility

should 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 if 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 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 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	1 year	No	Results pending
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California	San Diego	2 years	No	BOS expanded
Washington	Seattle	Ongoing	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. In order 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 bus on shoulder 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 MPO, FHWA, Transit Operators, and the DOT 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 DOT, 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 project was set up as a pilot 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 SR 527 on-ramp to NE 195th Street off-ramp and from SR 522 on-ramp to 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 to 9 AM 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 shoulders 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. Additionally, 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 while operating on the narrow shoulder. Left shoulder operations 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 as 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 was 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 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 the 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 private 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, 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: • Regular route buses • Privately operated uses • School buses • Para-transit	• Regular route bus service only

OPERATING HOURS AND SPEEDS

Operating hours and operating speeds of bus on shoulder facilities are set by the BOS policy and are based infrastructure and safety. For hours of operation, the facility can have fixed hours posted on regulatory signs in the corridor or no posted hours (see examples in Figure 1). 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 events that are causing congestion. Leaving the hours unrestricted also maintains flexibility for use as traffic congestion levels or times change over time.

Setting 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 a narrow shoulder, must be prepared to encounter and weave around stopped vehicles on the shoulder, and as a safety precaution 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 a bus and adjacent traffic is a best practice supported by experience and recommendations of traffic safety experts. It is the responsibility of the bus driver 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 criteria 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 SPEED CRITERIA

	Typical BOS Criteria for Consideration	Recommended Elements for BOS Implementation
Operating Hours	• Option 1: Fixed hours • Option 2: No restrictions on hours	• No restrictions—available during any time transit service is in operation
Operating Speeds	• Maximum speed ranges from 25 to 45 MPH • Maximum speed differential between shoulder and adjacent lane is 10 to 15 MPH	• 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 also 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

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.

<u>Note:</u> This sign is repeated approximately every half mile between the start and end of the BOS.

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.

This regulatory sign, in combination with the Shoulder Authorization sign, is placed at the beginning of the BOS.

This regulatory sign, in combination with the Shoulder Authorization sign, is placed at the end of the BOS.

This warning sign is placed on the entrance ramps for traffic entering the freeway where a BOS exists.

This warning sign is placed in advance of locations where narrow shoulders or safety considerations require buses to merge back into general traffic.

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.

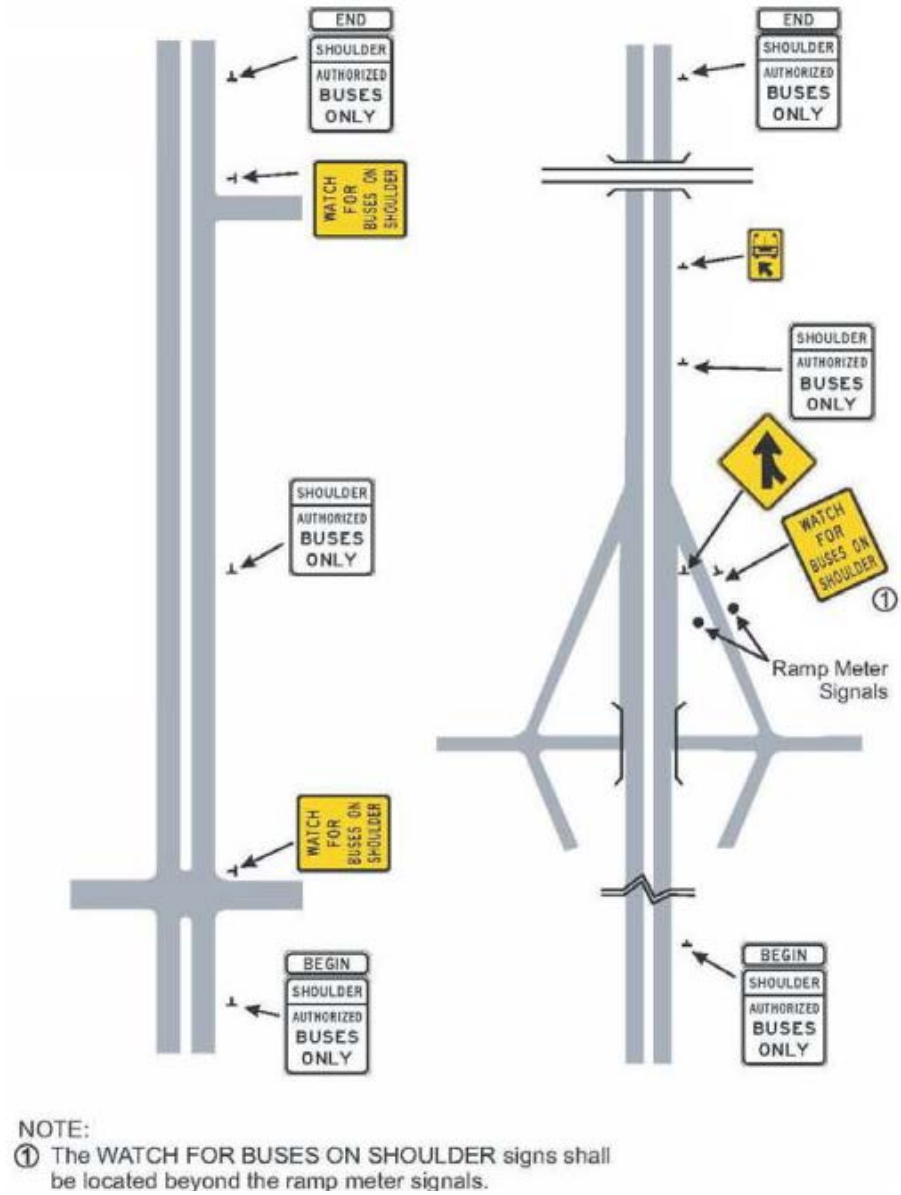
Rule-of-thumb guidelines with a foundation in the ramp volumes were developed in Minnesota and can provide guidance for the weave strategies. BOS ramp weaves are generally not an issue for any ramp volume below 1,000 vehicles per hour (vph). Ramps with volumes of 1,000 to 1,500 vph become challenging 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 safely 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 alternate 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 not re-enter the shoulder until after the on ramp weave. This would minimize motorist surprise at these interchange weave areas but can limit the travel time savings of the BOS facility and is not necessary in most locations.

