



Everett Link Extension

ATTACHMENT A

Transportation Technical Analysis Methodology



Everett Link Extension

Transportation Technical Analysis Methodology

October 2023

1 INTRODUCTION

This technical analysis methodology memo for the Everett Link Extension (EVLE) Project Environmental Impact Statement (EIS) describes the methods that will be used to analyze project effects on local, corridor, and regional transportation system elements. The analysis results will be documented in the Transportation chapter of the EIS and the Transportation Technical Report.

The intent of the Transportation Technical Report is to inform the public about the potential transportation effects of the Build and No Build Alternatives (defined in the Introduction to the EIS Technical Analysis Methods Report), provide an appropriate level of analysis to make informed decisions, and identify areas in which mitigation might be necessary to reduce potential project impacts. With EVLE, the environmental analysis will proceed in parallel to a variety of other project development efforts, including but not limited to further refinement of the Build Alternatives, including conceptual construction plans, as part of concept design; refinement of the transit integration plans between the relevant transit agencies; and station area planning to integrate the project within the surrounding community. These efforts provide additional opportunities for collaboration between Sound Transit, partner agencies, and the community.

This transportation analysis will identify and evaluate the Build and No Build Alternatives potential impacts for the following transportation elements during both operations and construction:

- Regional transportation, including vehicle miles of travel, vehicle hours of travel, vehicle hours of delay, and mode share
- Transit services, including regional and local services, corridor and station ridership, and transit operations
- Arterial and local street system, including corridor analysis, intersection level of service (LOS), property access and local traffic circulation
- Parking, including the loss of parking due to the alignments and potential hide-and-ride parking impacts near stations
- Non-motorized facilities (bicycle and pedestrian) around stations and on major bicycle or pedestrian trails affected by the alignment(s)
- Safety (all modes)
- Aviation
- Freight (truck, rail, and water)

2 GUIDING REGULATIONS, PLANS, AND POLICIES

In addition to the relevant regulations, plans, and policies considered in all environmental analyses, the transportation analysis will be guided by the following laws and regulations:

- 23 Code of Federal Regulations (CFR) Part 450 (implementing 23 United States Code [USC] Section 111, which requires the U.S. Secretary of Transportation to approve access revisions to the Interstate System)
- 23 CFR Part 710 (Right-of-Way Regulations for Federally Assisted Transportation Programs)
- Revised Code of Washington (RCW) Chapter 47.06 (Statewide Transportation Planning) and 47.24 (City Streets as Part of State Highways)
- Snohomish County Code Chapter 30.66.B (Concurrency and Road Impact Mitigation)
- City of Everett Code Chapter 19.51 (Transportation Mitigation)
- City of Lynnwood Municipal Code Title 11 (Traffic)

Analysis of local transportation impacts will also be guided by the policy direction established in the numerous plans and policy documents adopted within the project corridor,¹ including the following:

- *2016 Washington State Public Transportation Plan* (Washington State Department of Transportation [WSDOT] 2016)
- *Washington State Freight System Plan* (WSDOT 2022b)
- *2022 Washington Statewide Human Services Transportation Plan* (WSDOT 2022c)
- *Regional Transportation Plan 2022-2050* (Puget Sound Regional Council [PSRC] 2022)
- *2023-2028 Transit Development Plan* (Community Transit 2023)
- *Long Range Transit Plan* (Community Transit 2011)
- *Everett Transit Long Range Plan* (Everett Transit 2018)
- *Transit Development Plan: 2022-2027* (Everett Transit 2022)
- *Connect Lynnwood: Active and Accessible Transportation Plan* (Lynnwood 2022)
- Comprehensive and/or transportation plans for the Cities of Lynnwood and Everett as well as Snohomish County
- Six-Year Capital Improvement Program for the Cities of Lynnwood and Everett as well as Snohomish County, including modal plans, such as the Everett Bicycle Master Plan
- WSDOT Synchro and SimTraffic Protocol
- WSDOT Traffic Analysis Guidebook

¹ Dates are for most recently adopted document. Any adopted updates will be used in the development of technical analysis.

- WSDOT Design Manual
- Level of service standards for the City of Lynnwood (Comprehensive Plan, Chapter 5), City of Everett (Comprehensive Plan, Chapter 5), Snohomish County (Comprehensive Plan, Transportation Element), and Washington State Highways (RCW 47.06.140(2))

3 DATA NEEDS AND SOURCES

A variety of data will be assembled to analyze the transportation-related effects of the Build and No Build Alternatives, including the following:

- Adopted PSRC Regional Land Use Forecast targets
- PSRC based regional travel demand model to calculate regional and project area traffic volume growth and other associated traffic metrics
- The Sound Transit Incremental Ridership Model to produce transit ridership forecasts
- City and county travel demand models, if applicable
- Existing transportation information from state and local jurisdictions such as WSDOT, Lynnwood, Everett, and Snohomish County, including:
 - Traffic counts
 - Physical roadway characteristics
 - Freight volumes and facilities existing and planned
 - Existing truck routes, over-dimension routes, and any truck restrictions
 - Pedestrian and bicycle volumes and existing and planned facilities
 - Crash data
 - Public parking information
- Existing transit route information in the study subareas from the local and regional transit agencies, and the Transit Integration Plan for future transit service prepared by Sound Transit and local transit providers
- Trip generation estimates from Link Light Rail Extension mode of access survey (2019) and/or Bay Area Rapid Transit (BART) Station Profile Study (BART 2015)
- Transportation facilities plans and other “committed” improvements assumed for the No Build Alternative, including:
 - WSDOT’s *Connecting Washington Package, Move Ahead Washington, and Washington State Highway System Plan* (WSDOT expected 2023)

- WSDOT's *Washington State Active Transportation Plan 2020 and Beyond* (WSDOT 2020)
- PSRC's *Regional Transportation Plan 2022-2050* (PSRC 2022)
- Sound Transit's ST2 and ST3 Programs (Sound Transit 2008, 2016)
- Regional capital and/or transportation improvement plans (CIPs/TIPs) for Snohomish County, City of Lynnwood, and City of Everett

Certain data sets may be analyzed at the corridor level or at a subarea level as detailed below.

4 STUDY AREA AND AREA OF EFFECT

4.1 Regional Transportation

Analysis of system-wide traffic impacts will address the Build and No Build Alternatives' regional effects within Sound Transit's district boundaries and the project-specific regional study subareas shown in Figure 4-1.

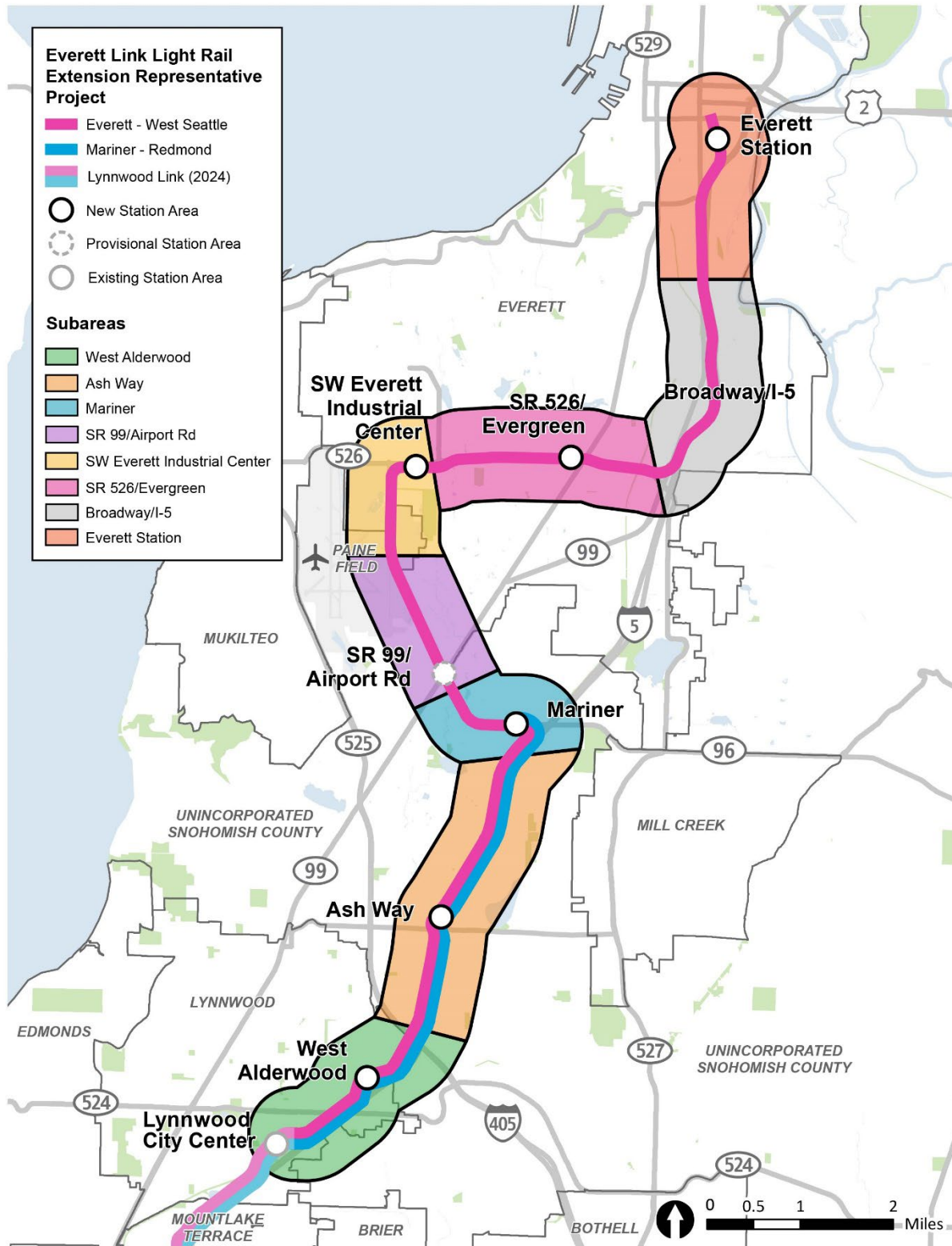


Figure 4-1 Study Area Subareas

4.2 Transit

The transit analysis study area for each subarea is generally the area within 0.5 miles of stations identified in the Build Alternatives. Transit connectivity with the Build Alternatives is addressed in the Transit Integration Technical Memorandum, included as Appendix A, developed by Sound Transit along with Community Transit and Everett Transit, and including Skagit Transit and Island Transit service. Pick-up/drop-off space for shuttle services to be provided by others at key station areas (e.g., SWI and MAR stations) will be defined, to the extent possible, and incorporated into the Transit Integration methodology and ridership forecasting efforts. For more broadly defined transit measures, the study subareas expand to the relevant regional transit system.

4.3 Arterials and Local Streets

The arterial and local street analysis study subareas will focus on locations affected by the light rail alternatives. The intersections that will be analyzed are those directly affected, such as by a change in channelization or intersection control, and those indirectly affected by changes in volume as a result of project trips accessing the system, including intersections and roadways surrounding transit stations and passenger pick-up and drop-off activity locations. Study intersections are listed in Table 4-1 through Table 4-8 and shown in Figure 4-2 through Figure 4-9. These study intersections were identified based on the alternatives in the Alternatives Development phase of the project as well as professional judgement. This list is preliminary based on expected direct and indirect impacts of the various alternatives identified by the Sound Transit Board to be studied in the EIS. AM and PM peak period level of service (LOS) analysis will be conducted at all study intersections. As needed, times outside of traditional weekday AM and PM peak periods will be added to the analysis based on identified local travel patterns. Final confirmation of intersections to be studied will be documented in the Transportation Technical Report and EIS chapter.



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections

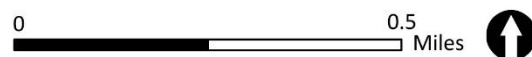
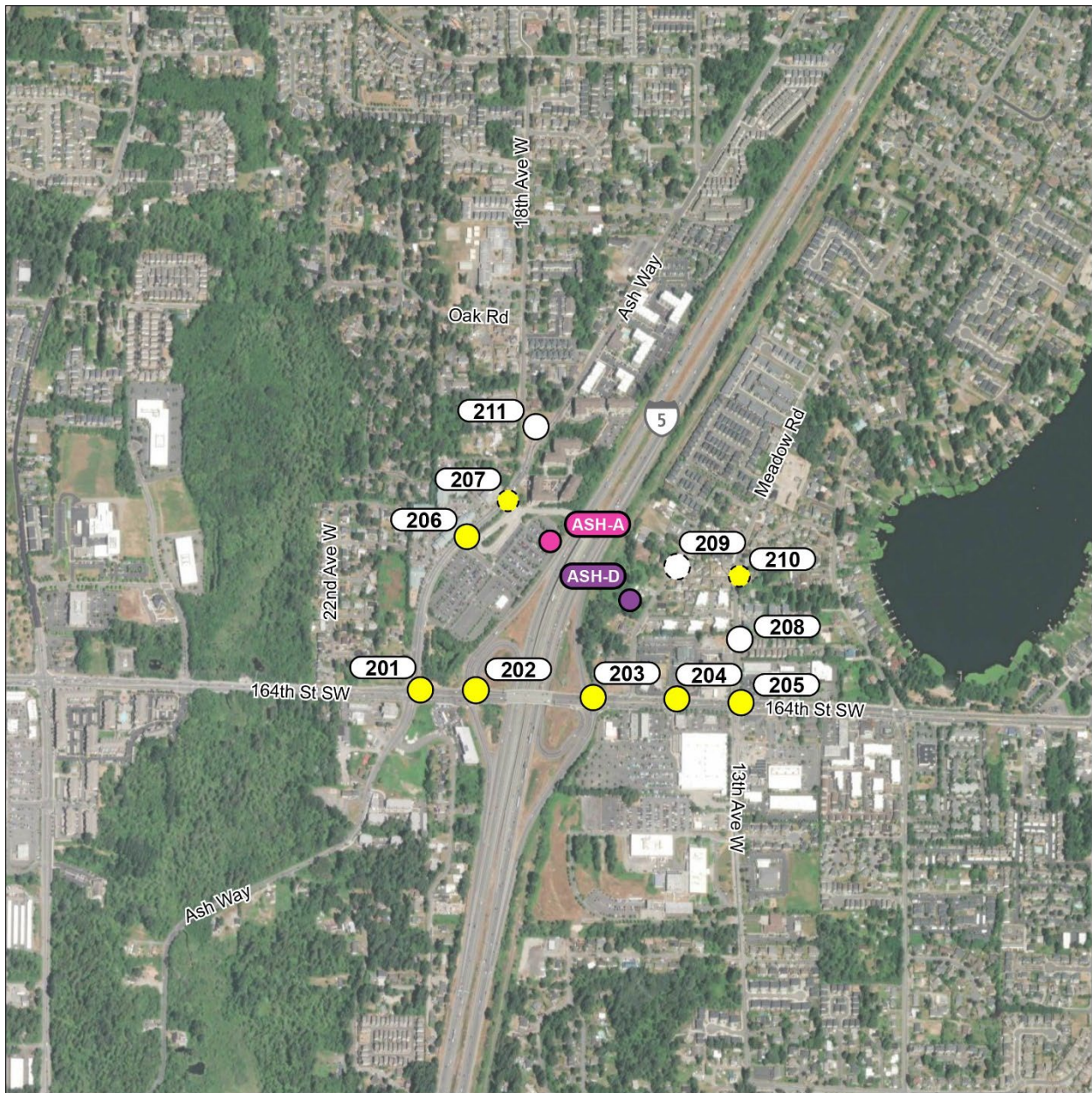


Figure 4-2 West Alderwood Station Subarea Intersections

Table 4-1 West Alderwood Station Subarea Intersections

ID	Intersection Location	Intersections to be Analyzed		
		ALD-B	ALD-D	ALD-F
100	Mall Access Rd/29th Ave	X		
101	Mall Access Rd/ALD-B Station Access	X		
102	Mall Access Rd/28th Ave	X		
103	Alderwood Mall Blvd/28th Ave	X		
104	188th St/33rd Ave		X	
105	33rd Ave/ALD-D Station transit access		X	
106	Mall Access Rd/188th St	X	X	
107	184th St/Mall Access Rd			X
108	184th St/33rd Ave			X
109	188th St SW/36th Ave W	X	X	
110	Alderwood Mall Blvd/33rd Ave W	X	X	
111	196th St SW/33rd Ave W/Poplar Way Bridge	X		X



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections

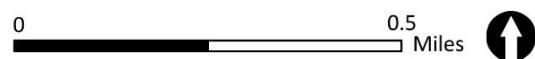
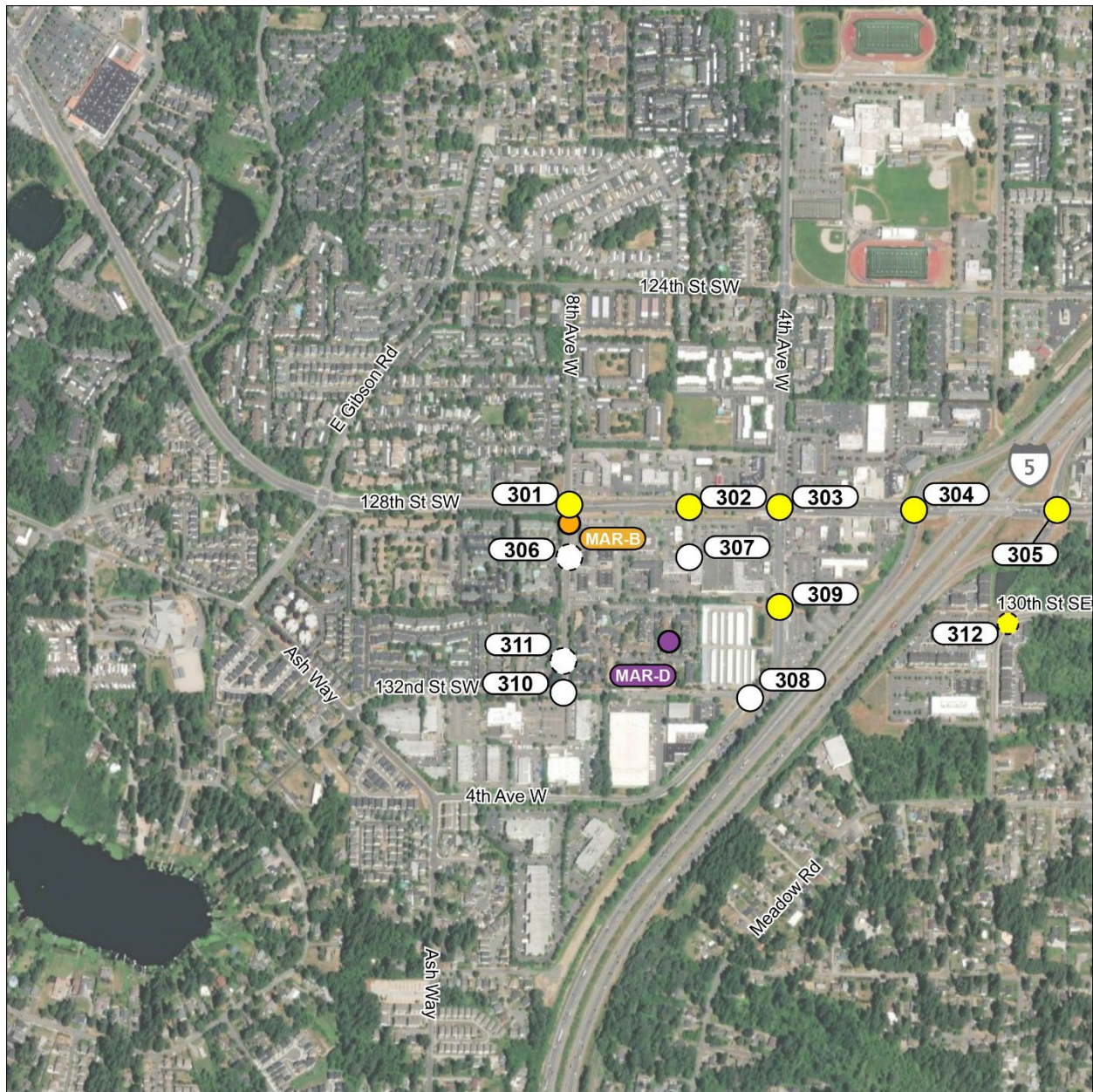


Figure 4-3 Ash Way Station Subarea Intersections

Table 4-2 Ash Way Station Subarea Intersections

ID	Intersection Location	Intersections to be Analyzed	
		ASH-A	ASH-D
201	Ash Way/164th St	X	
202	164th St/I-5 SB Ramps	X	X
203	164th St/I-5 NB Ramps	X	X
204	164th St/14th Pl		X
205	164th St/13th Ave/Meadow Rd		X
206	Ash Way/ASH-A Park & Ride Access	X	
207	Ash Way/ASH-A Transit Access	X	
208	Meadow Rd/ASH-D Transit Access		X
209	Motor Pl/Bridge over I-5	X	X
210	Meadow Road/161st St	X	X
211	Ash Way/18th Ave W	X	