BOS 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.

Geometric conditions in which the entry ramp is obstructed from view do not allow much advanced warning for the bus driver of a vehicle on the ramp. These conditions may warrant a reduced speed of buses on the shoulder where adequate stopping sight distance is achieved. 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.

FIGURE 5: EXAMPLE SIGNAGE FOR BOS OPERATIONS



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

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 trained on 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 (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.

A best practice in bus on shoulder implementations includes 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 or 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 that permits 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 unlikely based on experience in other communities, the both monitoring by enforcement and communication to motorists through an engagement plan should be used.

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 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.

Key barriers to implementation in many states 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

Because SR-14 and the northern portion of I-205 are located in the State of Washington, the legal framework is already established. 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).

OREGON

Oregon does not have comparable language in Oregon Revised Statutes (ORS) that expressly permits designation of a shoulder as a BOS lane. However, the legal framework does exist for the Oregon Department of Transportation to designate exclusive use of lanes for buses. [1] In addition, the Oregon Transportation Commission has broad authority [2] to control operations of state highways, including use of shoulders.

If the Oregon Department of Transportation or Oregon Transportation Commission wanted to establish express legal authority for BOS, they could do so through an Oregon Administrative Rule (OAR) or by amending the ORS. Based on existing Minnesota law, the following example text 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.

POLICY AND DOCUMENTATION

Several policy and concurrence steps must be implemented before a BOS project can begin. These involve process within Washington State Department of Transportation (WSDOT) and Oregon Department of Transportation (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 (WSDOT)/Design Exception (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 receives 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 to either 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 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 for designation of a BOS facility.

Oregon

Design Approval

Similar to Washington, the Oregon Department of Transportation'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, the Oregon Department of Transportation may require approval at the Director or Deputy Director level, or seek approval of the Oregon Transportation Commission before making any designations.

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 remain in conformance with the agreement.

Table 4 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 4: SUMMARY OF RECOMMENDED ELEMENTS OF BOS IMPLEMENTATION

	Typical BOS Options for Consideration	Recommended Minimum Elements/Standards
BOS Project Limits	• Left shoulder • Right shoulder	• Right shoulder • Exact start and end point of BOS project should be listed in the letter
Permitted Vehicles/Services	• Regular route buses • Privately operated uses • School buses • Para-transit	• Regular route bus service _____

	Typical BOS Options for Consideration	Recommended Minimum Elements/Standards
Training	• Required training on rules and procedures • Field training without passengers • Required for all bus operators	• Required training on rules and procedures • Field training without passengers • Required for all bus operators before their use of shoulder
Operating Hours	• Fixed hours • No restrictions on hours	• No restrictions—available during any time transit service is in operation
Operating Speeds	• Maximum speed ranges from 25 to 45 MPH • Maximum speed differential between shoulder and adjacent lane is 10 to 15 MPH	• 35 MPH maximum speed • 15 MPH maximum speed differential • Buses can enter shoulder when speeds are below 35 MPH
Merging Requirements	• Entering vehicles must yield to buses • Buses must yield to entering vehicles	• 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	• Facility owner is responsible for all BOS infrastructure maintenance (signs/shoulders) • Transit funding sources pay for portion of capital and/or maintenance investments	• Document any fiscal responsibilities of agencies for capital and ongoing costs related to the BOS
Incident Management	• Shoulders are available for stalled vehicles, crashes, and other incidents	• 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	• 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	• 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

Transit Service Plan

A BOS facility can improve the bus travel times and on-time performance of routes. In the deployment of a BOS, consideration should be given to determine whether the transit service schedules for the routes that will benefit from the BOS will 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.

Current Travel Time & 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 C-TRAN's estimate of the impact of peak period traffic congestion on the route's travel time.

The comparison between the scheduled and actual travel times are shown in Table 5 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 number of minutes (plus or minus) that about two-thirds of the trips are within the average travel time. So, 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 minutes 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 5. SCHEDULED AND ACTUAL TRAVEL TIME; STANDARD DEVIATION OF TRAVEL TIMES (ALL TIMES IN MINUTES)

Scheduled and Actual Travel Time	#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 MOBILEstatistics
[1] Routes #164 & #177 travel on I-5 during the PM peak period.
[2] Route #41/SR-14 Limited only travels during peak periods.

Table 5 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 that peak hour, peak direction travel times. This is time that a Bus on Shoulders project can address.

FUTURE SERVICE

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, with an overall 25 percent increase in service a reasonable assumption. 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 to 18th Street and/or possibly having a park and ride in the Camas/Washougal area that would alleviate future demand out of Fisher's and also benefit the SR14 corridor.

Bus on Shoulder Project Service Impacts

The Bus on Shoulder (BOS) project will improve travel time and service reliability by reducing the impact of traffic congestion on the transit service. In addition, the reduced travel times will provide savings in operating cost, which can be used increase service one or more of these three routes, or 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 should the decision be to advance the BOS project to the next phase of development.

Travel Time

The estimated travel time savings for a BOS operation is derived from the #65 Parkrose Limited current actual travel times. As noted earlier, the data indicates that midday service is 2.4 minutes faster southbound and 9 minutes faster northbound that peak hour, peak direction travel times. A BOS project can reduce that discrepancy between off-peak and peak running times by reducing the impact of traffic congestion. Since the #65 Parkrose Limited uses both SR-14 and I-205, it is assumed that the travel times impacts from peak hour congestion are split evenly between SR-14 and I-205. Thus, the congestion impacts are estimated to be about 1.2 minute impact each for I-205 and SR-14 southbound and westbound, and a 4.5 minute impact each or I-205 and SR-14 northbound and eastbound. It is further assumed that a BOS project can reduce the travel time difference by half. As a result, the following travel time assumptions are used to calculate travel time, operating cost, and ridership impacts for the BOS project

- **Route #41 SR-14 Limited**: A 1.2 minute savings westbound in the morning and 4.5 minute savings eastbound in the afternoon. These estimates are double the estimated impact of SR-14 based on Route #65 due to the fact that Route #41 is on SR-14 for a longer distance.
- **Route #65 Parkrose Limited**: A 1.2 minute of saving for peak hour eastbound/southbound travel and 2.3 minute savings for peak hour northbound/westbound travel.
- **Route 164 Fisher's Landing Express**: A 1.2 minute savings for morning peak hour eastbound/southbound travel and 4.5 minutes of savings for afternoon peak hour eastbound travel on SR-14 (route uses I-5 northbound in the afternoon, so uses SR-14 from I-5 east to Fisher's Landing).

- **Route 177 Evergreen Express**: A 0.6 minute of saving for morning peak hour southbound travel and 2.4 minute of savings for afternoon peak hour eastbound travel on SR-14 (between I-5 and I-205).

This simplified travel time assessment should be carefully scrutinized using a traffic model as part of a more detailed analysis of the project should the project move forward.

Reliability

Reducing the impact of congestion with a Bus on Shoulders can be expected to improve reliability by eliminating a portion of the route delay. This is especially true if the extent of the delay varies from trip to trip and 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.

Operating Cost

Based on the estimated peak hour travel time savings attributable to the BOS project, operating cost savings are projected to be about $735 per weekday, or about $189,000 per year (see Table 6). This savings can only be realized if C-TRAN adjusts their schedules and bus assignments to take advantage of the reduced travel time.