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections

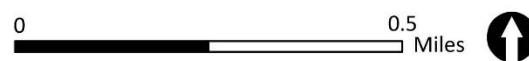
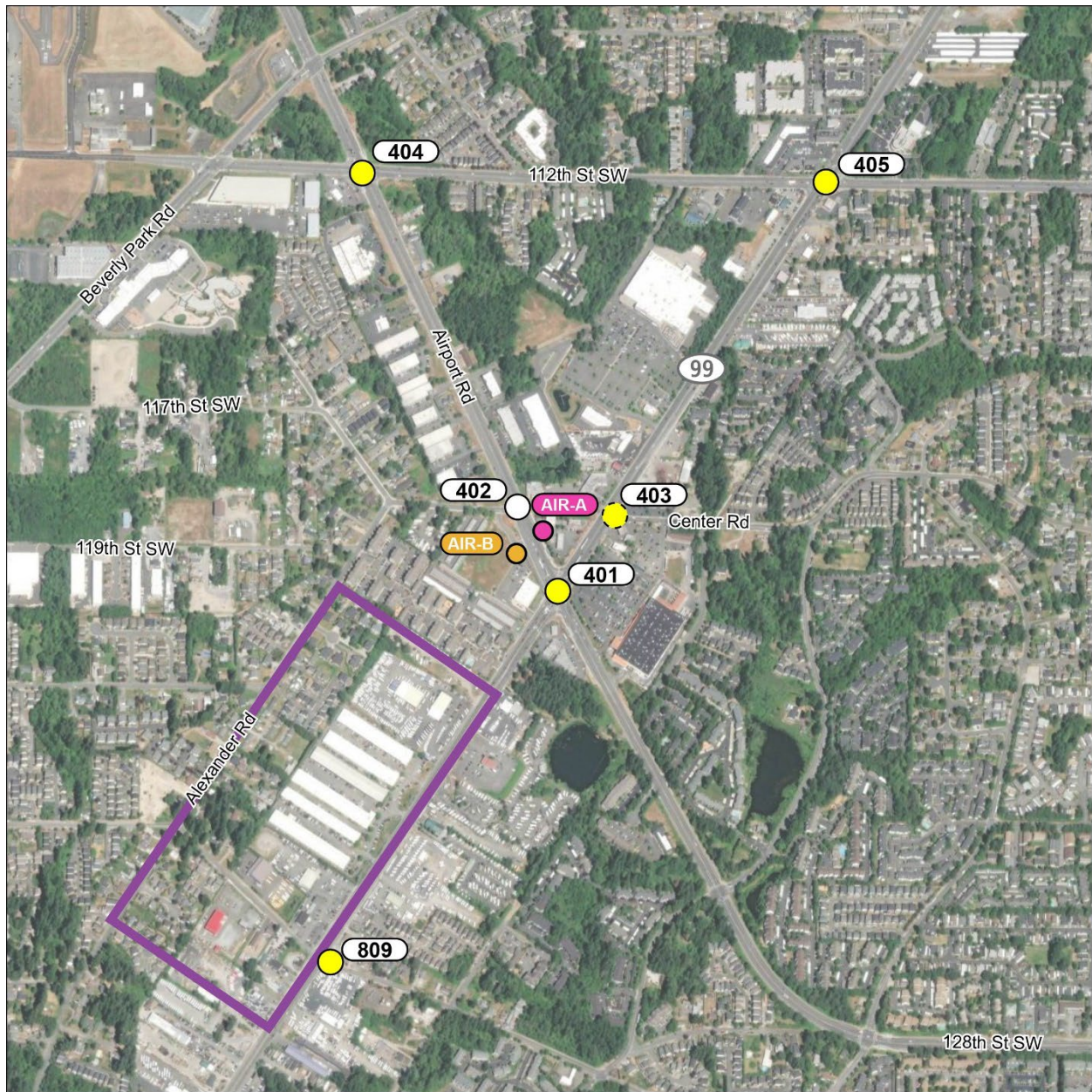


Figure 4-4 Mariner Station Subarea Intersections

Table 4-3 Mariner Station Subarea Intersections

ID	Intersection Location	Intersections to be Analyzed	
		MAR-B	MAR-D
301	128th St/8th Ave	X	
302	128th St/5th Pl	X	
303	128th St/4th Ave	X	X
304	128th St/I-5 SB Ramps	X	X
305	128th St/I-5 NB Ramps	X	X
306	8th Ave/MAR-B Transit Access	X	
307	5th Pl/MAR-B Transit Access	X	
308	132nd St/4th Ave		X
309	130th St/4th Ave		X
310	132nd St/8th Ave		X
311	5th Ave/MAR-D Station parking lot access		X
312	130th St/Meridian Ave		X



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections
- OMF North Site Alternative

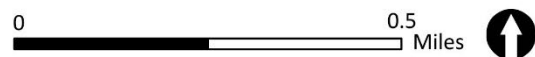
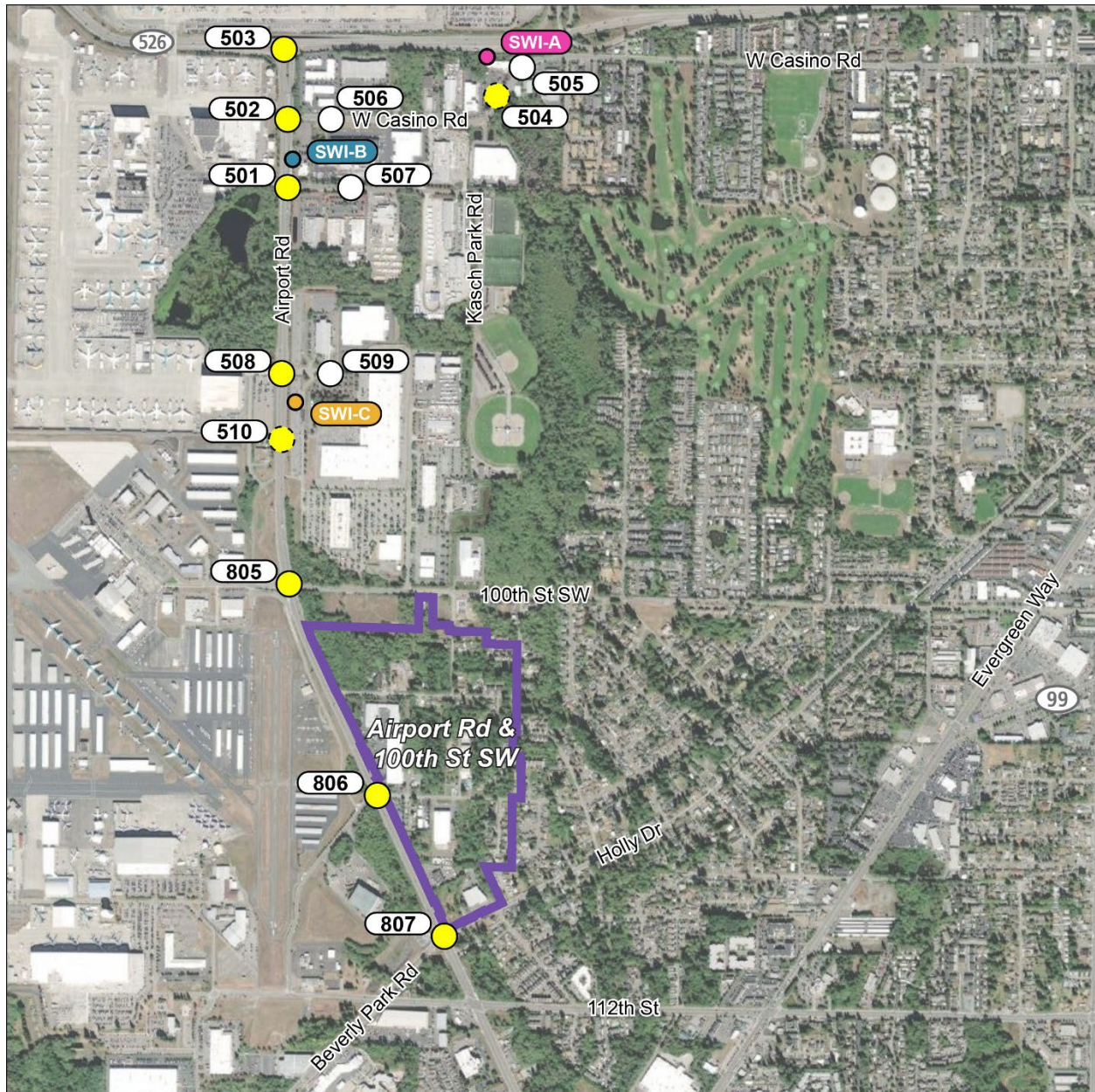


Figure 4-5 SR 99/Airport Road Station and SR 99 & Gibson Road OMF Site Subarea Intersections

**Table 4-4 SR 99/Airport Road Station and SR 99 & Gibson Road OMF Site
Subarea Intersections**

ID	Intersection Location	Intersections to be Analyzed		
		AIR-A	AIR-B	SR 99 & Gibson Road OMF Site
401	Airport Rd/SR 99	X	X	X
402	Airport Rd/Center Rd	X	X	X
403	SR 99/Center Rd	X	X	
404	Airport Rd/112th St	X	X	
405	SR 99/112th St	X	X	
809	SR 99/Evergreen Way/Gibson Rd			X



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections
- OMF North Site Alternatives

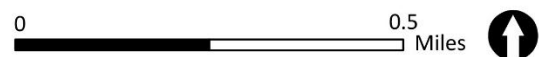
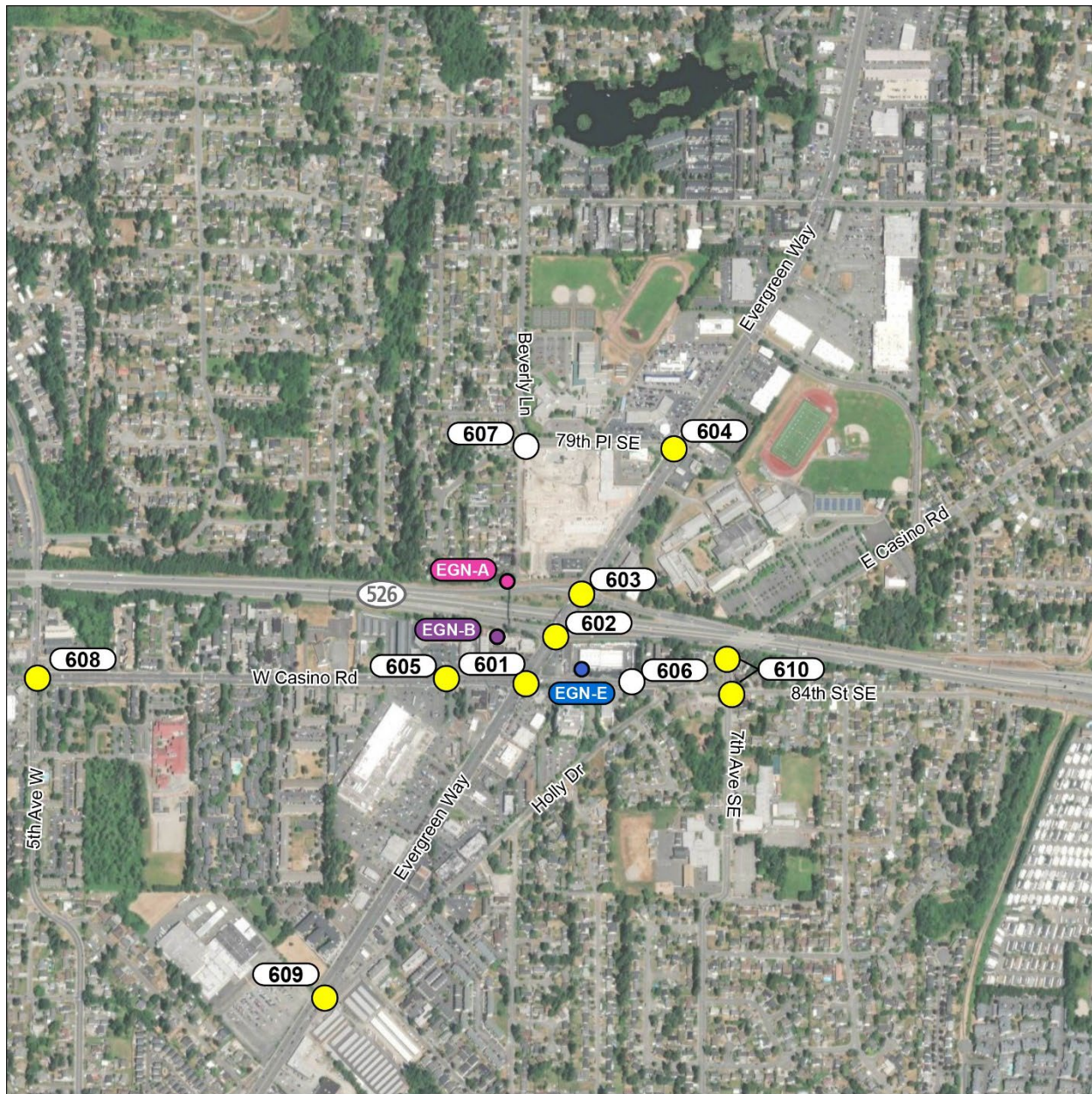


Figure 4-6 SW Everett Industrial Center Station and Airport Road & 100th Street SW OMF Site Subarea Intersections

**Table 4-5 SW Everett Industrial Center Station and Airport Road & 100th Street
SW OMF Site Subarea Intersections**

ID	Intersection Location	Intersections to be Analyzed			
		SWI-A	SWI-B	SWI-C	Airport Road & 100th Street SW OMF Site
501	Airport Rd/Kasch Pk Rd	X	X	X	
502	Airport Rd/Casino Rd	X	X	X	
503	Airport Rd/Boeing Fwy	X	X	X	
504	Casino Rd/SWI-A Transit access	X			
505	Casino Rd/SWI-A Station access	X			
506	Casino Rd/SWI-B Station access		X		
507	Kasch Pk Rd/SWI-B Station access		X		
508	Airport Rd/94th St			X	
509	94th St/SWI-C Station Access			X	
510	Airport Rd/SWI-C Station access			X	
805	Airport Rd/100th St				X
806	Airport Rd/106th St				X
807	Airport Rd/Holly Rd				X



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections

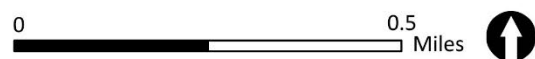
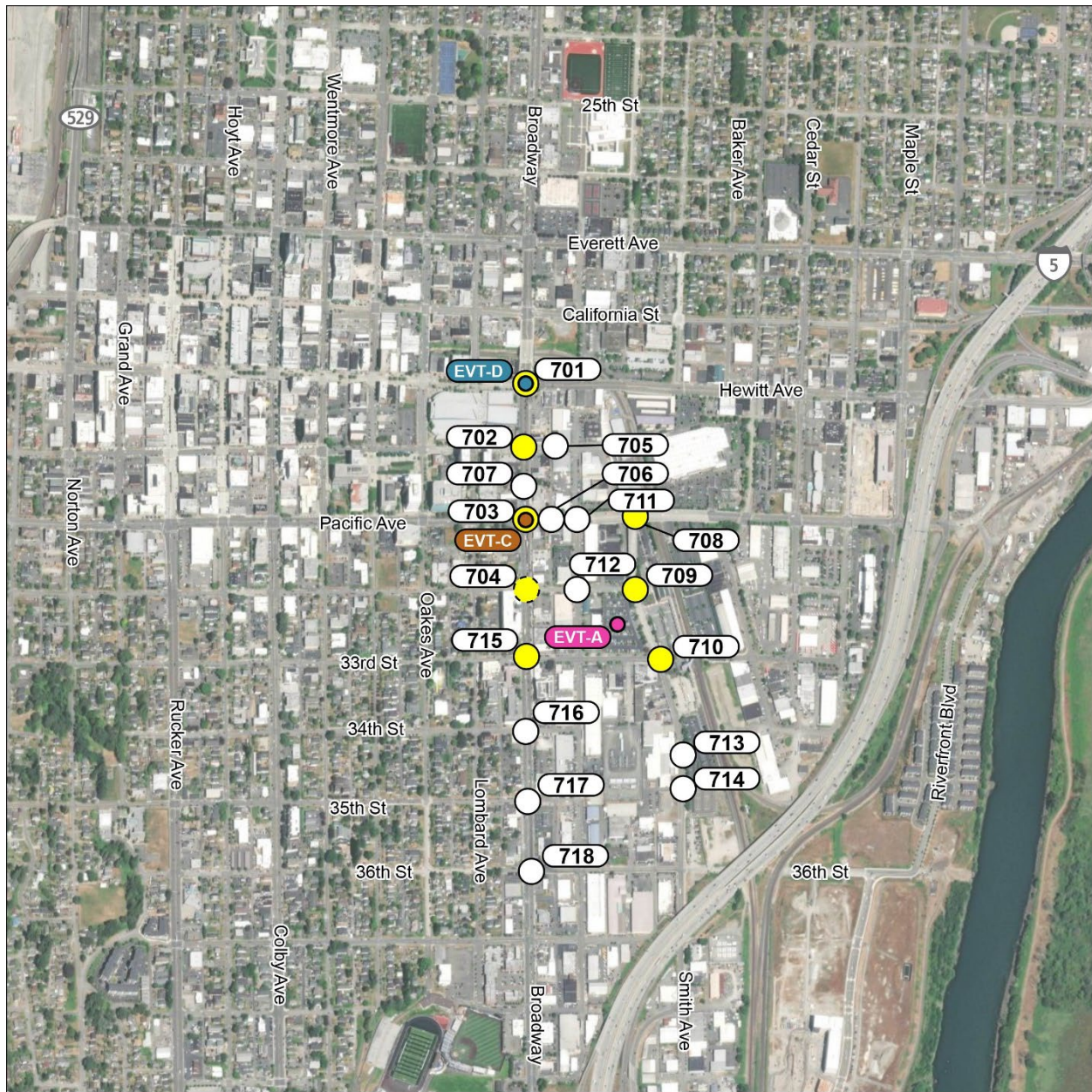


Figure 4-7 SR 526/Evergreen Way Station Subarea Intersections

Table 4-6 SR 526/Evergreen Way Station Subarea Intersections

ID	Intersection Location	Intersections to be Analyzed		
		EGN-A	EGN-B	EGN-E
601	Evergreen Way/Casino Rd	X	X	X
602	Evergreen Way/SR526 EB Ramps	X	X	X
603	Evergreen Way/SR526 WB Ramps	X	X	X
604	Evergreen Way/79th Pl	X		
605	Casino Rd/EGN-B Station access/EGN-D Station access		X	
606	Casino Rd/EGN-C Station access/EGN-E Station access			X
607	Beverly Lane/79th Pl	X		
608	Casino Rd/5th Ave W		X	X
609	Evergreen Way/Holly Dr		X	X
610	7th Ave SE/Casino Rd/84th St SE			X



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections

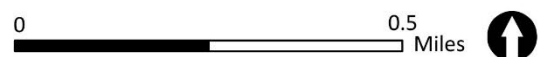
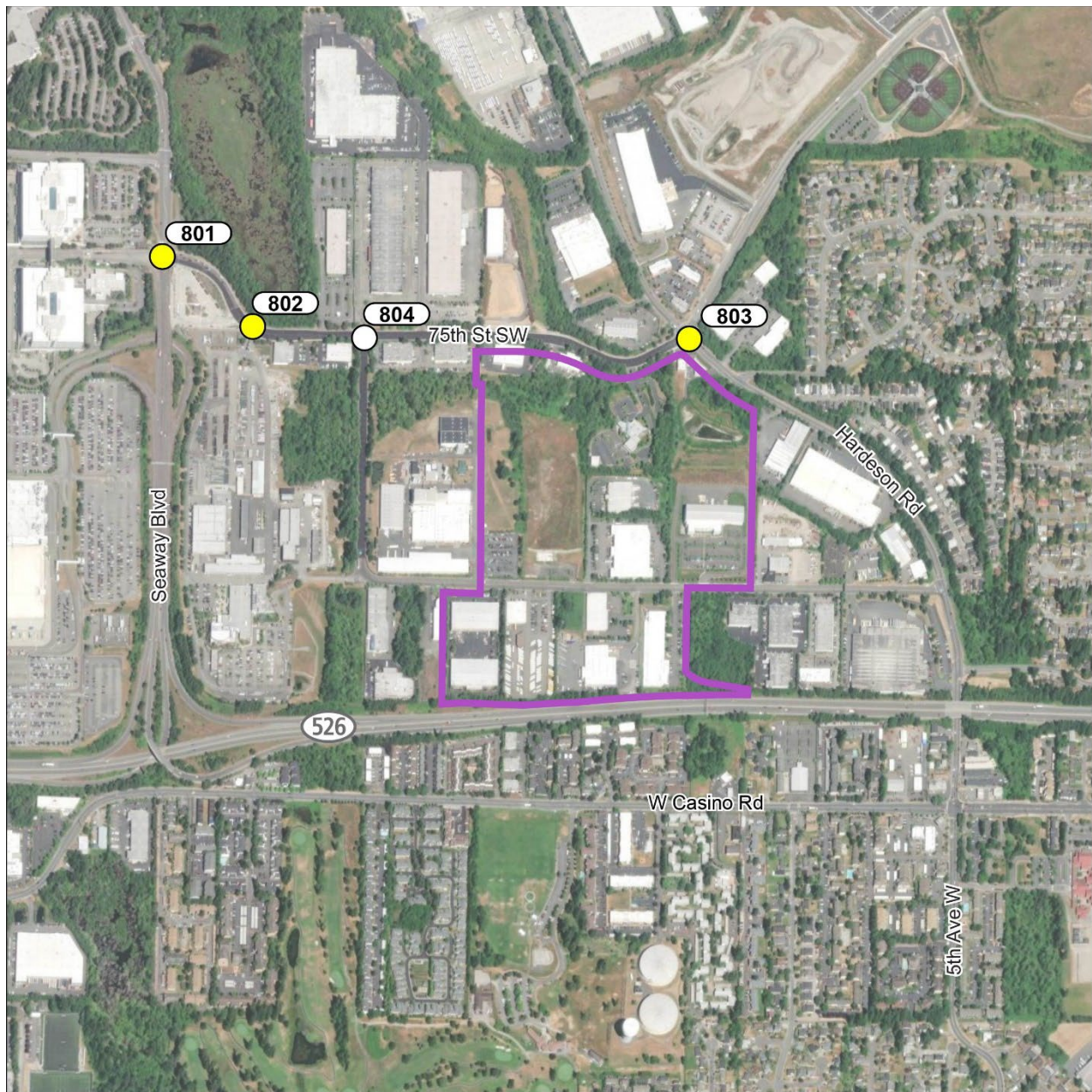


Figure 4-8 Everett Station Subarea Intersections

Table 4-7 Everett Station Subarea Intersections

ID	Intersection Location	Intersections to be Analyzed		
		EVT-A	EVT-C	EVT-D
701	Broadway Ave/Hewitt Ave			X
702	Broadway Ave/Wall St			X
703	Broadway Ave/Pacific Ave		X	X
704	Broadway Ave/32nd St		X	
705	Wall St/EVT-D Station Access			X
706	Pacific Ave/EVT-D Station Access			X
707	Broadway Ave/EVT-D Station Access			X
708	Smith Ave/Pacific Ave	X		
709	Smith Ave/32nd St	X		
710	Smith Ave/33rd St	X		
711	McDougall Ave/Pacific Ave		X	X
712	McDougall Ave/32nd St		X	
713	Smith Ave/EVT-A Station Access	X		
714	Smith Ave/EVT-A Transit Access	X		
715	Broadway Ave/33rd St		X	
716	Broadway Ave/34th St	X		
717	Broadway Ave/35th St	X		
718	Broadway Ave/36th St	X		



Legend

- Signalized Existing Intersections
- Signalized Future Intersections
- Unsignalized Existing Intersections
- Unsignalized Future Intersections
- OMF North Site Alternatives

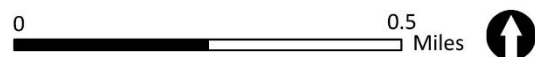


Figure 4-9 SR 526 & 16th Avenue and 75th Street SW & 16th Avenue OMF Site Subarea Intersections

Table 4-8 SR 526 & 16th Avenue and 75th Street SW & 16th Avenue OMF Site Subarea Intersections

ID	Intersection Location	Intersections to be Analyzed	
		SR 526 & 16th Avenue OMF Site	75th Street SW & 16th Avenue OMF Site
801	75th St/Seaway Blvd	X	X
802	75th St/Snohomish PUD	X	X
803	75th St/Hardeson Rd	X	X
804	75th St/Site Access	X	

4.4 Freight

The methodology will identify freight volumes in study subareas, as applicable. The study subareas for freight will be the same as for regional and local roadways. Truck freight will be classified into two vehicle types: small/medium trucks and large trucks (the remaining percentage of total vehicles would consist of passenger vehicles). As part of this analysis, attention will be paid to freight facilities, freight operations, and freight movements in the SW Everett Industrial Center.