TABLE 6: ESTIMATED OPERATING COST IMPACT FROM THE BOS PROJECT

	Existing Service				With BOS Project			
Route	**Operating Cost per Hour**	**Service Hours per Weekday (revenue hrs *1.1)**	**Weekday Operating Cost**	**Annual Operating Cost (Weekday Service)**	**Operating Cost per Hour**	**Service Hours per Weekday (revenue hrs *1.1)**	**Weekday Operating Cost**	**Annual Operating Cost (Weekday Service)**
41 SR 14 Limited	$ 138.47	1.9	$ 259	$ 65,512	$ 138.47	1.7	$ 228	$ 57,804.30
65 Parkrose Limited	$ 138.47	21.8	$ 3,016	$ 763,017	$ 138.47	19.9	$ 2,757	$ 697,505.24
164 Fisher's Landing Express	$ 138.47	28.7	$ 3,975	$ 1,005,795	$ 138.47	26.2	$ 3,625	$ 917,161.58
177 Evergreen Express	$ 138.47	5.4	$ 746	$ 188,827	$ 138.47	5.1	$ 701	$ 177,266.52
TOTALS		**57.8**	**$ 7,997**	**$ 2,023,151**		**52.8**	**$ 7,311**	**$ 1,849,738**
Estimated Annual Savings with BOS Project								**$ 173,413**

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 7below estimates the ridership impact of the BOS project.

TABLE 7. ESTIMATED RIDERSHIP IMPACT FROM THE BOC PROJECT

	Route	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
Southbound/ Westbound	**41 SR-14 Limited**	18	17	6%	3%	21	22	1
	65 Parkrose Limited	12	11	8%	5%	133	140	7
	164 Fisher's Landing Express	26	25	4%	2%	466	477	11
	177 Evergreen Express	30	29	3%	2%	43	44	1
Northbound/ Eastbound	**41 SR-14 Limited**	20	16	20%	12%	7	8	1
	65 Parkrose Limited	17	15	12%	7%	150	161	11
	164 Fisher's Landing Express	31	27	13%	8%	310	334	24
	177 Evergreen Express	40	38	5%	3%	34	35	1
	TOTALS					**1,164**	**1,219**	**55**

The table shows an increase of approximately 55 riders per weekday (a 5 percent increase in peak hour peak direction riders on these routes), which is approximately 14,000 riders annually. This should be considered a conservative estimate since it does not account for improvements in service reliability, which studies show is an important factor in a person's mode choice decision.

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 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 of Oregon State Police, and Study Area Cities and Counties.

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 its benefits are beneficial to 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 what the next steps for BOS are 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 in development of the materials, several good examples of community outreach materials that were utilized for implementation of BOS in a region 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 a BOS implementation are straightforward. The main focus on training is for 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 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 pilot corridor. The training topics covered in the classroom portion should include the topics listed in Table 5.

TABLE 8: CONTENT AREAS FOR BOS TRAINING

Training Topic	Content to Cover
Purpose of BOS	• Description of BOS concept • Overview of where it is used nationally • Expected benefits
Project Location	• Map of BOS area • Transit routes covered by pilot
BOS Design	• Signing and pavement marking design • Merge/exit locations • Constraint points (if any)
Operating Guidelines	• Operating speeds • Merging into/out of shoulder • Actions when encountering stalls and incidents
Operator Responsibilities	• Safety • Reporting incidents
Engagement with Customers	• Basic bus operations information to provide customers
Operating Procedures for Driving Scenarios	• 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 BOS. 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 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.

Project Costs and Financing Resources

Though BOS is a relatively low-cost transportation strategy, decisions must be made regarding responsibility for upfront and ongoing costs. Agency staff resources at WSDOT, ODOT and C-TRAN are needed for design and implementation of the 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.

BOS concepts for each corridor will be developed in two general cost categories.

- **Minimal Cost Concepts**: Use of existing roadway width with improvements limited to signing and striping changes
- **Low Cost Concepts**: Widen/Strengthen roadway surface, minor adjustments to ramp merge/diverge points, queue jumps on ramps and signing and striping changes

Higher cost concepts such as reconfiguring interchanges, moving ramps or widening structures may be discussed at the workshop but will not be evaluated.

Identification of BOS Risks and Mitigation Strategies

Bus on shoulder programs have few risks, and they are generally known risks based on previous implementation experiences.

TABLE 9: RISKS AND MITIGATION STEPS FOR BOS PROJECT IMPLEMENTATION

Risk	Mitigation
Project costs are not secured	• Identify full project costs • Secure funding agreements for all elements of implementation prior to project start
Shoulder infrastructure is inadequate to handle buses	• 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	• 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	• 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

Benefits of 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 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 proposed by C-Tran on SR-14 connecting the Fisher's Landing Transit Center at the 164th Avenue Interchange to the I-205 interchange is part of the larger BOS study that is being evaluated in the workshop. To date, the feasibility study has shown the SR-14 segment to be a 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; 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.