4.5 Nonmotorized

The study area and area of effect for non-motorized facilities will be within 0.5 mile of each station for pedestrian facilities and within 1.5 miles of each station for bicycle facilities as measured along the network. Pedestrian facilities include sidewalks, trails, and other pedestrian facilities such as grade-separated crossings. Bicycle facilities include bicycle lanes, bicycle routes, and shared use paths. Analysis may identify existing and planned barriers to non-motorized connectivity.

4.6 Safety

The safety analysis will consider all modes of transportation and therefore the study subareas and areas of effect will be the same as described for each mode above.

4.7 Parking

The study will evaluate the availability of publicly accessible parking including public on-street and off-street parking in an area limited to one block on either side of the project footprint, the area used for construction, and the area within a 0.25-mile walking distance of each station. Off-street parking services provided by Sound Transit will be evaluated as well. The supply (capacity for vehicle parking) and regulation (including time limits, loading zone restrictions, paid parking areas, and no parking zones) of public curb space and off-street public parking within these areas will be inventoried based on available information from the appropriate jurisdictions and review of aerial photography. Off-street public parking is defined as parking that is available for public use and not privately owned (i.e., pay lots by private companies will not be inventoried). Data will be collected and reported by parking type/regulation (e.g., time-limited parking, unrestricted parking, paid parking, and loading zone) and location (e.g., block face) in

areas likely to be accessible to passengers and subject to spillover parking or areas to be impacted by project construction. Private parking impacts will be assessed in the Acquisitions, Displacements, and Relocations section of the Draft EIS.

4.8 Aviation

The study area for aviation impacts will be defined by the requirements of the Federal Aviation Administration (FAA) Obstruction Evaluation/Airport Airspace Analysis.

5 ANALYSIS ASSUMPTIONS AND TOOLS

5.1 Transportation Analysis Years and Period

Based on the project's schedule and available traffic forecasting data, the traffic analysis will focus on three analysis horizons:

- Existing Year – 2023
- Future Opening Year – 2037. This scenario represents the opening of the Operations and Maintenance Facility (OMF) North in 2034 and serving all planned stations between the West Alderwood and SW Everett Industrial Center stations in 2037. It does not include construction of parking facilities at the stations. This is consistent with the interim opening schedule identified by Sound Transit.
- Future Horizon Year – 2046. This is the proposed horizon analysis year consistent with regional planning. This horizon year is consistent with Sound Transit long-range planning and assumes the full build-out of Sound Transit's ST3 system, including service to Everett Station in 2041 and construction of parking facilities at the stations in 2046. This horizon year would utilize the PSRC land uses and roadway network assumptions.

In the existing and horizon year analysis, the AM and PM peak periods will be evaluated with the focus on the impact analysis during the peak hour. The intersections that will be evaluated under each time period are identified in Table 4-1 through Table 4-8. The AM peak period is between 6:00 a.m. and 9:00 a.m. and the PM peak period is between 3:00 p.m. and 6:00 p.m., although both peak periods will be confirmed through historical daily counts. These peak periods are considered the timeframes when traffic impacts are the highest; therefore, the analysis will be of the worst-case scenario for overall traffic conditions. Common peak hours will be determined for each study subarea as opposed to individual intersection peak hours.

5.2 EIS Analysis Conditions

5.2.1 Analysis Conditions

The EIS analysis will be developed for the conditions listed in Table 5-1. The existing and No Build conditions will provide a point of comparison against the Build and construction conditions. This comparison determines project benefits and impacts based on the measures described in Section 7 of this report.

Table 5-1 EIS Evaluated Conditions

Condition	Existing Year (2023)	Opening Year (2037)	Horizon Year (2046)	Notes
Existing	X			Includes land use, roadway, and transit network conditions for the year 2023.
No Build Alternative		X	X	Based on travel demand forecasts and an assumed list of constructed background projects and transit service modifications.
Build Alternatives		X		The opening year condition assumes the project is constructed and operating as far as SW Everett Industrial Center station, but no structured parking facilities are constructed.
Build Alternatives			X	The horizon year condition assumes the full-length project is constructed and operating including structured parking facilities.

5.2.2 Background Project Identification

The future year conditions will include state, regional, and local agency projects that are reasonably foreseeable, are in an officially adopted plan, have completed environmental review, or are funded or permitted. These projects are assumed to be built and in place before the EVLE Project is completed. The list of background projects will provide valuable insight into how the transportation system within and surrounding the project's study area will change from existing conditions. These projects may directly affect transportation conditions, such as by altering travel patterns, affecting roadway operations and safety, and influencing non-motorized access and connections. The sources for developing the background project list will include the following:

- WSDOT Connecting Washington and Move Ahead Washington funding packages and *Washington State Highway System Plan* (WSDOT expected 2023)
- *2022 Washington State Freight System Plan* (WSDOT 2022b)
- *Regional Transportation Plan 2022-2050* (PSRC 2022)
- City of Everett Comprehensive Plan (2021)
- City of Lynnwood Comprehensive Plan (2021)
- Snohomish County Comprehensive Plan (2018)
- Sound Transit's ST2 and ST3 Programs (Sound Transit 2008, 2016)
- *Long Range Transit Plan* (Community Transit 2011)
- *Everett Transit Long Range Plan* (Everett Transit 2018)

- EVLE Transit Service Integration Technical Memorandum (Sound Transit in progress)
- Relevant local agency CIPs/TIPs

5.3 Analysis Tools and Processes

This section describes the analysis tools and modeling process that will be used to conduct the transportation analysis for the EIS.

5.3.1 Travel Demand Forecasting Models and Process

The transportation analysis will use the following regional travel demand models to support the assessment of future conditions:

- The Sound Transit Incremental Ridership Model, to produce transit ridership forecasts
- A PSRC-based regional travel demand model, to calculate regional and project area traffic volume growth and other associated traffic metrics

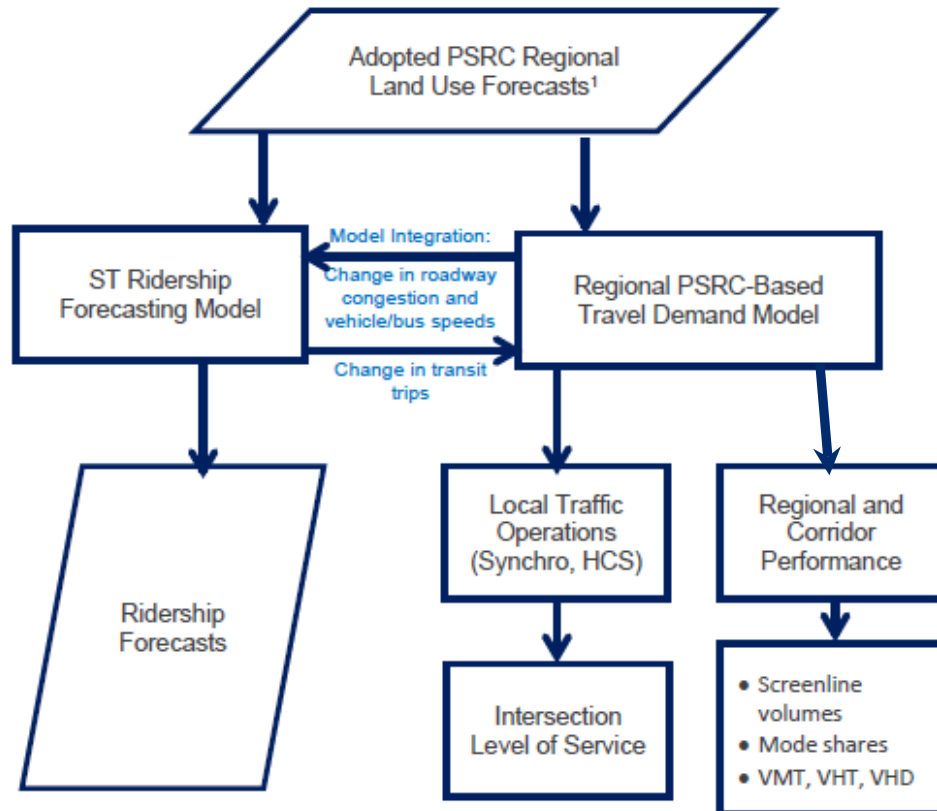
These models provide data included in the regional measures, transit system and local and arterial traffic operations analysis, as well as for a variety of other environmental analyses.

While the transit ridership and travel demand models will be run independently of one another, they use many of the same data sources, including land use, costs, and transit networks. Figure 5-1 illustrates the relationship between the two demand models. The Sound Transit Incremental Ridership Model is discussed in more detail in Appendix B.

5.3.1.1 Sound Transit Incremental Ridership Model

The current version of the Sound Transit Incremental Ridership Model uses analytical ridership forecasting procedures developed over three decades of incremental methods applications. During this period, the methods have been subjected to substantial external review, including three independent expert review panels and four cycles of review by the FTA over the course of New Starts grant applications for Link light rail projects (FTA 2013). As previously noted, the Sound Transit and PSRC modeling procedures are the foundation of the transportation technical analysis and are interrelated and complementary. The Sound Transit ridership model uses data from the PSRC modeling process to establish measures of change in external factors, including population and economic growth, and highway congestion. For more detailed information about the Sound Transit Incremental Ridership Model, see Appendix B, Sound Transit's Transit Ridership Forecasting Methodology Report.

The Sound Transit model will be used to produce rail and bus ridership forecasts for use in the EIS and will be part of a post-processing step to provide adjustments to the regional traffic model.



¹ This model will be updated to reflect the latest adopted PSRC land use forecasts available at the beginning of the EIS process. It is assumed this will be PSRC's "Land Use Vision – Implemented Targets" released in 2023.

Figure 5-1 Sound Transit Ridership Forecasting Model and PSRC Based Regional Model Relationship

Transit Ridership Forecasting Process

The Sound Transit Incremental Ridership Model will be used to perform the transit ridership (bus and rail) forecasts for the future horizon year of 2046 (or other land use forecast available from PSRC at the time of the analysis) and any interim opening year analysis. The transit ridership output from this model is used to analyze transit impacts as well as provide information used to analyze the regional system, traffic and roadway conditions, station areas, and nonmotorized system. The existing transit system and future transit system, which includes the planned Sound Transit system and a reasonably foreseeable future bus network, will be documented through a transit integration plan developed with Community Transit and Everett Transit. This transit integration plan will be used to code the transit services/networks for the Build and No Build Alternatives in the ridership model. The Sound Transit ridership model will then be run for the Build and No Build Alternatives to prepare transit forecasts for analysis in the EIS. For the 2046 horizon year, the Sound Transit ridership model is run to estimate a range of future ridership reflecting uncertainty about future assumptions, while maintaining a consistent transit network between the three scenarios. This is similar to the way the ridership forecasts were prepared for ST3: The Regional Transit System Plan, where forecasts were presented as ranges rather than a single number (Sound Transit 2016).

PSRC-Based Four-County Regional Travel Demand Model

The regional travel demand model that will be used in this analysis has been developed specifically for the four county PSRC area as a refinement of the PSRC trip-based travel demand model. The model is rooted in the latest PSRC model and includes enhancements to trip generation, trip distribution, and assignment methodologies to reflect localized conditions within the project corridor.

The land use inputs used in the regional travel demand model will be consistent with those used for the Sound Transit ridership model. While the official control totals (at the city level) are used for regional consistency, land use distribution modifications have been made in the regional model based on specific data provided by PSRC jurisdictions (Seattle, Bellevue, Redmond, Tacoma, Issaquah, Tukwila, Federal Way, Kent, Des Moines, King County, Snohomish County) that have utilized the model for other recent projects.

Regional Travel Demand Model Process

Future No Build (Baseline) Travel Demand Conditions

For the future No Build conditions, the regional traffic demand model will be run and trip tables assigned to networks by time of day. Differences in traffic volumes from the model assignments will be applied to the observed traffic volume counts to develop estimated future PM peak hour and daily traffic forecasts. In addition, volumes will be post-processed in the vicinity of major planned development and redevelopment projects to ensure traffic effects of these developments are adequately represented.

Future Build Travel Demand Conditions

The regional travel demand model will be used to generate traffic volumes for the Build Alternatives based on the integration of transit ridership forecasts developed for the Build Alternatives from the Sound Transit Incremental Ridership Model. The projected changes to transit demand associated with the Build Alternatives will be incorporated into the regional travel demand model to reflect travel pattern and volume effects from changes in transit ridership. This process is illustrated in Figure 5-1. This process will only be used to produce traffic volumes for the Build Alternatives at the regional, corridor, and subarea system levels (e.g., vehicle miles traveled [VMT], vehicle hours traveled [VHT], vehicle hours of delay [VHD], and screenline data).

To develop traffic volumes for the Build condition used in the arterial and local street analysis, the traffic volumes developed for the No Build condition will be used as a base, with additional volumes added to reflect the vehicle traffic anticipated to be generated by the project. This is explained further in Section 7. In the forecasting integration process, the goal is to supplement the transit demand forecasts generated by the PSRC model with the data from Sound Transit's Incremental model to ensure consistency in the forecasts between the two models. This is accomplished by supplying future roadway congestion and vehicle speed information from the PSRC model to the Sound Transit model to develop the future transit ridership forecasts. The transit ridership forecasts from the Sound Transit model are then input into the PSRC regional travel demand model to develop the traffic forecasts for the Build Alternatives.

Trip Generation (General)

Trip generation at transit stations or other Sound Transit facilities will be developed for various

modes of travel, including:

- Park-and-rides and other public parking facilities
- Auto trips: drop-off/pick-up, including private vehicles and transportation network company trips such as Uber and Lyft
- Transit trips: number of buses serving a station
- Walk/bike trips: bus transfers and walk/bike trips

Trip generation estimates for all modes listed above will be based on several sources. One consideration is the Sound Transit mode of access survey for the Link Light Rail Extension collected in spring 2019. The mode of access survey collected data for the full length of the light rail line from the University of Washington Station to the Angle Lake Station. Additionally, national data sources such as data from the BART Station Profile Study (BART 2015) will be considered. The BART study is a comprehensive mode of access and egress survey of BART rail users in the San Francisco Bay area. Available research and data related to transportation network company trips to and from transit stations will also be considered.

Trip generation at park-and-rides will assume the parking supply is fully utilized and will be based on the maximum capacity of the parking facility and not forecasted demand. Trip generation will be calculated based on a per space rate, which will be developed from several sources including the latest ITE Trip Generation Manual (Land Use Code 090 Park-and-Ride with Bus or Light Rail Service), relevant Sound Transit mode of access data, and available traffic counts at park-and-ride driveways. Trip generation for other Sound Transit facilities (e.g., maintenance facility parking) will be based on maximum parking capacity or projected use, as appropriate.

Information on bus service for each station will be developed by Sound Transit, Community Transit, and Everett Transit service planners as part of the planning-level transit service integration plan. This plan includes changes in local transit circulation to and from the station area, which will be incorporated into the overall trip generation.

The vehicle and nonmotorized (pedestrian and bicycle) trips associated with the light rail station ridership forecasts for the alternative with the highest ridership at that station will be used for evaluating the station area effects. Exceptions may be made at locations with substantial differences between alternatives (e.g., one has bus transfer opportunities, and one does not). In these cases, two trip-generation scenarios may be developed. Trips will be assigned to the nonmotorized and vehicular networks around the station locations based on existing and anticipated future circulation patterns.

Trip Generation (OMF North)

Information on opening year and 2046 trip generation for the OMF North facility will reflect employee ingress and egress and deliveries. These traffic volumes will be added to the future No Build Alternative traffic volumes as the basis on which to analyze the Build Alternatives. In locations where the facility will replace an existing land use that generates trips, the Institute of Transportation Engineers Trip Generation Manual will be used to estimate the change in peak trips for the existing land use.

5.3.2 Traffic Operations Analysis Tools

The traffic operations analysis will be consistent with WSDOT protocols. The Synchro/SimTraffic 11 studio suite combines the modeling capabilities of Synchro and the micro simulation and animation capabilities of SimTraffic. Synchro is a macroscopic analysis and optimization software application that supports the Highway Capacity Manual's (HCM) 7th Edition (Transportation Research Board 2022), 2010 and 2000 for signalized intersections and unsignalized intersections. Synchro's signal optimization routine allows users to weight specific phases, thus providing more options when developing signal timing plans. SimTraffic is a powerful, easy-to-use traffic simulation software application. With SimTraffic, individual vehicles are modeled and displayed traversing a street network. The study subarea intersection operations and 95th percentile queuing results will be evaluated and compared based on SimTraffic models to understand the true impact of traffic congestion and closely spaced intersection interactions. At locations where queue analysis is needed, SimTraffic will be used.

Synchro/SimTraffic models will be developed for the existing year (2023), opening year (2037), and future year (2046) Build and No Build Alternatives. Existing signal timing plans will be obtained from local agencies and used in the existing Synchro/SimTraffic models. SIDRA (version 9 or later) will be used to analyze study subarea intersections that either currently operate as, or are anticipated to operate as, roundabouts consistent with WSDOT protocols.

5.3.3 Other Tools

Mode-of-access tools including geographic information system (GIS)-based software will be utilized to define the walk, bicycle, and automobile "access sheds" in study subareas described previously. As existing travel behaviors continue to change and travel behaviors emerge that provide mobility options and choices for travelers, such as rideshare vehicles, additional analysis software and/or tools may be developed to provide support for evaluation measures related to these behaviors.

6 AFFECTED ENVIRONMENT

The affected environment for transportation will document existing conditions in year 2023 for each element of the transportation system evaluated within the study area. These elements include Regional and Corridor Traffic, Transit, Arterials and Local Streets, Freight, Nonmotorized, Safety, Parking, and Aviation. Particular focus for these modes will be on transportation facilities in the vicinity of proposed transit stations because these will be the primary site-specific traffic generators.

The detailed means for documenting the existing conditions for these transportation elements are discussed in Section 5 because the methods and measures to assess the existing conditions, No Build Alternative, and Build Alternatives are largely the same. Existing conditions information will be both quantitative and qualitative and will be displayed both graphically and in a tabular format as appropriate.

7 TRANSPORTATION RESOURCE ANALYSIS AND MEASURES

This section discusses the transportation analysis and measures that will be documented in the EIS to understand the affected environment and the direct impacts of the Build and No Build Alternatives. Direct impacts include measures to assess the long-term operation impacts as well as short-term construction impacts. This section also includes the analysis and measures used to determine indirect and cumulative impacts on the transportation system.

7.1 Assessment Methods and Analysis Thresholds

The analysis and measures in this section are presented by the specific transportation element that will be documented in the Transportation Technical Report and Transportation chapter of the EIS. The transportation analysis will be performed at three assessment levels, depending on transportation element: regional, corridor and subarea, and local.

Regional measures are defined as within the project area and beyond, and are considered region-wide (e.g., Snohomish County and beyond). Measures at the corridor and subarea level are intended to provide information for the project area or a segment within the project area. Measures at the local level would provide information specific to a certain location, transit route, or transportation facility. Table 7-1 summarizes the transportation analysis measures. Measures for assessing these transportation elements, discussed in the following sections, will be both quantitative and qualitative, and results will be displayed both graphically and in a tabular format as appropriate.

Table 7-1 Transportation Measures by Transportation Element

Transportation Element	Assessment Level	Measures
Regional and Corridor Traffic	Regional	Growth rate, VMT, VHT, VHD
	Corridor and subarea	Growth rate, vehicle volumes, volume to capacity (v/c) ratio/LOS, person trips, mode share
Transit	Regional	System-wide daily transit trips and boardings, total daily light rail boardings, total daily Sounder boardings
	Corridor and subarea	Project-wide daily trips on project, project-wide daily trips on project by transit-dependent population, station area boardings, travel times
	Local	Effects on local transit patterns and access and circulation to proposed station locations
Arterials and Local Streets	Local	Traffic patterns, street closures, property access modifications
		Intersection LOS, delay, and queue lengths
Freight	Local	Identify truck and rail freight routes and impacts, as well as impacts to business loading zones and access
Non-motorized Facilities and Modes	Local	Pedestrian and bicycle access, circulation and facility gaps surrounding stations, Americans with Disabilities Act (ADA) accessibility barriers immediately adjacent to project infrastructure, school walk route impacts, and bicycle parking at stations

Transportation Element	Assessment Level	Measures
Safety	Local	Historical intersection and roadway collision type and frequency. Safety assessment of effects on auto, freight, transit, and nonmotorized modes.
Parking	Local	Parking availability, restrictions, and utilization near stations, including off-street parking provided by the project, off-street parking spaces and/or curb space capacity removed as a result of the project, and on-street spaces; estimated access and parking demand; and assessment of drop-off/pick-up area needs based on estimated station access and rideshare forecasts
Aviation	Local	Obstruction Evaluation/Airport Airspace Analysis

7.2 Regional and Corridor Traffic

7.2.1 Operations

7.2.1.1 Regional Traffic

Evaluation Measures

Information from the regional model developed for this study will be the key data source for this analysis. The following types of data will be produced for opening year and horizon year 2046 to analyze the effect of the Build and No Build Alternatives on regional or system-wide traffic characteristics:

- Traffic growth rate – the annual growth rate for vehicle traffic in the region
- VMT – Total average daily vehicle miles traveled on the regional highway system
- VHT – Total average daily vehicle hours traveled on the regional highway system
- VHD – Total average daily vehicle hours of delay on the regional highway system, which indicates the total level of congestion on the highway system

Evaluation Approach

Information from the regional model will be used to generate the Build and No Build Alternatives VMT, VHT, and VHD data for the long-term conditions. This model will be run in an iterative process with the Sound Transit Incremental Ridership Model, with highway traffic volumes reflecting changes in transit ridership as described in Section 5. Matrices of vehicle trips and travel times on an origin-destination pair level from the model will be used to quantify estimated VHT, and matrices of vehicle trips and hours of delay per trip will be used to quantify the impact of the Build and No Build Alternatives on VHD.

Short-term changes in regional traffic during construction will not be assessed unless there are direct construction impacts on a regional facility, such as state highways.

7.2.1.2 Corridor Traffic

Evaluation Measures

- Growth rate – Vehicle traffic demand within the EVLE project area will be forecasted and presented as an annual growth rate.

Additional measures used to evaluate effects within a corridor and/or subarea of the study area will be based on a screenline-level analysis for the PM peak hour. Screenlines are imaginary lines drawn across one or more roadways to compare aggregate changes in traffic conditions. The following data will be included for each screenline:

- Vehicle volumes
- Vehicle v/c ratio/LOS
- Person trips – The number of person trips across screenlines
- Mode share – The proportion of vehicle and person trips at screenlines taken by transit (bus and rail) versus personal auto

Evaluation Approach

The analysis of traffic impacts in various segments of the corridor will involve comparing traffic conditions on the highway and local street system at selected screenlines for each alternative, with the exception of the growth rate measure, which is an area measure based on transportation analysis zones (TAZs) within the study area.

The screenline comparisons will provide a snapshot of traffic operations along each corridor. A map and table will be used to present data at screenline locations.

Information for each screenline will be generated from the project's regional model and Sound Transit's ridership model and will include PM peak hour and daily values. The v/c ratio at the screenlines may be expressed as a generalized facility-based LOS.

7.2.2 Construction

Construction impacts will be qualitatively and quantitatively assessed to determine if the project's construction would have any impact on the regional and corridor traffic measures. This analysis may include factors such as long-term closures or reductions in capacity to regionally significant roadways, extended diversions of transit trips, or other disruptions to regional and corridor traffic as a result of construction activities.

7.3 Transit

7.3.1 Operations

7.3.1.1 Regional Transit

Evaluation Measures

The following measures will be considered for assessing effects of the project on system-wide bus and rail transit for the horizon year (2046):

- Annual transit ridership (linked trips)
- Daily transit ridership (linked trips)
- Annual Link light rail boardings
- Daily Link light rail boardings

Evaluation Approach

As described earlier, the Sound Transit ridership model will be used to produce data related to regional transit forecasts associated with the alternatives. The network will be coded to reflect the Build and No Build Alternatives, and then the model will be run to produce transit forecasts for each alternative. Ridership forecast results will be provided as direct outputs from the ridership model.

7.3.1.2 Corridor Subarea Transit

This section describes the corridor and subarea analyses that will evaluate projected changes to transit services (light rail and bus) resulting from the Build Alternatives.

Evaluation Measures

The following evaluation measures will be considered to understand the corridor and subarea effects on transit service for horizon year 2046:

- Daily project ridership – Daily trips on project by project alternative. For the No Build Alternative, when no rail service will be present, corridor daily bus ridership will be estimated for bus routes in the general project area to provide consistency with the Build Alternatives.
- Station area boardings – Daily and PM peak period station boardings by project alternative will be produced from the Sound Transit Incremental Ridership Model. Each alternative will have a specific transit integration plan and parking capacity developed, along with transit travel times (light rail and bus) within the EVLE corridor and other key areas.

Evaluation Approach

As described earlier, the Sound Transit Incremental Ridership Model will be used to produce ridership data related to the project subarea transit forecasts with the Build Alternatives. Ridership will be forecast for both the PM peak and daily periods.

7.3.1.3 Local Transit

The transit quality of service assessment will analyze the expected project effects on the existing and future bus and light rail services within the EVLE study area using both qualitative and quantitative information. The approach will follow the methodology and guidelines presented in the Transit Capacity and Quality of Service Manual (Transportation Research Board 2017). Transit quality of service information will be reported at station areas within the EVLE study area.

Evaluation Measures

The evaluation will document the transit service effects for existing conditions, No Build Alternative, and Build Alternatives. This will include:

- Transit access and circulation, including any changes in travel times for buses accessing stations
- Walk time for transferring passengers from Swift BRT service to Link platforms

Evaluation Approach

Expected changes in transit service and routing with the Build Alternatives will be identified and compared to the transit service and routing under No Build conditions. These changes will be developed in conjunction with Community Transit, Everett Transit, and Sound Transit service planners as part of the project's transit integration plan. The comparison will focus on changes in coverage area and potential effects on travel time based on existing information from the transit agencies, traffic operations results, and/or other traffic analysis data. Passenger load data will be provided from the Sound Transit Incremental Ridership Model.

7.3.2 Construction

This analysis will evaluate the potential short-term impacts to regional, corridor, and local transit combined. Transit impacts during construction will be closely coordinated with the following sections: Regional and Corridor Traffic, Arterials and Local Streets, and Nonmotorized. Construction impacts to transit will consider both the transit service and transit rider. This assessment will evaluate the potential modifications to roadway capacity and operations during construction of transit service and the ability to access transit as a result of the project construction activities. This would include construction activities that could prohibit access to transit stops or activities that would close transit stops and require riders to relocate to another transit route or stop.

7.4 Arterials and Local Streets

7.4.1 Operations

7.4.1.1 Property Access and Local Circulation

This evaluation will assess permanent local area traffic circulation impacts including access to properties affected by the Build Alternatives. Refer to Section 7.4.2 for construction impacts to property access and local circulation.

Evaluation Measures

The evaluation will document any physical change to the traffic patterns and movements along with changes in property access. This will evaluate only vehicle movements; refer to Section 7.3 and Section 7.6 for how transit and nonmotorized modes will be evaluated for the project.

Evaluation Approach

This assessment will include such factors as:

- Effect of potential street closures on localized traffic movement
- Loss of access (such as left turns) to and from driveways
- Changes in property access

7.4.1.2 Intersection Operations (Including Station Area Traffic Analysis)

Evaluation Measures

Effects on intersection operations will be evaluated based on the opening year and horizon year 2046 peak hour intersection LOS. LOS measures the quality of traffic operations at an intersection. As described in Table 7-2, LOS ratings range from “A” to “F.” LOS A represents the best operation and LOS F the poorest operation. Queue lengths will be reported at intersections that operate at or below (failing) the agency’s LOS threshold.

Table 7-2 Level of Service Definitions for Signalized and Unsignalized Intersections

LOS	Average Control Delay (seconds per vehicle)		Traffic Flow Characteristics
	Signalized Intersections	Unsignalized Intersections	
A	≤ 10	≤ 10	Virtually free flow; completely unimpeded.
B	> 10 and ≤ 20	> 10 and ≤ 15	Stable flow with slight delays; less freedom to maneuver.
C	> 20 and ≤ 35	> 15 and ≤ 25	Stable flow with delays; less freedom to maneuver.
D	> 35 and ≤ 55	> 25 and ≤ 35	High density but stable flow.
E	> 55 and ≤ 80	> 35 and ≤ 50	Operating conditions at or near capacity; unstable flow.
F	> 80	> 50	Forced flow; breakdown conditions.

Source: Transportation Research Board 2022.

Agency transportation goals and LOS standards are developed as part of each agency’s comprehensive planning efforts. Although agencies accept different levels of congestion, a delay-based intersection LOS analysis is typically conducted for impacts analyses and is proposed for this project. Delay is expressed in terms of average delay (in seconds) per vehicle as a result of the intersection operations.

Although intersections may be located along a state route or state facility, the intersection operations standard may be under the jurisdiction of the local municipality as opposed to WSDOT. Specific agency thresholds and relation to intersection operations will be assessed in the Transportation Technical Report.

Evaluation Approach

Synchro (version 11) software will be used to determine the projected peak hour LOS for the analysis years identified in Table 5-1 at the intersections identified in Section 4.3. The HCM report from the Synchro software will be used to summarize average intersection delay, LOS, and v/c ratios (HCM 2022 7th Edition will be used unless unavailable for the configuration under study, in which case HCM 2000 will be used). The signalized intersections' LOS will be defined in terms of average intersection delay. The LOS at an unsignalized intersection is also defined in terms of delay, but only for the worst operating movement, which is typically on the minor street (i.e., stop) approaches. For unsignalized intersections that are stop-controlled on each approach, the average intersection delay is reported. Vehicle queue lengths will be reported from SimTraffic for intersections not meeting agency LOS standards, tightly spaced intersections, or intersections with direct physical project impacts, as agreed to with the relevant jurisdictions, to understand if the Build Alternatives impact vehicle queues beyond the storage length. The impacts of special events would be described qualitatively, with descriptions of when and how frequently they would occur and assessments of congestion levels during those periods.

Default assumption values for the analysis will be developed for intersections where actual values are not available. These will include assumptions with respect to saturation flow rates, geometry, traffic, and signalization conditions. Table 7-3 provides assumptions for existing, opening year, and future horizon year (Build and No Build Alternatives) input values and assumptions when data are not available.

Table 7-3 Default Synchro Parameters and Assumptions^a

Arterial Intersection Parameter	Existing Year (2023)	Opening Year (2037) and Horizon Year (2046)
Peak Hour Factor	From count and for entire intersection; otherwise: If total entering vehicles ≥ 1000 , 0.92. If total entering vehicles < 1000 , 0.90.	Use 0.95 for all intersections except where existing peak hour factor (PHF) is greater than 0.95 or less than 0.80. Use existing PHF in cases where the PHF is greater than 0.95. If existing PHF is less than 0.80, then use peak 15-minute volumes multiplied by a factor of 4.
Conflicting Cyclists and Pedestrians per Hour	From traffic count, otherwise assume 10 pedestrians/cyclists in both AM and PM periods.	For the No Build Alternative, apply growth rate from adjacent street to existing volumes. For the Build Alternatives, add the number of pedestrians based on the station ridership and mode of access forecasts.
Area Type	"Other" for all areas.	Same as existing.

Arterial Intersection Parameter	Existing Year (2023)	Opening Year (2037) and Horizon Year (2046)
Ideal Saturation Flow (for all movements)	1,750 vehicles per hour for urban areas; 1,900 vehicles per hour for rural.	Same as existing.
Lane Utilization	Default software assumptions unless data/engineering judgment suggests otherwise.	Same as existing.
Lane Width	Existing lane widths. Assume 11 feet if no information available.	Same as existing, unless improvements proposed; then use agency standards/plans.
Percent Heavy Vehicles	From count, otherwise 3%.	Same as existing.
Percent Grade ^b	Flat approach = 0%. Moderate grade on approach = 3%. Steep grade on approach = 6% or from field/elevation data.	Same as existing.
Parking Maneuvers per Hour	Based on parking regulations. For less than 15-minute parking, assume 4 maneuvers per hour; otherwise, assume 1 maneuver per hour, unless data/information gathered or provided from agencies suggest otherwise.	Same as existing. For new parking, assume existing assumptions for maneuvers based on parking durations.
Bus Blockages	Headway information provided by transit agencies.	Use future service assumptions developed by Community Transit, Everett Transit, and Sound Transit as part of the Transit Service Integration Technical Memorandum.
Intersection Signal Phasing and Coordination	From agency signal phasing sheets or their existing analysis files.	Splits, offsets, and cycle lengths optimized between existing and no-build conditions. Signal timings kept consistent between Build and No Build Alternatives, but splits and offsets optimized. For timing adjustments: Left turns, if permitted in existing, will be examined for a protected phase based on LOS, access/geometry, safety, and agency guidance. For Build and No Build Alternatives: Any left turn conflict with at-grade light rail will include a separate lane and have protected phasing. Left turns will be restricted (or protected with a gate or similar treatment) at unsignalized intersections. For elevated light rail, mid-block left turns will be restricted. Signal warrant analysis will be completed at unsignalized intersections that are proposed or considered for new traffic signals.

Arterial Intersection Parameter	Existing Year (2023)	Opening Year (2037) and Horizon Year (2046)
Intersection Signal Timing Optimization Limits	Not applicable.	Between 60 and maximum of 180 seconds.
Minimum Green Time	Per signal timing cards.	Based on pedestrian times (minimum of 7 seconds walk time and 3.5 feet per second for flashing don't walk clearance). If no crosswalk: 10 seconds.
Yellow and All Red Time	Per signal timing cards.	New signals: Yellow = 4 seconds, and All Red = 1 second. Consider clearance times longer than 1.0 seconds for larger intersections (DDI, SPUI)
High-occupancy Vehicle (HOV) Lanes	Lane Utilization Method ^c	Same as existing.
Right Turn on Red	Allow (unless signed otherwise).	Same as existing.
Right Turn Overlaps	Per signal timing cards.	Identify if used.
Vehicle Queue Lengths	Based on 25 feet per vehicle.	Same as existing.

a Synchro parameters will be adjusted to meet jurisdictional standards, where applicable. An appendix detailing any changes from "default" parameters will be provided, with an explanation of these changes.

b Percent grade assumed for at-grade intersections only.

c This methodology assumes intersection lane designations will be coded exactly as shown in the field. Shared through (HOV) and right turn lanes will be coded as a general-purpose traffic lane because Synchro does not have a special method for HOV lane analysis. To account for lower HOV lane volumes, the lane utilization factors will be adjusted to reflect this condition. In instances of congested intersections with HOV lanes, adjusting the lane utilization factor may not assist in replicating the congested conditions. In this case, other Synchro parameters (such as the Saturation Flow Rates and Headway Factors) will be adjusted in the model.

7.4.2 Construction

The assessment of construction-related transportation impacts on local and arterial streets will focus primarily on corridors near light rail alignment or on streets that could be substantially affected by construction of any of the Build Alternatives. For the purposes of impact assessment on local and arterial streets, the construction phase considered to be most disruptive to traffic operations in the corridor will be the one assessed in the most detail. This phase will be identified in coordination with Sound Transit staff and staff from local jurisdictions, as appropriate. The construction analysis on local and arterial streets will consider the following:

- Changes in roadway capacity including potential lane closures, parking restrictions, roadway modifications, areas of construction activity adjacent to travel lanes, or other reductions to capacity as a result of project construction activity
- Identification of access and impacts from potential construction staging areas on roadway operations
- Assessment of potential for neighborhood traffic intrusion related to road closures, and options for traffic detours
- Estimation of construction truck traffic

The analysis will be summarized in a tabular format to identify the following:

- Impact location(s)
- Street characteristics
- Type of construction activity, including likely duration of impact to roadways (characterized as full or partial closures for short-term or long-term periods) on local and arterial roadways
- Level of construction traffic (characterized as high, moderate, or low). High truck traffic is generally associated with major fill, excavation, and concrete work.
- Availability and identification of potential detour routes. Potential for detoured traffic to affect a residential neighborhood. (This is characterized as high, medium, or low and is related to both potential for road closures and options for traffic detour.)

7.5 Freight

7.5.1 Operations

7.5.1.1 Evaluation Measures

Evaluation measures will include the following:

- Truck volumes – Change in truck volumes and/or percentages between existing and future conditions
- Truck operations – Change in congestion levels and/or travel speeds along identified freight facilities/routes
- Truck access – Physical impacts on truck routes, loading zones, or access to local businesses
- Freight rail impact – Physical impacts to freight rail corridors or port intermodal facilities

Evaluation Approach

Impacts of the Build Alternatives on freight movements will be qualitatively assessed. This assessment will focus on truck movement and truck routing impacts as well as the potential impact to freight rail corridors and facilities and port intermodal support facilities. The assessment of truck issues will focus on designated major truck routes and truck service areas, access to these facilities and areas, and loss of on-street loading zones and/or modifications of truck access to local businesses. The assessment of freight rail impacts will focus on physical changes proposed within, above, or below railroad right-of-way.

7.5.2 Construction

The assessment of freight impact during construction will include analysis of freight trucks and freight rail. The construction impacts will consider the impacts on freight routes, load ratings along routes, and intermodal and port terminal facilities, including access and circulation. This

assessment will be coordinated with the construction impacts identified in the Arterials and Local Streets section.

7.6 Nonmotorized

7.6.1 Operations

7.6.1.1 Evaluation Measures

The Nonmotorized section will evaluate pedestrian and bicycle access, circulation and facility gaps surrounding stations, barriers, ADA accessibility, and school walk route impacts. The assessment of future nonmotorized (pedestrian and bicycle) facilities will address the following issues:

- Pedestrian access and circulation within 0.5 miles of the proposed stations in relation to the forecasted ridership
- Identification of short-term and long-term bicycle parking near the proposed stations
- Direct (physical) effects on pedestrian and bicycle facilities along the alignment of each alternative. This would include identifying any barriers to nonmotorized movements the Build Alternatives might create and any ADA accessibility barriers immediately adjacent to proposed station and OMF locations or other project infrastructure.
- Identification of existing physical barriers for nonmotorized pedestrian movements accessing proposed stations within 0.5 miles of the stations
- Identification of currently missing and funded new sidewalk sections for city arterials within 0.5 miles of the stations
- Impacts on designated school walk routes
- Identification of deficiencies in the existing and funded regional bicycle paths and routes within 1.5 miles of proposed station locations

7.6.1.2 Evaluation Approach

The evaluation of nonmotorized facilities and modes will be conducted through an inventory of the existing and planned future nonmotorized facilities surrounding each proposed station and OMF location as identified in the evaluation measures. This will identify existing and future gaps in the nonmotorized network. In coordination with the regional travel demand and transit ridership forecasts, future estimated pedestrian and bicycle volumes will be generated for each station and assigned to the nonmotorized facilities within the station nonmotorized study subareas. This will be conducted for both the Build and No Build Alternatives. This assignment of the pedestrian and bicycle forecasts will identify any physical barriers limiting access to the stations.

A quantitative pedestrian LOS analysis will be conducted for sidewalks at intersections within one block (approximately 300 feet) of proposed station entrances with substantial pedestrian ridership projections (the study area may exceed one block or 300 feet from the station depending on the location of transfer points, major key intersections for pedestrian connections,

or nearby pedestrian generators). The Transit Capacity and Quality of Service Manual (Transportation Research Board 2017) and HCM methodology for determining sidewalk LOS will be used for this analysis. This methodology produces a score that indicates the pedestrian's perception of the travel experience and is based on the average pedestrian space and average flow rate.

7.6.2 Construction

Nonmotorized construction analysis will be coordinated with the local and arterial traffic analysis considering the potential pedestrian or bicycle facility impacts on roadways or nonmotorized facilities as a result of project construction activity that could close or modify these facilities. This analysis will summarize the impact location, type of facility, and construction activity, including likely duration of impact (short-term versus long-term).

7.7 Safety

7.7.1 Operations

Potential effects of the project on safety will be assessed qualitatively, and where appropriate, quantitatively, for all modes within the study subareas, including general traffic, transit, freight, bicycle, and pedestrian modes.

7.7.1.1 Evaluation Measures

Evaluation measures will include the following:

- Intersection and roadway collision histories (type, severity, and frequency).
- Qualitative effects on general-purpose traffic, transit, freight, and nonmotorized safety.

7.7.1.2 Evaluation Approach

A safety analysis will be used to assess historical collisions/crashes within the project limits in terms of type, severity, and frequency. Collision data from the latest three years will be compiled and summarized to identify any current safety deficiencies. Unique collision patterns (e.g., high frequency of a specific pattern) will be noted. The collision data will be collected for any directly affected study intersections and roadways.

A safety assessment of the intersection and roadway design will be conducted only where the Build Alternatives are proposed to be either at-grade in semi-exclusive right-of-way or elevated within the road right-of-way, predicted to substantially increase volumes of one or more modes, or will result in a physical change to the roadway geometrics or channelization. Along these streets, a qualitative discussion of how the project may directly affect the existing collision type and frequency will be developed and documented.

Safety effects on general vehicle traffic and truck freight travel due to station trip activities will be qualitatively assessed based on projected changes in traffic volumes and critical queue lengths, modal conflicts, and proposed roadway design.

Safety effects on bicycle and pedestrian travel will also be qualitatively assessed based on changes in the number of conflicts with motorized modes and changes in facilities provided for their travel. This assessment will consider school walk routes and school bus zones.

7.7.2 Construction

Construction impacts will be qualitatively assessed to determine if the project's construction would have any impact on the safety of the transportation system. This will include assessing the safety of transit riders, arterial and local streets, nonmotorized modes (pedestrians and bicyclists), and freight travel.

7.8 Parking

7.8.1 Operations

Demand for parking will likely vary depending on location throughout the study subareas. An assessment of drop-off/pick-up activity and informal parking near station areas will be conducted through analysis of existing mode-of-access survey information and data from Sound Transit for similar station areas. This data will be used to estimate the impact of driving and/or parking for stations along the corridor.

If station park-and-ride (surface or garage) facilities are included in the project, the project will estimate the demand for station parking for the length of the project. While the station parking analysis will estimate the demand compared to the proposed parking to be provided, the traffic analysis will assume that station parking facilities are full in order to analyze the worst-case condition.

7.8.1.1 Evaluation Measures

Analysis of the impacts of the project on existing on-street and off-street public parking will consider roads where permanent facilities would be located in the right-of-way and roadways around stations. The analysis will consider the loss of existing public on-street and off-street parking supply and the potential for hide-and-ride parking.

7.8.1.2 Evaluation Approach

The evaluation of parking impacts will include an inventory of parking supply, regulation, and pricing of publicly accessible on- and off-street parking in the area within a 0.25-mile radius of stations (and within one block of the project and the area impacted by construction). This information will be compared to the potential changes to the availability of parking in the station area under each of the Build and No Build Alternatives, including the potential for use of public parking on-street by people seeking to access Link stations. For selected locations, if parking inventory and/or travel demand indicates the potential for effects to publicly accessible parking availability, parking utilization for select block faces will be collected for peak utilization periods (11:00 AM-2:00 PM) plus alternative time windows associated with local patterns of demand if needed. Field data related to station access via auto modes will be used to assess the impact these modes may have in and around station areas along the alignment.

Along the alignment, the assessment of potential changes to the availability of publicly accessible parking will be based on review of the inventory of the supply, regulation, and pricing

of parking in the station area, available data on the utilization and availability of such public parking during periods of peak demand for access to transit, and an evaluation of the conceptual drawings for the Build Alternatives. Comparison between existing supply, regulation, and utilization, and the projected supply remaining after construction of the Build Alternatives will form the basis for identifying recommendations for changes to parking regulation or management and potential changes to parking availability likely to be attributable to parking by transit passengers in association with each Build Alternative. This comparison will also consider possible mitigation strategies. The potential change to parking availability, if any, will be presented by both location (block face and facility) and type of curb space and/or parking space regulation (e.g., time limited, paid parking, load zones, or no parking zones). Off-street parking lots will be considered in the analysis as additional supply for the loss of on-street parking. In station areas, the potential for transit passengers to park in publicly available on-street parking areas surrounding the station will be estimated based on ridership forecasts, existing parking restrictions, the availability of other transit access alternatives, and the potential walkshed of the station.

7.8.2 Construction

The assessment of construction-related parking impacts will consider the following:

- Changes in roadway supply, parking restrictions, regulations, utilization, and availability
- Impacts to on- and off-street public parking supply, management, utilization, and availability
- Additionally, there may be some temporary loss of off-street parking supply and/or availability as a result of the location and operation of construction staging, as well as construction worker parking

7.9 Aviation

7.9.1 Operations

Potential effects of the project on aviation facilities in the project corridor and FAA requirements will be studied, including potential effects on the following: Design Criteria, Airspace (Part 77 Surfaces), and Land Release.

7.9.1.1 Evaluation Measures

If necessary, project elements will be summarized through an Obstruction Evaluation/Airport Airspace Analysis, documented through a Form FAA 7460-1, and presented to FAA and Snohomish County.

7.9.1.2 Evaluation Approach

Project elements will be reviewed with FAA and Snohomish County to determine if there are potential aviation impacts.

7.9.2 Construction

Proposed construction elements in proximity to aviation facilities in the project corridor will be

summarized along with potential aviation impacts.

7.10 Indirect Effects

Indirect impacts are potential effects that would be caused at a later time or farther distance but are still reasonably foreseeable. Typical indirect transportation effects are those associated with changes in land use over time. The land use changes will be described in the Land Use technical report and EIS section, and the associated potential impacts to transportation will be discussed qualitatively.

7.11 Cumulative Effects

The cumulative transportation effects of the project are already generally analyzed through traffic modeling and ridership modeling that incorporates past and reasonably foreseeable future actions and projected growth.

A qualitative assessment will address additional cumulative transportation effects for specific reasonably foreseeable future plans or proposals that have not completed environmental review or are not fully funded for construction (and therefore are not directly accounted for in the modeling) but could foreseeably be built by the horizon year. These may include, but are not limited to, consideration of effects from actions such as the following:

- Highway/lane management, such as from the implementation of tolls on state and/or local facilities, that could further alter travel behavior in the corridor
- Construction activities from other transportation projects that could affect or be influenced by the project construction activities
- Local developments and public infrastructure projects that could contribute to cumulative traffic delays on local arterial streets over the construction period

8 MITIGATION MEASURES

Potential impacts to transportation will be controlled through project planning, design, and the application of required best management practices (BMPs) during construction and operation. Measures to avoid and minimize potential impacts of the alternatives will be incorporated as appropriate. Where impacts cannot be avoided or minimized, mitigation measures will be developed.

The development of potential mitigation measures will be coordinated with the relevant federal, state, and local agencies and jurisdictions to identify strategies that may already be under consideration but that could benefit the project.

8.1 Regional Transportation

Mitigation would be determined if any impacts to the measures evaluated within the Regional and Corridor Traffic section during operations or construction were identified.

8.2 Transit

The performance of the transit system will be assessed under the Build, No Build, and construction conditions using analysis results as stated in Section 7.3. The objective of the transit service integration plan collaboratively developed between Community Transit, Everett Transit, and Sound Transit is to be cost neutral, therefore potential mitigation for transit service hours or fleet is not expected with the project. Project-related operational delays, facility impacts, and mitigation identified as part of the traffic analysis conducted near the station areas and alignments will be reviewed to determine if there are needed transit improvements to maintain transit speed and reliability through these impacted locations (see Section 8.3).

At these locations, impacts will be reviewed and potential mitigation, design changes, and/or service revisions will be determined collaboratively by Community Transit, Everett Transit, and Sound Transit.

8.3 Arterials and Local Streets

Mitigation to property access and local circulation will be developed to address impacts to the roadway system and/or individual properties caused by the project. This could include project impacts that create substantial out-of-direction travel or would substantially limit access to areas or properties through road closures or direct barriers the project creates. Local circulation mitigation could also be determined if the project shifts traffic and causes intersections to operate with an unacceptable LOS based on the LOS standards established in this section.

For intersection operations, if the intersection LOS is equal to or better than the jurisdictional agency's LOS standard with the Build Alternatives, then that intersection is considered to meet the jurisdictional agency's standard and does not require mitigation. In situations where the intersection already operates worse than the jurisdictional agency's LOS standard (e.g., LOS F) in the No Build Alternative, then mitigation is only required if the overall intersection delay and/or LOS noticeably degrades (greater than a 15-second increase in the delay) with the project alternatives. In these situations, the project is only obligated to bring the operating condition back to the overall intersection delay levels in the No Build condition. Additionally, depending on the agreement with the relevant jurisdictions, potential mitigation may be needed if the project extends queue lengths further than those in the No Build Alternative and beyond the storage provided. Potential mitigation might include operational changes to signal phasing and physical modification such as restriping, extending, or adding turn lanes. Potential mitigation will also be reviewed against the nonmotorized conditions evaluated under Section 7.6 and safety conditions evaluated under Section 7.7, as well as any mitigation identified under Section 8.5 or Section 8.6. Potential mitigation measures that are found to have adverse effects on nonmotorized conditions or safety will be reviewed with relevant jurisdictions for resolution.

Mitigation measures, if necessary, will be developed to address construction impacts on the local and arterial roadway system with respect to property access and circulation, and arterial and local roadway operations.

8.4 Freight

Potential improvements will be identified to mitigate potential direct (long-term and construction) impacts from the Build Alternatives on freight. This will consider degradation of freight

operations access and circulation impacts along affected roadways, commercial loading zones, and rail.

8.5 Nonmotorized

Potential improvements will be identified to mitigate potential direct (long-term and construction) impacts from the Build Alternatives on the nonmotorized system. This will consider degradation of pedestrian and bicycle conditions surrounding station areas, and any identified direct impacts to the pedestrian and bicycle facilities.

8.6 Safety

Potential improvements will be identified to mitigate potential direct (long-term and construction) impacts from the Build Alternatives on the safety of the transportation system. This will consider degradation of safety to transit riders, arterial and local streets, nonmotorized modes (pedestrians and bicyclists), and freight travel. The Federal Highway Administration Crash Modification Factor Clearinghouse will be used to identify safety countermeasures, if needed.

8.7 Parking

Potential parking mitigation will be considered where the project permanently or temporarily (e.g., during construction) removes public parking, including loading zones, or, where parking utilization by transit passengers is projected to result in a substantial change to the availability of public parking within a local sub-area or block face (e.g., more than 50% of parking is removed for the project or used by transit passengers), resulting in a condition where less than 15% of the capacity of the facility or area is available during periods of peak demand. Areas with a high potential for a significant change to parking availability due to transit passenger demand will be identified, with recommendations for changes to local parking regulation and management as mitigation strategies to reduce the likelihood of this activity. Potential changes to the availability of private parking would be addressed as a property acquisition impact.

8.8 Aviation

Any mitigation measures identified in the Obstruction Evaluation/Airport Airspace Analysis necessary to address impacts to aviation during operations or construction will be identified.

9 PROPOSED FIGURES, MAPS, OR OTHER DATA

Potential figures include:

- Study subareas
- Screenlines
- Freight routes and facilities
- Study intersection volumes

- Intersection LOS
- Walksheds and bikesheds
- Existing and future nonmotorized facilities
- Existing and future transit networks

Potential tables and graphs include:

- Roadway v/c ratio
- Station mode of access
- Station ridership

10 DOCUMENTATION

For the EVLE EIS, the transportation discipline will develop the following documentation:

- Transportation Technical Report
- EIS chapter

11 DATA DEVELOPED FOR USE BY OTHER DISCIPLINES

Specific types of transportation data will also be developed for use in analyzing project impacts on other environmental resources.

11.1 Air Quality

To support the Air Quality impact analysis, the following types of data will be produced:

- Daily VMT estimates by speeds for two areas: EVLE study area and regional system. These estimates will be provided in a tabular format for greenhouse gas analyses.

The above information will be provided for existing conditions (2023) and the horizon year (2046).

11.2 Noise and Vibration

To support the Noise and Vibration impact analysis, the following types of data will be produced:

- Existing (2023) and horizon year (2046) PM peak hour Synchro model files and general system-wide vehicle classification information (i.e., heavy vehicle percentage)

11.3 Energy

To determine operational energy impacts, the following types of data for year 2046 will be produced:

- Daily regional VMT and VHT
- Daily light rail transit VMT

11.4 Economics

To support the Economics analysis, the following information will be provided:

- Changes in access
- Parking impacts
- Construction detour routes
- Long term effects on general and freight mobility
- Temporary construction impacts to freight routes or loading zones

11.5 Environmental Justice and Social Resources, Community Facilities, and Neighborhoods

To support the Environmental Justice and Social Resources, Community Facilities, and Neighborhoods analysis, a variety of data will be produced, including the following:

- Estimated travelsheds as determined by using the travel demand model to identify transportation analysis zones relevant to the Environmental Justice and Social Resources, Community Facilities, and Neighborhoods analysis
- Estimated travel times to selected destinations for use in the analysis of access to employment centers, educational institutions, and medical services for environmental justice populations
- Analysis of temporary or permanent impacts on ADA parking or designated parking at social services, as well as percentage of parking spaces temporarily or permanently lost in designated commercial shopping districts
- Permanent and temporary changes in transit and traffic operations, circulation, and access on corridor roadways and potential mitigation

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13 APPENDICES

Appendix A: Transit Integration Technical Memorandum

Appendix B: Sound Transit's Transit Ridership Forecasting Methodology Report



Everett Link Extension

APPENDIX A

Transit Integration Technical Memorandum



Everett Link Extension

Transit Integration Technical Memorandum

December 2022

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Acronyms

EIS	Environmental Impact Statement
EVLE	Everett Link Extension
OMF	Operations and Maintenance Facility
ST3	Sound Transit 3 Plan

1 INTRODUCTION

1.1 Overview

The Everett Link Extension (EVLE), referred to in this memo as “the EVLE Project” or “the project,” will extend the Link light rail 16 miles from the Lynnwood City Center Link light rail station to the Everett Station area, adding six new stations and considering one provisional (or unfunded) station. The project is part of the Sound Transit 3 Plan (ST3) approved by voters in 2016. ST3 included a description of the “representative project” which identified the mode, station locations and related features, such as an Operations and Maintenance Facility (OMF). This formed the basis for the scope, schedule and budget assumed for the expansion of light rail to Everett. The ST3 representative project itself is the result of extensive, multi-year planning and public involvement work.

A map of the ST3 representative project showing the extension and planned station areas is shown in Figure 1-1 (Everett Link Extension Representative Project). The EVLE Project will extend the Lynnwood Link Extension, currently under construction, and will provide fast, reliable, frequent transit service to communities in Lynnwood, Snohomish County, and Everett. The EVLE Project provides important north/south connections to major employment, population, and activity centers, and connects to other local and regional transit services including Community Transit, Everett Transit, Community Transit *Swift* bus rapid transit (BRT) lines, and Sounder commuter rail service.

Sound Transit is leading the Alternatives Development phase (Phase I) of the EVLE Project planning process. Agency partners, the public, and other stakeholders were involved throughout this process. The Alternatives Development phase identifies, evaluates, and narrows down a wide range of alternatives. The information generated during this phase, as well as feedback from the public and stakeholders, will assist the Sound Transit Board in identifying a Preferred Alternative to study in a future Environmental Impact Statement (EIS). During the Alternatives Development phase, Sound Transit initiated agency coordination and robust public engagement to identify potential alternatives for light rail routes and profiles, as well as potential station and OMF North locations. Alternatives were analyzed through evaluation criteria based on the EVLE Project’s purpose and need statement. Consideration was also given to Sound Transit’s System Expansion Implementation Plan and federal funding program requirements.

Based on feedback received and the results of the alternatives evaluation, the Sound Transit Board is expected to identify a Preferred Alternative and other alternatives to advance into the next planning phase: Draft EIS and Conceptual Engineering (Phase II). Figure 1-2 (EVLE Project Overview) provides an overview of the project planning process.

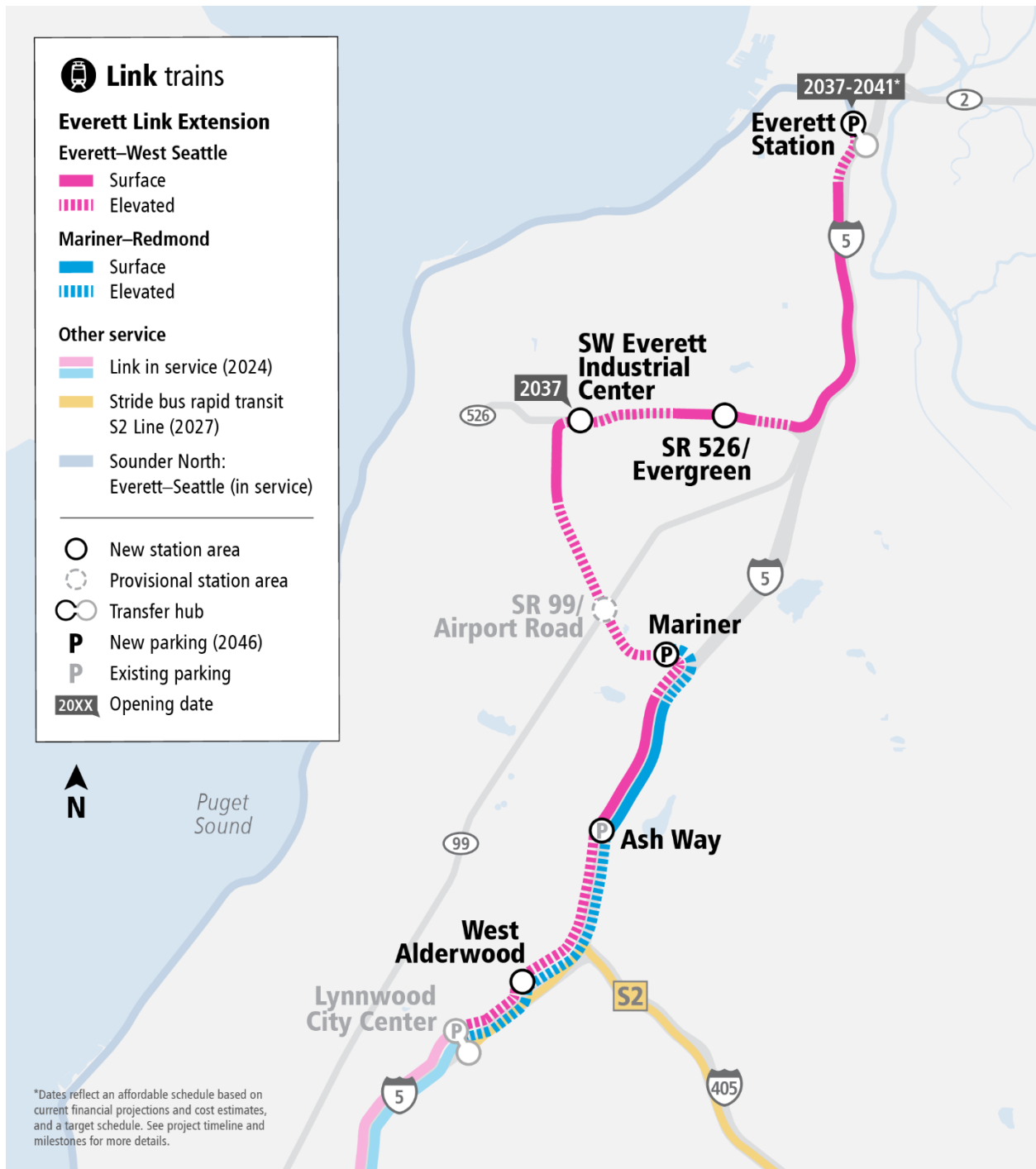


Figure 1-1 Everett Link Extension Representative Project

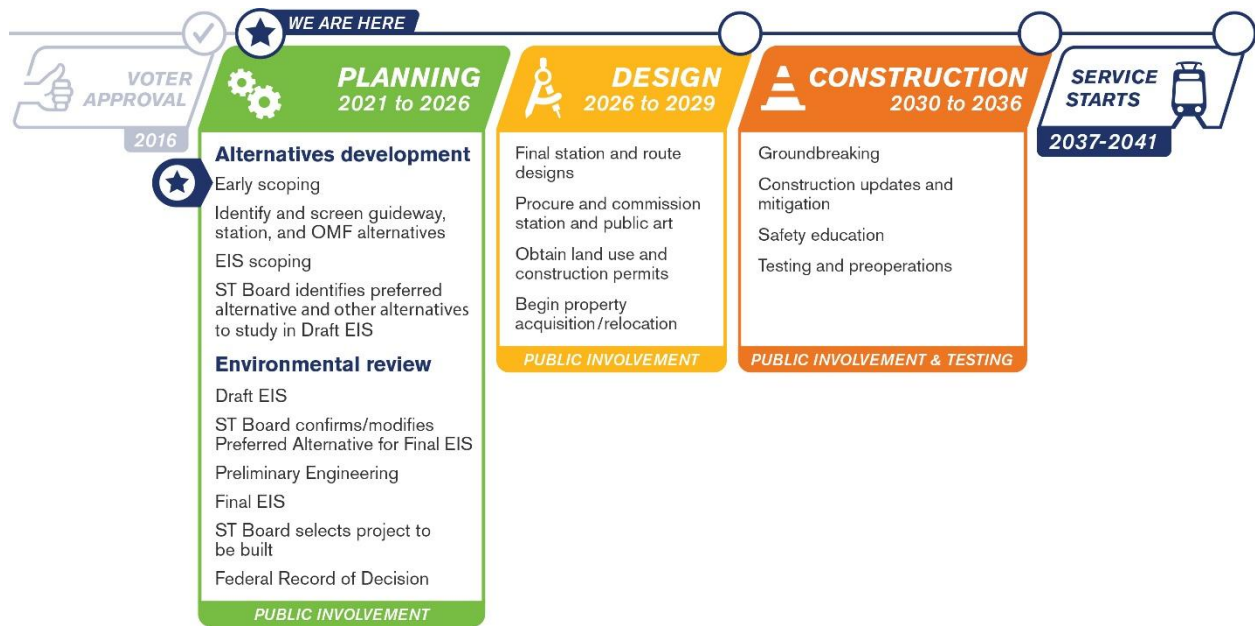


Figure 1-2 EVLE Project Overview

1.2 Purpose of Report

This technical memorandum describes the process of evaluating transit integration during Phase I of the EVLE Project. This process includes a multi-level evaluation approach that eliminates lower-performing alternatives and analyzes remaining alternatives in more detail as the evaluation progresses. Each level considers evaluation criteria and measures consistent with the preliminary purpose and need for the EVLE Project. The alternatives evaluation process will inform the Sound Transit Board's identification of a Preferred Alternative and any other alternatives to advance into the Draft EIS and Conceptual Engineering phase.

2 OVERVIEW OF LEVEL 1 AND LEVEL 2 ANALYSES

During Phase I, possible alternatives were identified through gathering data on existing conditions and local and regional plans, as well as through collaboration with partner agencies, tribes, and the public. The process began with 56 potential station location alternatives across the seven station areas. Through each level of evaluation, the analysis became more detailed and rigorous as data was gathered and conceptual design advanced, and low-performing alternatives were eliminated from consideration to arrive at a smaller number of the most promising alternatives. The initial 56 station location alternatives were screened down to 29 alternatives for the Level 1 evaluation and 20 alternatives for the Level 2 evaluation covered in more detail in this memo.

The initial screening process determined if the identified alternatives met the project purpose and need and rated alternatives based on their ability to satisfy the evaluation criteria relative to the ST3 representative project. The alternatives development process measured the performance of each station area alternative relative to other alternatives in the same station area.

The Alternatives Development process will result in the Sound Transit Board identifying a Preferred Alternative and other alternatives to advance to the Draft EIS for further evaluation. The evaluation process consisted of three levels to identify the alternatives that best meet the preliminary purpose and need for the EVLE Project. The first two evaluation levels (Screening and Level 1) reviewed alternatives by specific station areas or study sections. The final evaluation level, Level 2, added an end-to-end corridor analysis of alternatives.

3 TRANSIT INTEGRATION ANALYSIS

This transit integration analysis was part of a broad set of evaluation criteria in the Level 1 evaluation and Level 2 evaluation and was necessary to assess the performance of station alternatives within the context of existing and proposed transit service. A new transit investment with accessible stations that are well-connected to existing transit service is more likely to meet the needs of current and future transit riders. Understanding potential transit service levels at each station alternative also helps to determine facility needs, such as layover space and active bus bays. Station locations were identified in the Screening evaluation and further refined as part of the Level 1 evaluation. For the Level 2 evaluation, several advancements were made for each station alternative progressed to that level. One example is station areas in Level 2 were further defined, including early conceptual station concept layouts that sized and configured station features such as rail platforms, pick-up/drop-off areas, and bus bays. Secondly, bus service networks and frequencies were developed for the surrounding bus network. These elements are depicted in the conceptual site plans and bus circulation graphics associated with each station alternative. Station concept layouts and transit integration networks were vetted with the Interagency Group (IAG), which included local transit operators.

The Level 1 transit integration evaluation included an assessment of connections between the station and both high-capacity transit and other bus transit services. Transit integration analysis for the Level 2 evaluation allowed for a more in-depth analysis associated with the further definition of station access facilities and transit integration networks. The evaluation included an assessment of the quality of transfers to planned bus services, a specific focus on connections to high-capacity transit, implications to bus routing and efficiency for station connections, and amount of planned bus connectivity. Similar to the Level 1 evaluation, alternatives within the same station area were compared to each other during Level 2. For transfer quality and connectivity to high-capacity transit, the analysis looked at whether bus routes served the station directly or indirectly, transfer distance to make bus-rail connections, potential barriers along transfer walking paths, and service connectivity to *Swift* BRT lines. For connecting transit service and operations, the project team examined potential diversions from existing or optimal bus routing. The amount of planned bus activity was based on the planned number of buses per hour serving the station. A score range of 1 to 5 was assigned to each station alternative, with 1 being poor performance and 5 being excellent performance.

A detailed overview of transit integration measures and methods for both the Level 1 and Level 2 evaluation is provided in Tables 3-1 (Level 1 Evaluation Measures and Methods for Transit Integration) and 3-2 (Level 2 Evaluation Methods and Measures for Transit Integration).

Table 3-1 Level 1 Evaluation Measures and Methods for Transit Integration

Category	Criteria	Measure	Methods
Increase Transit Connectivity and Capacity  Improve regional mobility by increasing connectivity and capacity in the EVLE corridor from the Lynnwood Transit Center to the Everett Station area to meet projected transit demand.	Modal Integration	Quality and capacity of transfers	Assessment of quality of bus-rail transfers based on distance and barriers between bus drop-off and station entrance and capacity to integrate bus transfers based on proximity to existing transit centers/park-and-rides, and/or capacity to accommodate direct drop-off or on-street transfers.
		Connectivity to high-capacity transit	Evaluation of ease of connections to existing and planned high-capacity transit stations and corridors, including <i>Swift</i> BRT at station alternatives.

Measures and methods in **bold** were changed/added from the Screening to Level 1 evaluation.

Table 3-2 Level 2 Evaluation Measures and Methods for Transit Integration

Category	Criteria	Measure	Methods
Increase Transit Connectivity and Capacity  Improve regional mobility by increasing connectivity and capacity in the EVLE corridor from the Lynnwood Transit Center to the Everett Station area to meet projected transit demand.	Modal Integration	Quality and capacity of bus-rail transfers*	Quality of bus-rail transfers based on distance from stop locations and barriers to walking transfers. Capacity to integrate bus transfers based on proximity to existing and/or funded transit centers, and capacity to accommodate direct drop-off or on-street transfers.
		Quality of potential access for transit vehicles	Assessment of quick and reliable bus access to station alternatives based on the roadway network, barriers, and available Community Transit, Everett Transit, and ST Express network assumptions.
		Planned level of bus service and connectivity	Planned total level of bus service to station alternatives.
		Connectivity to high-capacity transit*	Evaluation of ease of connections to existing and planned high-capacity transit stations and corridors, including <i>Swift</i> BRT at station alternatives.

Measures and methods in **bold** were changed/added from the Level 1 to Level 2 evaluation.

* - Measure is refined or revisited.

4 TRANSIT SERVICE INTEGRATION ASSUMPTIONS

The planned future with project bus networks were developed based on information from the local transit operators and partner agencies - Community Transit and Everett Transit – as well as from future plans for Sound Transit bus route service. The project included close coordination with both local transit operators throughout Phase I to develop and refine transit integration networks, bus facilities, and circulation shown in station concept layouts. Prior to the project team developing bus integration networks, Community Transit and Everett Transit jointly provided a 2036 route network that represented the current projection of a combined service network - - integrated with completion of the EVLE Project. That was accompanied by a table indicating station assignments for specific bus routes at each of the planned EVLE stations. The project team continued to collaborate with Community Transit and Everett Transit during the process of adjusting that network to reflect both short-term transit network changes being planned by Community Transit for a 2024 implementation (“Transit in 2024”) that would have corresponding modifications to the 2036 network and to modify the network to reflect the varying EVLE Project station locations being analyzed in the Level 2 evaluation. These agencies also provided design requirements for bus bays and bus circulation at EVLE Project stations. Refined bus networks reflecting specific Level 2 station alternatives and transit operator-defined bus bay quantity and sizing requirements were then used to define the number of active and layover bus bays needed at each station.

See Figure 4-1 and Figure 4-2 for the existing bus service networks for Community Transit and Everett Transit, respectively. See Figure 4-3 for the proposed refined bus service network developed for the EVLE Level 2 evaluation.

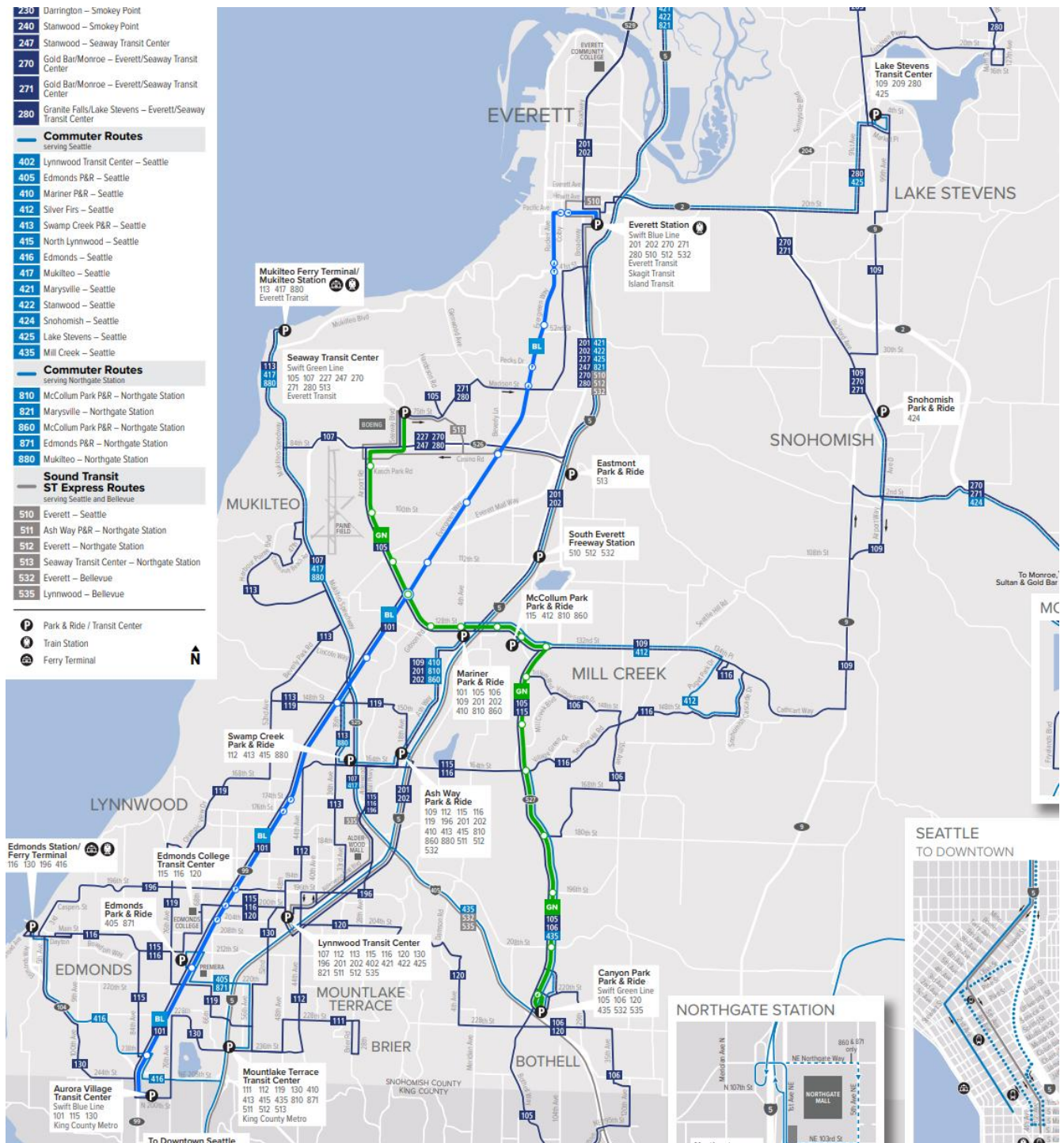


Figure 4-1 Existing Service, Community Transit



Figure 4-2 Existing Service, Everett Transit

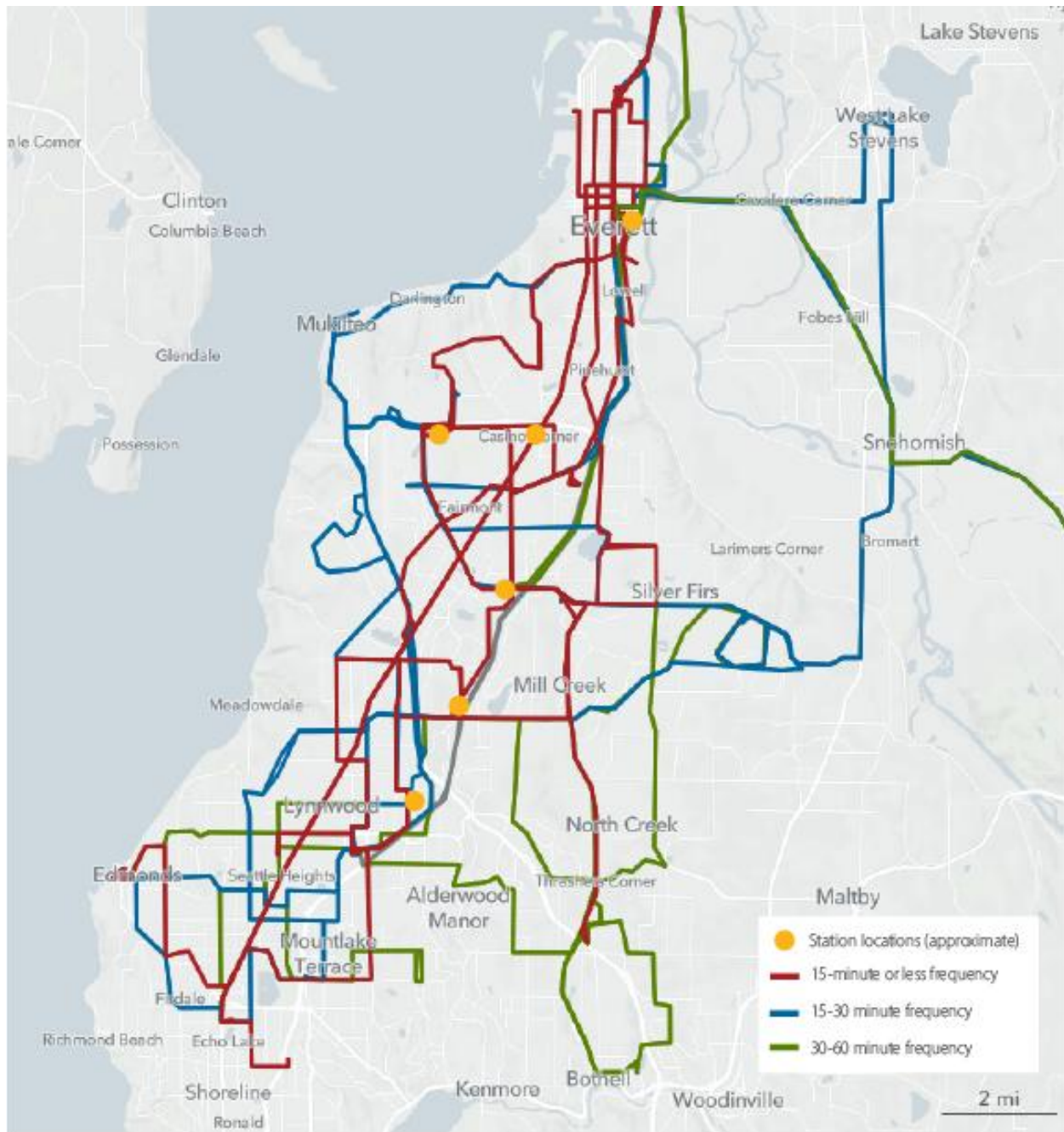


Figure 4-3 Proposed Transit Service

4.1 Service

Table 4-1 (Buses per Hour by Station Area) documents the number of buses on each route per hour that will serve each EVLE station. Note that the table sums the number of buses traveling in each direction per route, so that a 15-minute frequency bi-directional through route would generate 8 buses per hour at a station. Routing information for each station area can be found in Chapter 5 (Conceptual Transit Integration by Station Alternative). It is anticipated that bus network assumptions will be refined for any alternatives that advance to future project phases,

which may change the routes and frequencies identified in this table.

Table 4-1 Buses per Hour by Station Area

Route	Buses per Hour at Peak Frequency (includes both directions)						
	West Alderwood	Ash Way	Mariner	SR 99/Airport Road (Provisional)	SW Everett Industrial Center	SR 526/ Evergreen	Everett Station
3/12					8	8	8
4							4
5							8
8			8				8
13	8						
14		8	8		8		
18							4
19			6	6			
29			8				8
70					4		
90X (Skagit)							2
101				8		8	
103	4				4		
104		8					
105			4				
111	4						
112		6					
116		4					
119		4					
121		4					
132			4				
166		4					
201							4
202							4
271							4
280							4
412 (Island)							3
Eastmont			6		6		
701 (Blue)				12		12	12
702 (Green)			12	12	12		

Route	Buses per Hour at Peak Frequency (includes both directions)						
	West Alderwood	Ash Way	Mariner	SR 99/Airport Road (Provisional)	SW Everett Industrial Center	SR 526/ Evergreen	Everett Station
703 (Orange)	12	12					
704 (Gold)							12
901			4				
902	4						
903			8				
904			8				
905			4				
Total	32	50	80	38	42	28	85

4.2 Active Bays and Layover Space

The numbers of active bays and layover bays required at each station were calculated based on the number of buses at the station per hour and a conversion rate of frequency to bays provided by the local transit operators. The resulting numbers of active bays and layover bays are documented in Table 4-2 (Bays and Layover Space Needs by Station Alternative). It is anticipated that bus network assumptions will be refined for any alternatives that advance to future project phases, which may change the space needs identified in this table.

Table 4-2 Bays and Layover Space Needs by Station Alternative

Station Area	On Street Bays	Off Street Bays	Layover Spaces
West Alderwood			
ALD-B	0	4	2
ALD-D	4	2	2
ALD-F	0	4	2
Ash Way			
ASH-A	0	10	9
ASH-D	0	10	8
Mariner			
MAR-A	2	19	7
MAR-B	2	19	7
MAR-D	2	15	28*
SR 99/Airport Road			
AIR-A	8	0	0
AIR-B	8	0	0
SW Everett Industrial Center			
SWI-A	0	8	2

Station Area	On Street Bays	Off Street Bays	Layover Spaces
SWI-B	2	8	2
SWI-C	2	6	2
SR 526/Evergreen			
EGN-A	6	0	0
EGN-C	6	0	0
EGN-D	6	0	0
EGN-E	6	0	0
Everett Station			
EVT-A	2	12	21*
EVT-C	17	0	0
EVT-D	17	0	0

*Totals include layover spaces that may be provided at the existing transit facilities.

Note: Minor inconsistency between bay requirements in Table 4-2 and station concept layouts will be addressed along with further refinement of bus network assumptions in Phase 2. The bay requirements shown in Table 4-2 are current as of the preparation of this memo and reflect assumptions used in Phase 1 ridership modeling.

Additional station access facility design standards provided by the local transit operators include:

- Paratransit locations with clear path to elevator.
- Each active or layover bay should allow for independent arrival and departure for an over-the-road 60' coach (most conservative vehicle type).
- *Swift* BRT stations are separate from local bus stops with distinctive station design requirements.
- *Swift* BRT coaches must have the ability to align all doors to boarding areas at *Swift* BRT stations.
- Dedicated space for TNC/Microtransit drop-off and pick-up is required at all stations.
- Avoid curb cuts and protruding objects such as signs and trees in vicinity of bus bays and layover.
- *For Mariner and SR 99/Airport Road*: Separate layover for two standby buses needed. This layover request is not included in Table 4-2. Provision for this layover space will need to be further considered in Phase 2.
- Sound Transit's [Station Experience Design Guidelines](#) provide additional station design guidance and principles to facilitate transit integration and access for vehicles and transit passengers.

5 CONCEPTUAL TRANSIT INTEGRATION BY STATION ALTERNATIVE

For each station alternative, conceptual routing and station area site plans were developed to define, for the purposes of the Level 2 evaluation, the location of active and layover bays, potential barriers and walking distances for bus-rail transfers, bus routing and access constraints and strategies, and the sizing and implications needed to accommodate the defined bus bay needs. As part of the Level 2 evaluation discussed previously, station location alternatives were compared to each other and given a rating on the basis of transfers, connectivity, and access. It is anticipated that both station layout concepts and transit integration networks will continue to be refined in Phase 2. The figures and associated findings for each station are provided in sections 5.1 through 5.7.

Station access facility concepts depict proposed on-street and off-street bus bays, including the location of existing *Swift* BRT stations and other bus bays that will remain. Potential layover bay spaces are depicted as well. General bus circulation flows and the relationship to planned pick-up/drop-off spaces are included.

Bus routing maps depict the planned transit integration network associated with each station alternative. Routes that would directly serve off-street transit centers are depicted as such on the graphics.

5.1 West Alderwood

5.1.1 ALD-B



Figure 5-1 ALD-B Station Access Facility Concept Map

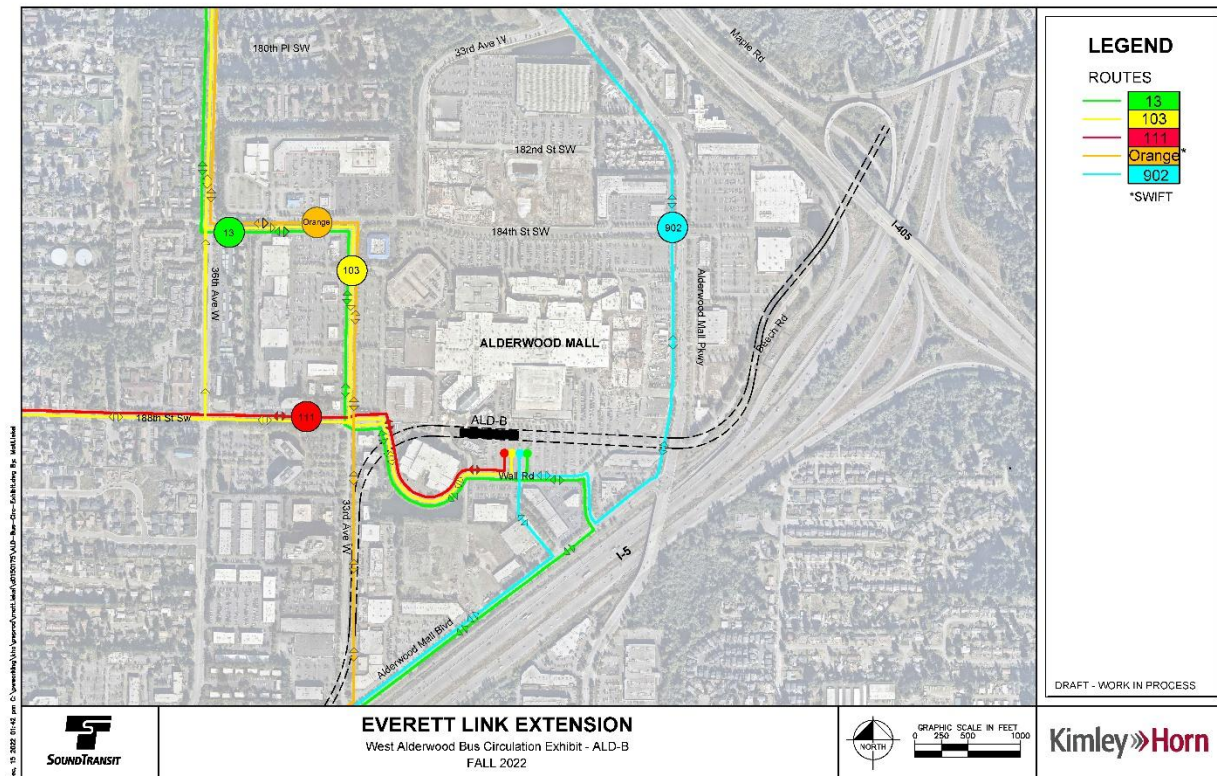


Figure 5-2 ALD-B Bus Routing Map

Quality and capacity of transfers

- Four routes serve this station alternative directly at an off-street transit center.

Connectivity to high-capacity transit

- Long transfer distance to the *Swift* BRT Orange Line, which remains on 33rd Avenue W at 188th Street SW.

Quality of access for transit vehicles

- Diversion from baseline routing.
- Diversion occurs along mall roads susceptible to congestion and lower speeds, impacting travel times.

Planned level of bus service

- Peak 18 buses/hour (weekday).

5.1.2 ALD-D

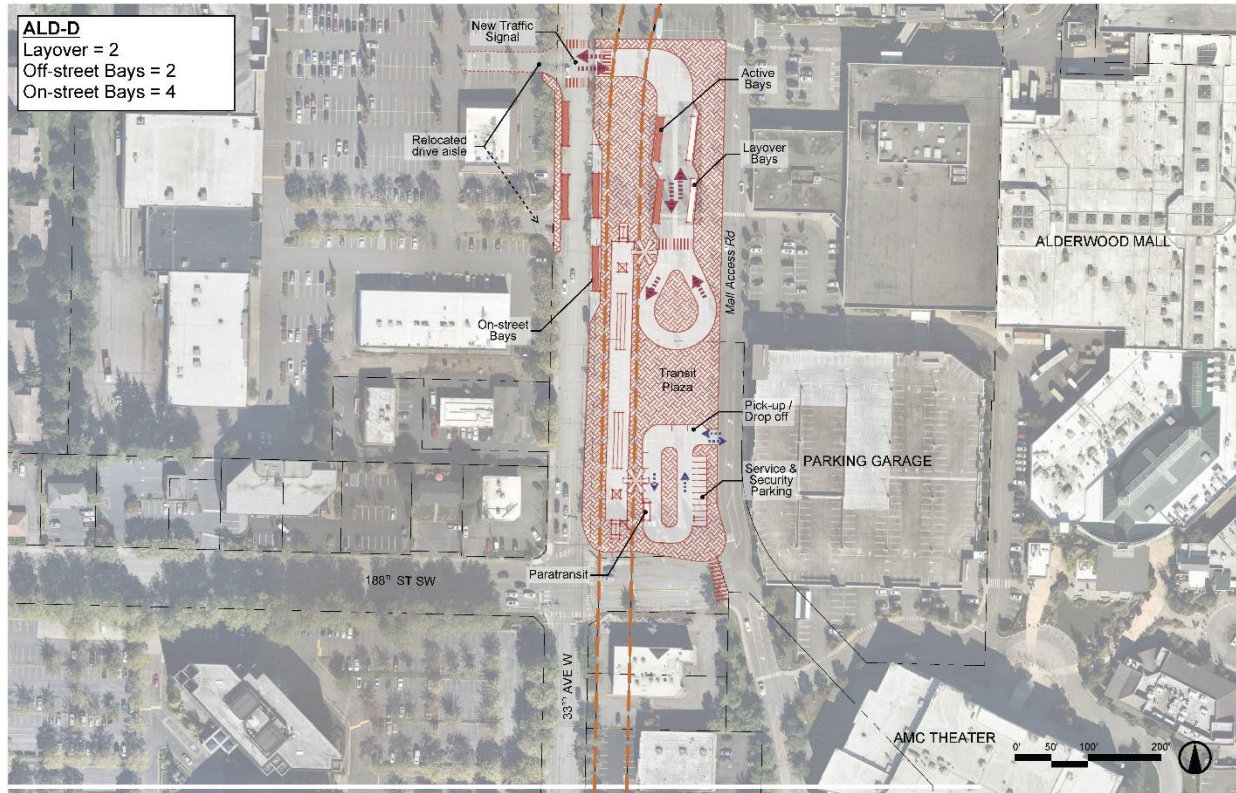


Figure 5-3 ALD-D Station Access Facility Concept Map

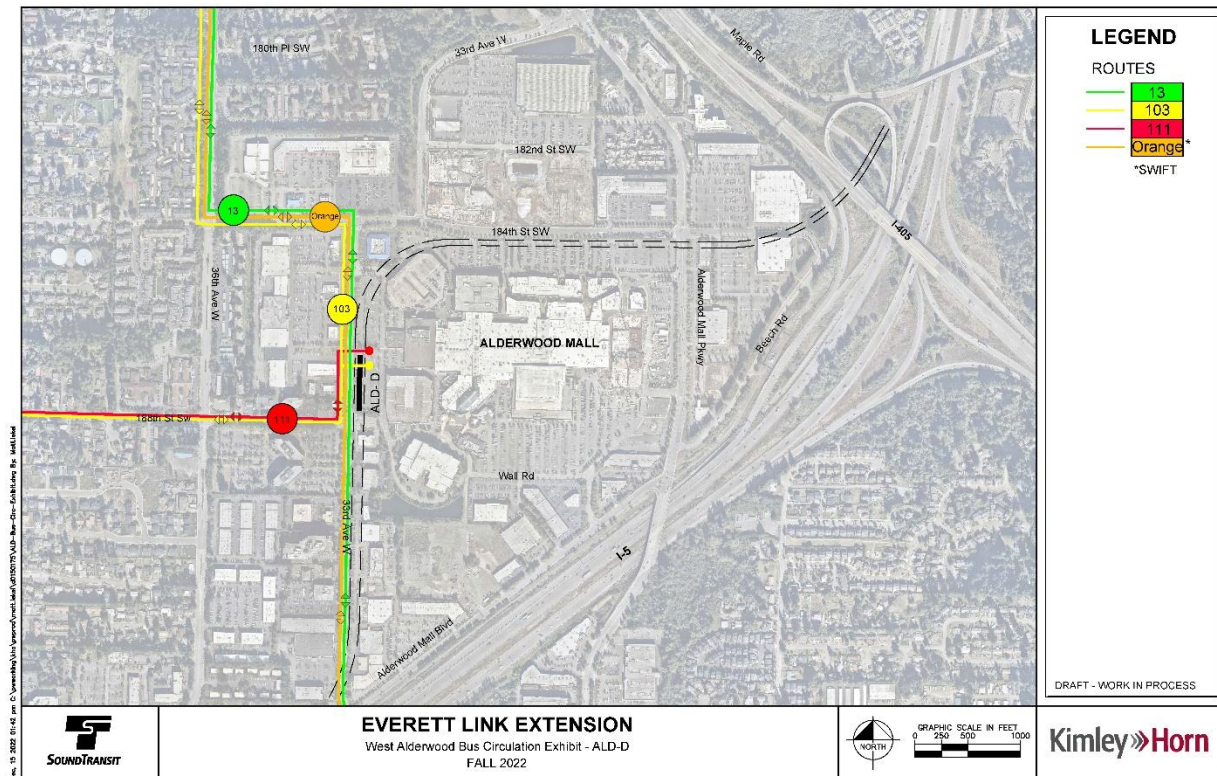


Figure 5-4 ALD-D Bus Routing Map

Quality and capacity of transfers

- Four routes serve this station alternative directly, with some accessed by passengers via bus stops on 33rd Avenue W and some within an off-street transit center facility.

Connectivity to high-capacity transit

- Direct connection to the *Swift* BRT Orange Line.
- Some transfers may require crossing 33rd Avenue W.

Quality of access for transit vehicles

- Minimal diversion for buses.
- On-street stops on 33rd Avenue W allow for no travel time penalty to access station for some routes.

Planned level of bus service

- Peak 26 buses/hour (weekday).

5.1.3 ALD-F

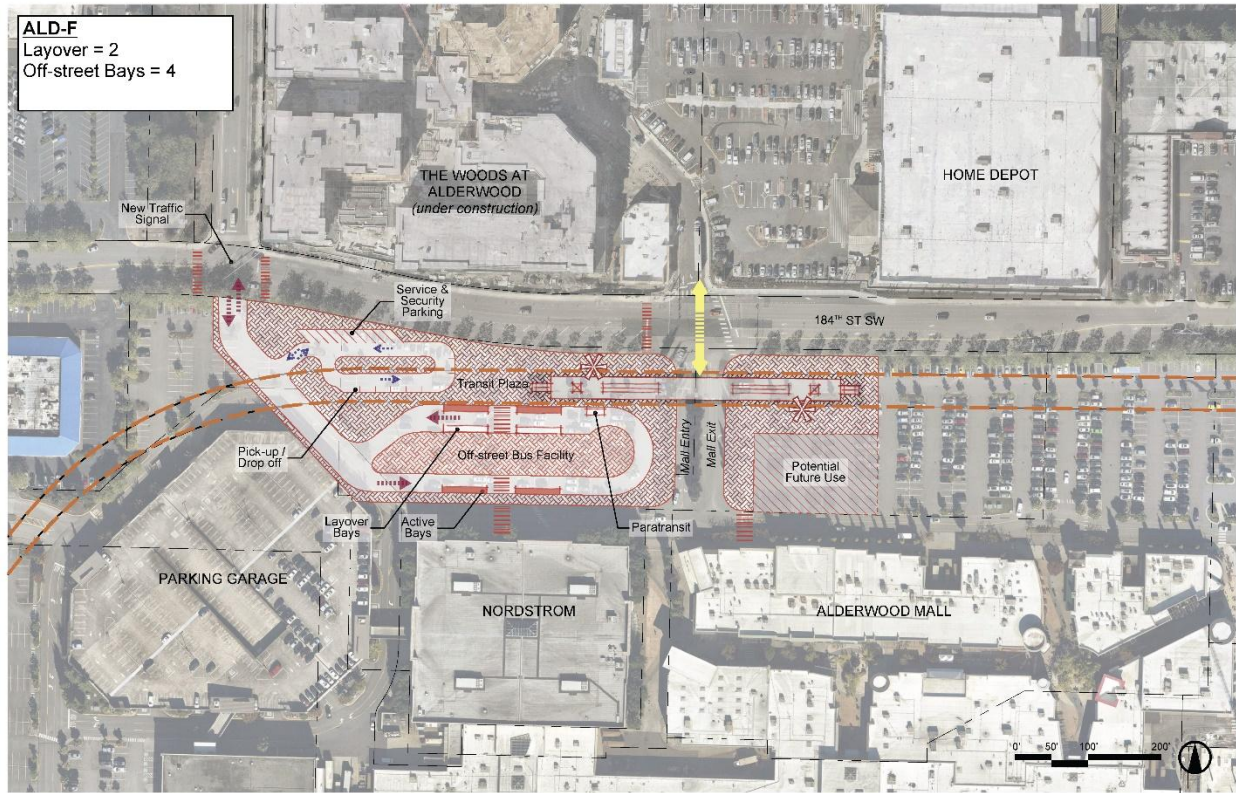


Figure 5-5 ALD-F Station Access Facility Concept Map

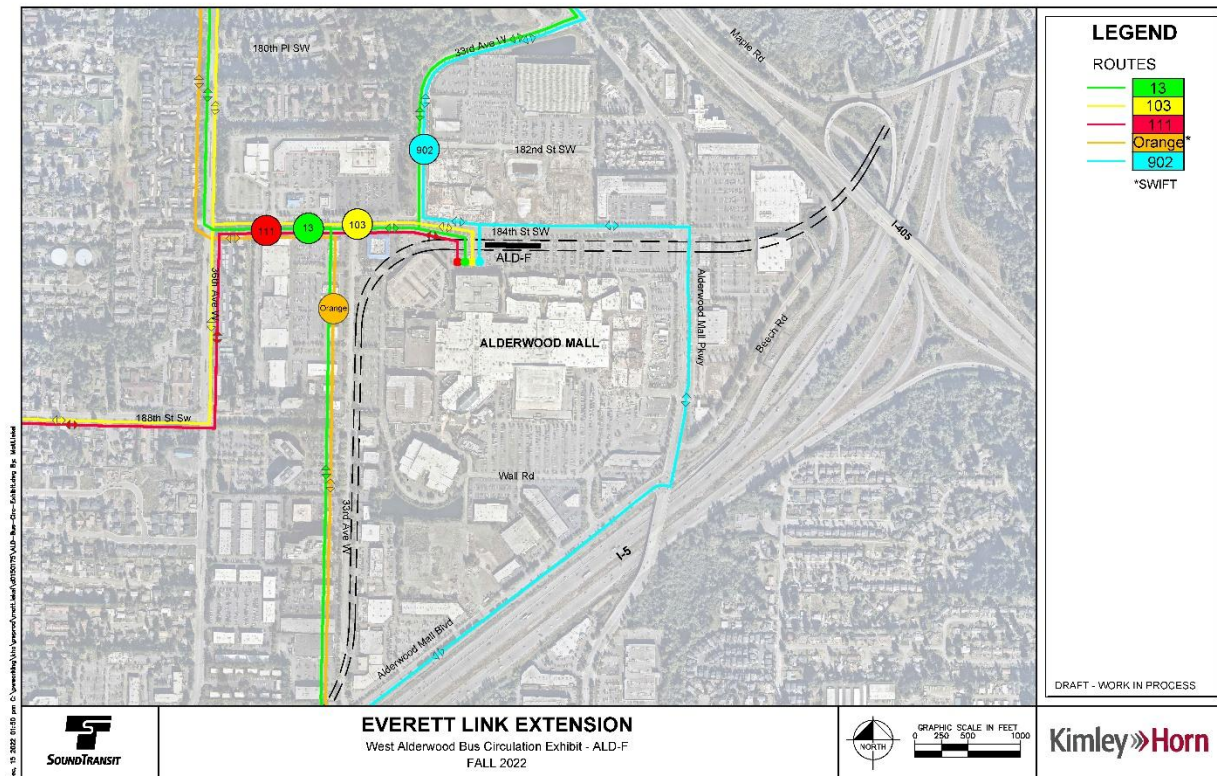


Figure 5-6 ALD-F Bus Routing Map

Quality and capacity of transfers

- Four routes serve this station alternative directly to an off-street transit center.

Connectivity to high-capacity transit

- Long transfer distance to the *Swift* BRT Orange Line, which remains on 33rd Avenue W at 188th Street SW.

Quality of access for transit vehicles

- Some diversion from baseline routing.

Planned level of bus service

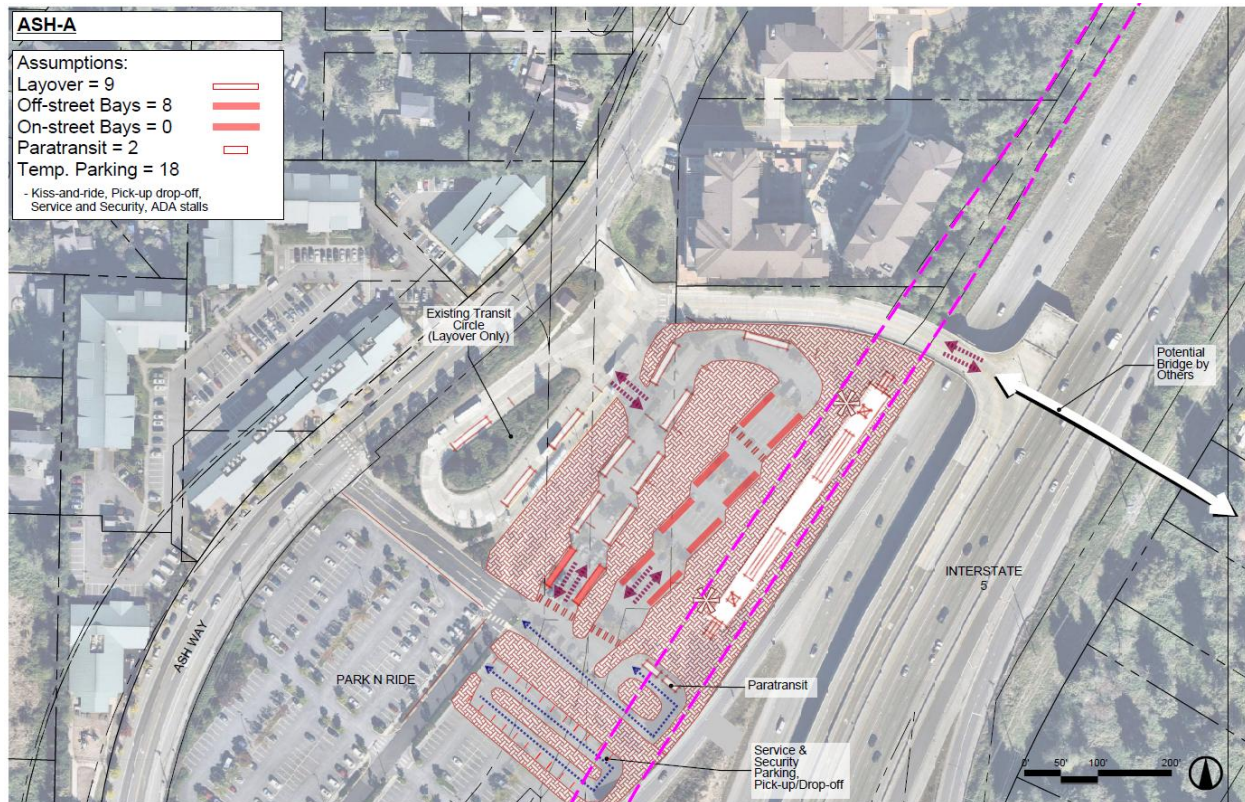
- Peak 18 buses/hour (weekday).

5.2 Ash Way

The two Ash Way station alternatives were both evaluated under two different background network scenarios. The “Without” background improvements scenario assumes the existing roadway network in the vicinity of the station. The “With” background improvements scenario assumes the addition of a new multimodal bridge crossing over I-5 to the north of 164th Street SW between Ash Way Park-and-Ride and Meadow Road.

5.2.1 ASH-A

The quality of transit integration with the ASH-A alternative would not fundamentally change between the “With” and the “Without” networks. While the new I-5 overcrossing would modify walksheds and bikesheds, transit routing and transfer patterns would generally be unchanged. The evaluation notes listed in this section would apply to both the “With” and “Without” networks.



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-7 ASH-A Station Access Facility Concept Map

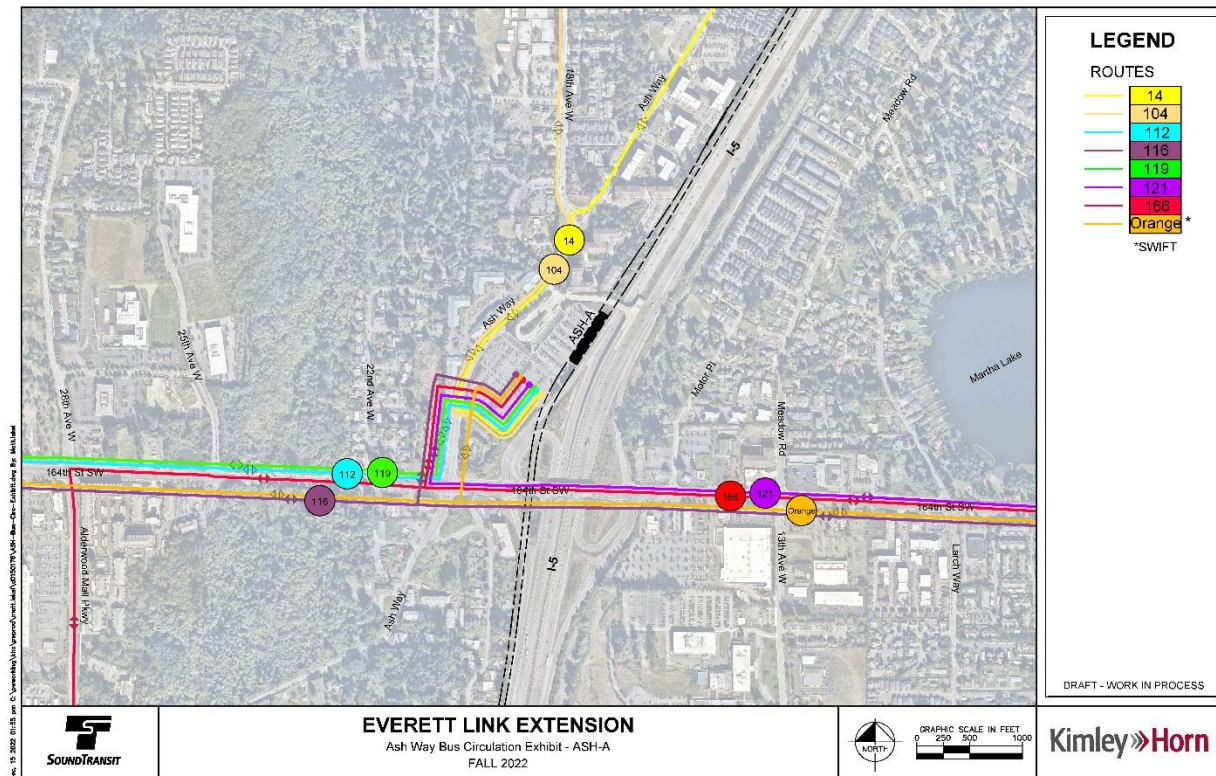


Figure 5-8 ASH-A Bus Routing Map

Quality and capacity of transfers

- Direct service from eight routes to off-street transit center.

Connectivity to high-capacity transit

- Direct connection to *Swift* BRT Orange Line.

Quality of access for transit vehicles

- Existing park-and-ride infrastructure with new transit signal being installed with the *Swift* BRT Orange Line at the transit loop entrance/exit to Ash Way allows buses to navigate easily.

Planned level of bus service

- Peak 43 buses/hour (weekdays).

5.2.2 ASH-D

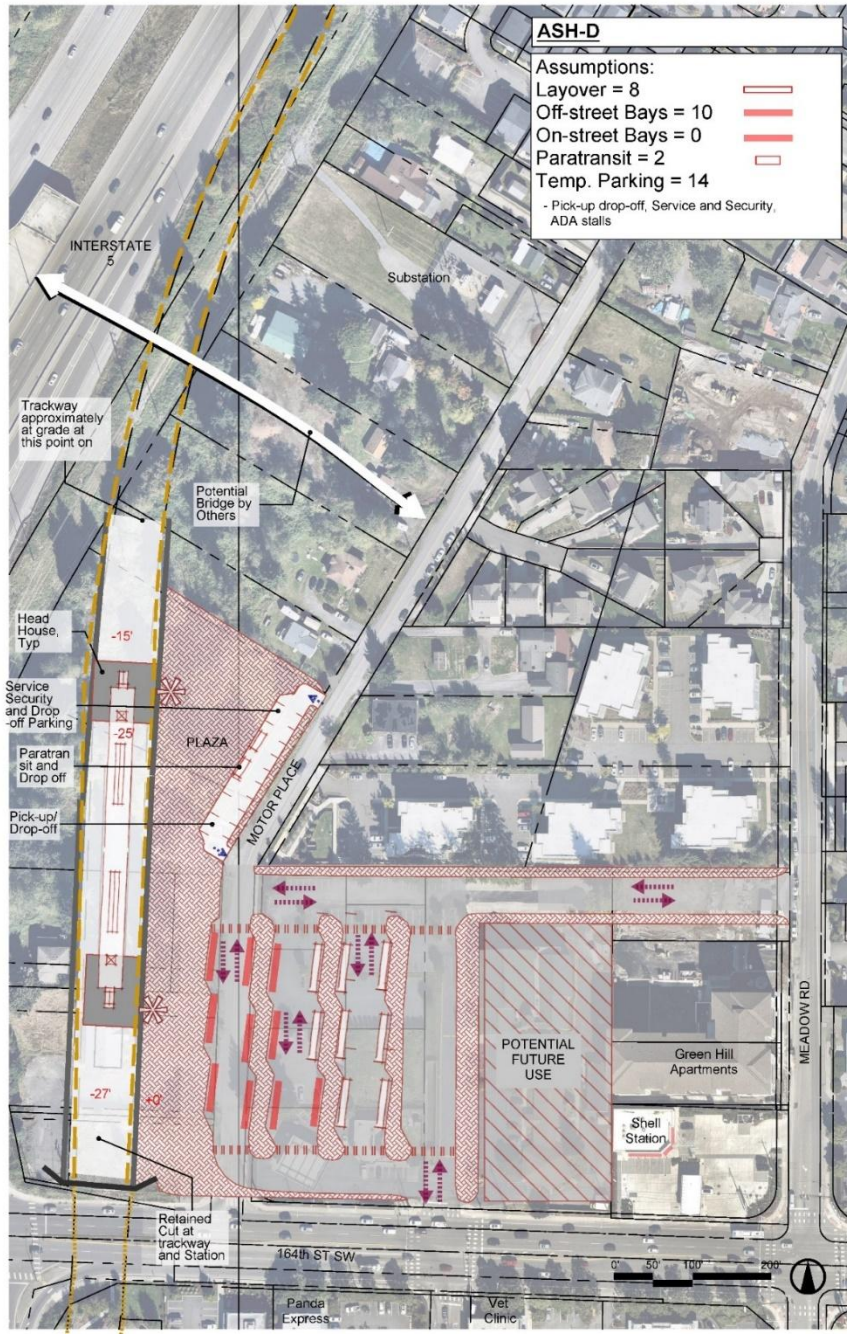


Figure 5-9 ASH-D Station Access Facility Concept Map

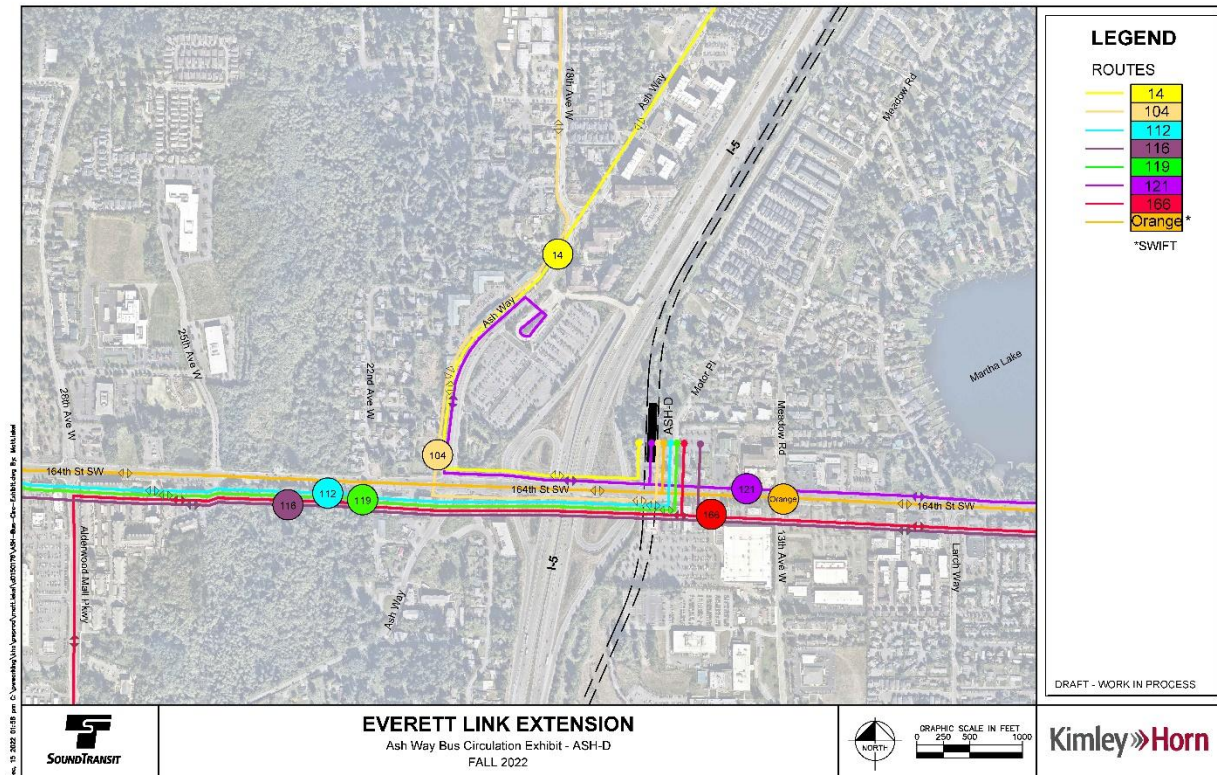


Figure 5-10 ASH-D (Without) Bus Routing Map

5.2.3 ASH-D (Without)

Quality and capacity of transfers

- Direct service from eight routes to off-street transit center.

Connectivity to high-capacity transit

- Direct connection to *Swift* BRT Orange Line.

Quality of access for transit vehicles

- Inefficient bus routing as some routes would need to serve both existing park-and-ride on the west side of I-5 and a new station on the east side.
- Several routes would be required to extend across interchange to reach terminus.

Planned level of bus service

- Peak 45 buses/hour (weekdays).

5.2.4 ASH-D (With)

The “With” background improvements scenario assumes the addition of a new multimodal bridge crossing over I-5 to the north of 164th Street SW between Ash Way Park-and-Ride and Meadow Road. This would provide buses traveling between the existing park-and-ride and the new station a more direct and less congested connection, allowing them to bypass congestion on 164th Street SW.

Quality and capacity of transfers

- Direct service from eight routes to off-street transit center.

Connectivity to high-capacity transit

- Direct connection to modified *Swift* BRT Orange Line.

Quality of access for transit vehicles

- Transit connection across I-5 assumed to facilitate access for buses to both existing and new transit centers.
- Longer route and additional stops are still required for some routes.

Planned level of bus service

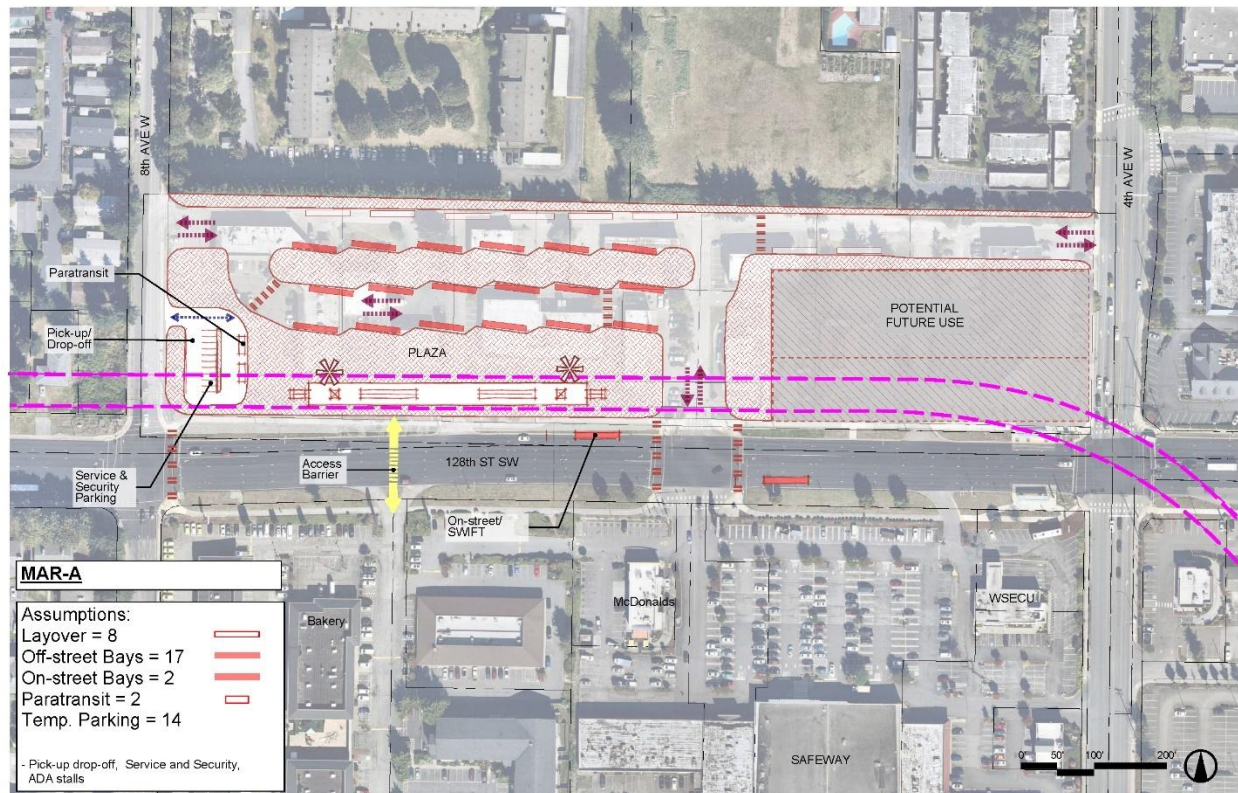
- Peak 45 buses/hour (weekdays).

5.3 Mariner

The three Mariner station alternatives were both evaluated under two different background network scenarios. The “Without” background improvements scenario assumes the existing roadway network in the vicinity of the station. The “With” background improvements scenario assumes the addition of a new multimodal bridge crossing over I-5 to the south of 128th Street SW to extend 130th Street SW to 8th Avenue W.

5.3.1 MAR-A

The quality of transit integration with the MAR-A alternative would not fundamentally change between the “With” and the “Without” networks. While the new I-5 overcrossing would modify walksheds and bikesheds, transit routing and transfer patterns would generally be unchanged. The evaluation notes listed in this section would apply to both the “With” and “Without” networks.



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-11 MAR-A Station Access Facility Concept Map

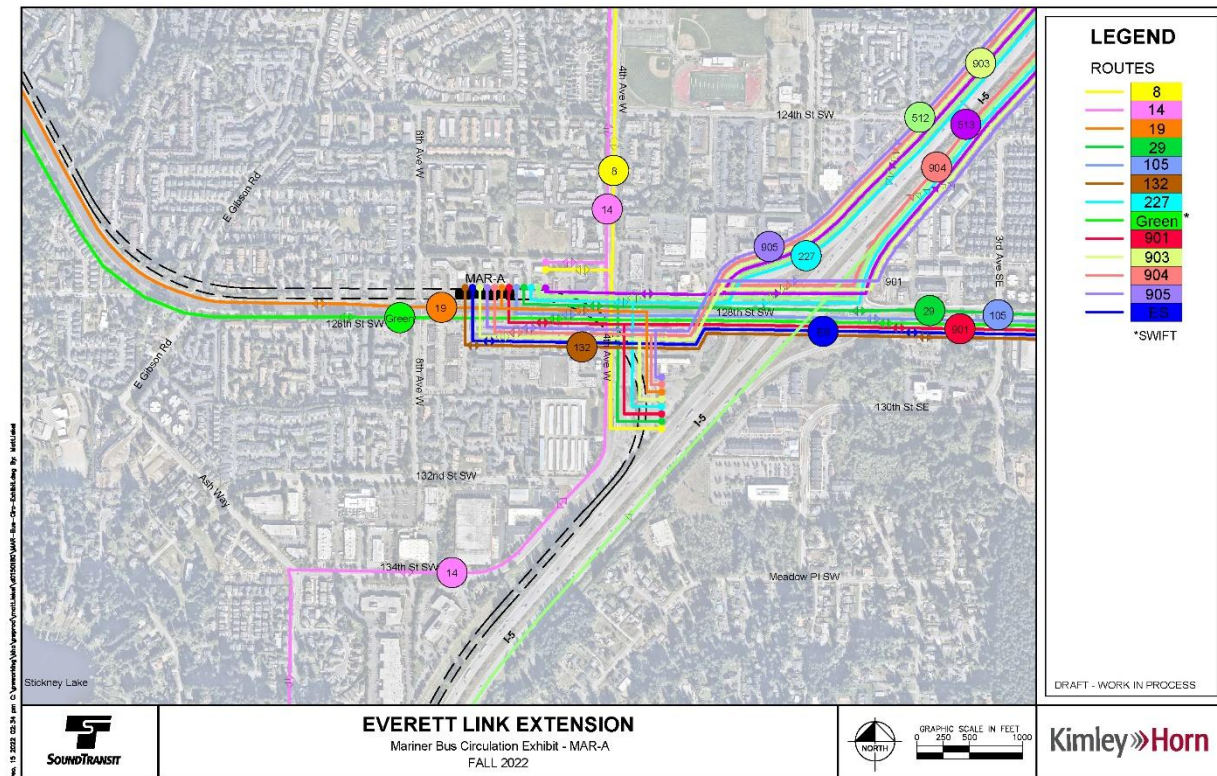


Figure 5-12 MAR-A Bus Routing Map

Quality and capacity of transfers

- All routes serve the station directly.
- All but *Swift* BRT Green Line are accessed via an off-street transit center.

Connectivity to high-capacity transit

- Transfers to *Swift* BRT Green are on-street.
- Some transfers may require crossing 128th Street SW.

Quality of access for transit vehicles

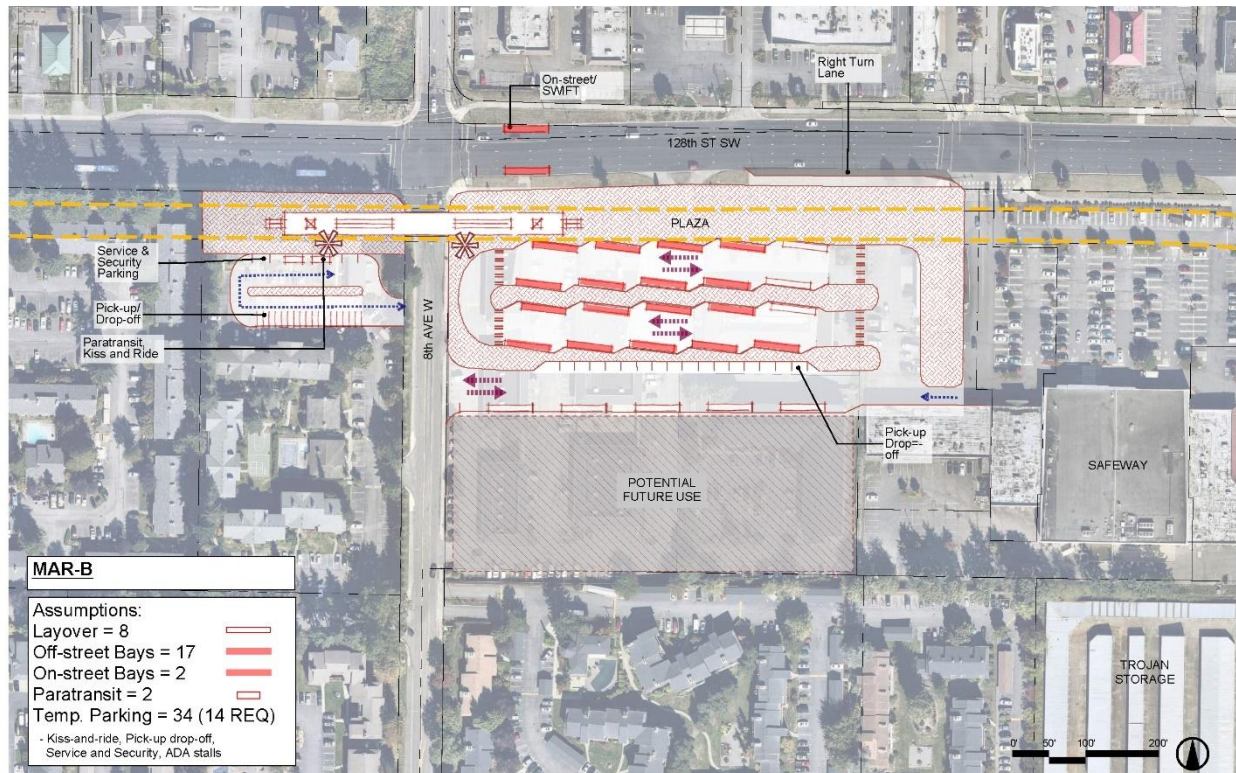
- Most routes have minimal to no diversion to access transit center, although many routes will experience longer route to back-track to layover at existing Mariner Park-and-Ride.
- Access for two routes to/from 4th Ave W may be inefficient.
- Transit center located approximately one-quarter mile west of the interchange used by many routes.

Planned level of bus service

- Peak 88 buses/hour (weekday).

5.3.2 MAR-B

The quality of transit integration with the MAR-B alternative would not fundamentally change between the “With” and the “Without” networks. While the new I-5 overcrossing would modify walksheds and bikesheds, transit routing and transfer patterns would generally be unchanged. The evaluation notes listed above would apply to both the “With” and “Without” networks.



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-13 MAR-B Station Access Facility Concept Map

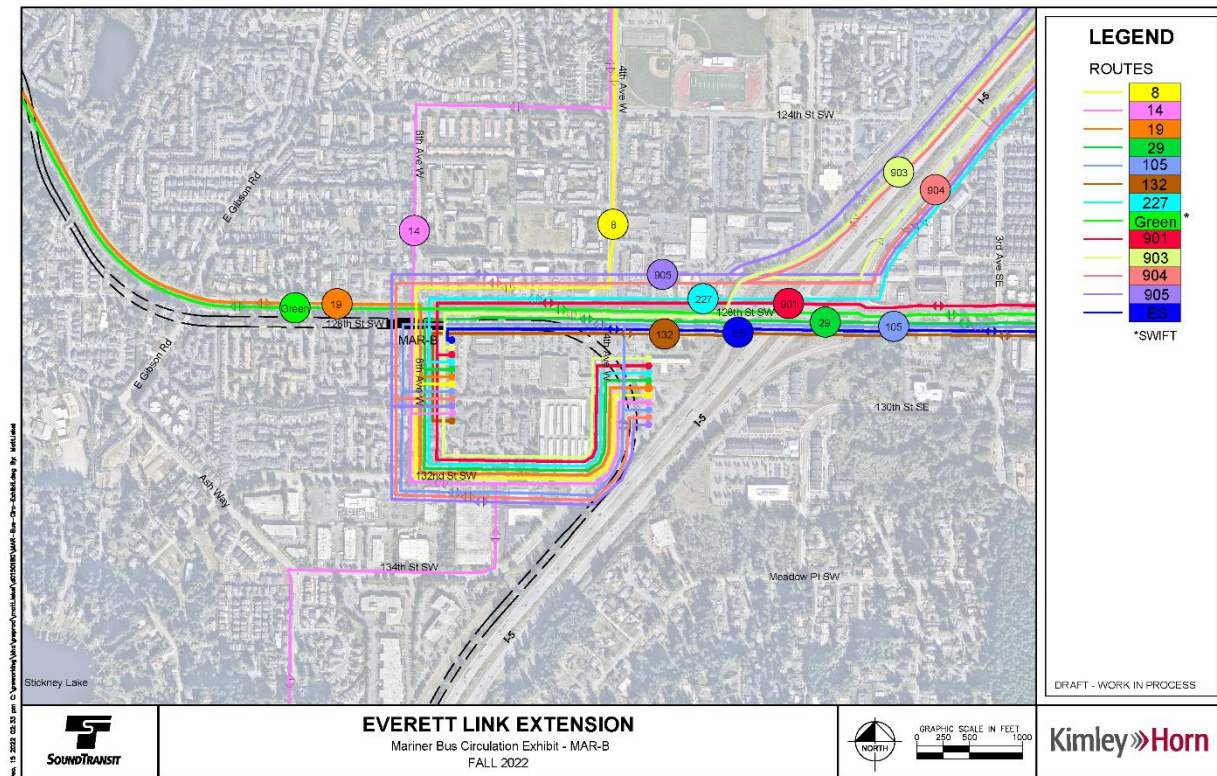


Figure 5-14 MAR-B Bus Routing Map

Quality and capacity of transfers

- All routes serve the station directly.
- All but *Swift* BRT Green Line are accessed via an off-street transit center.

Connectivity to high-capacity transit

- Transfers to *Swift* BRT Green Line are on-street.
- Some transfers may require crossing 128th Street SW.

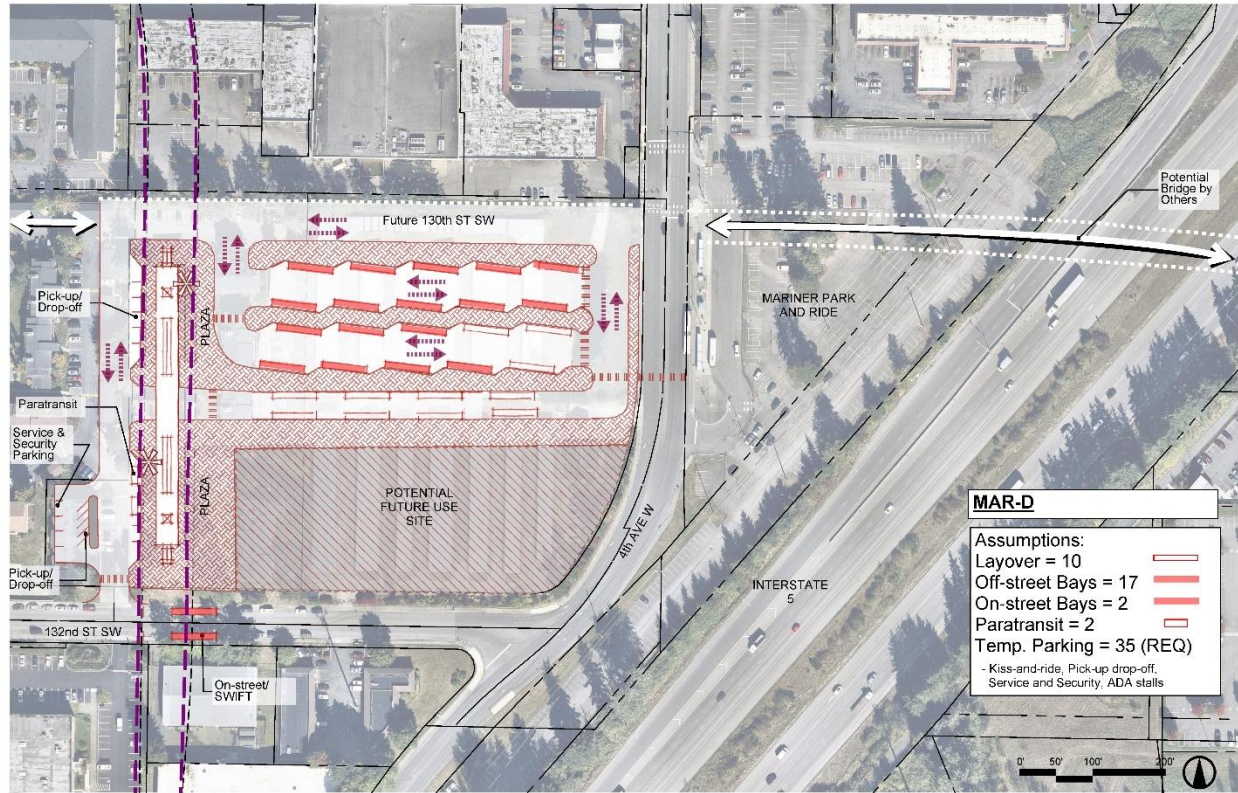
Quality of access for transit vehicles

- Most routes have minor diversion to access transit center, as there is no direct access for buses from 128th Street SW.
- Many routes will experience longer route to back-track to layover at Mariner Park-and-Ride.
- Transit center located approximately a half mile west of the interchange, used by many routes.

Planned level of bus service

- Peak 88 buses/hour (weekday).

5.3.3 MAR-D



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-15 MAR-D Station Access Facility Concept Map

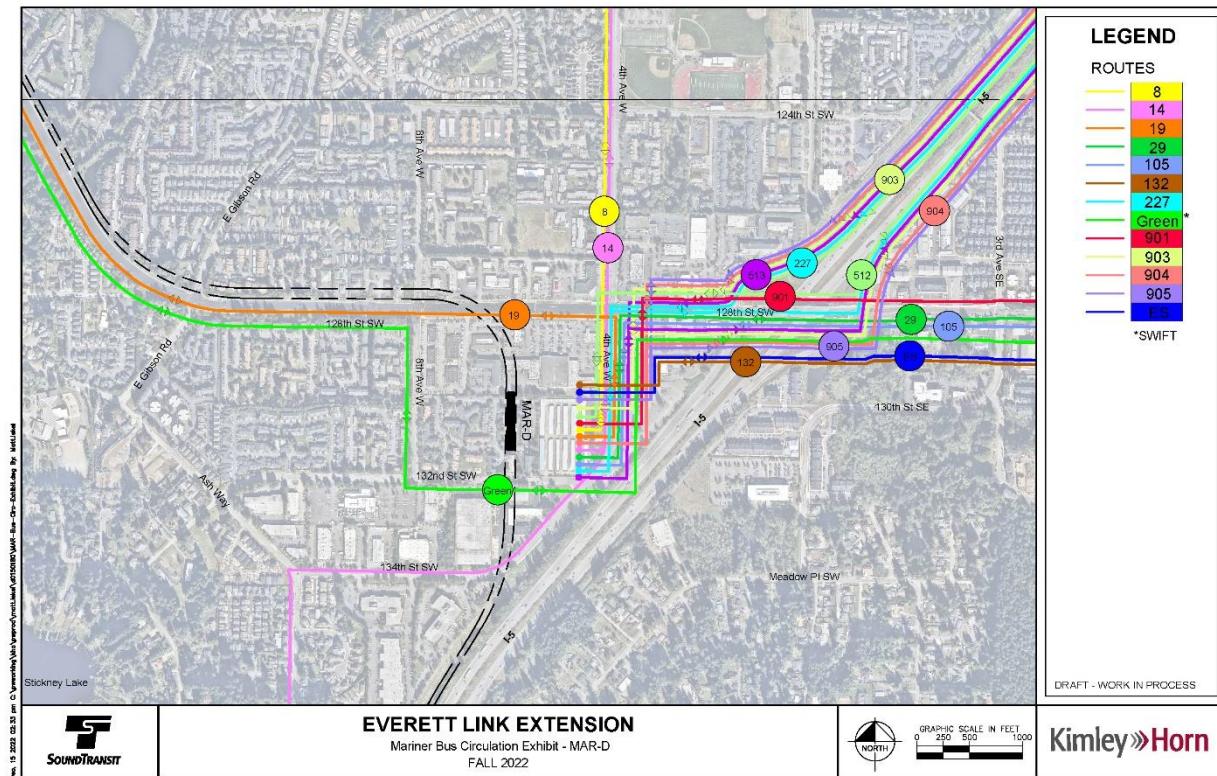


Figure 5-16 MAR-D (Without) Bus Routing Map

5.3.4 MAR-D (Without)

Quality and capacity of transfers.

- All routes serve station directly.
- All but *Swift* BRT Green Line are accessed via an off-street transit center.

Connectivity to high-capacity transit

- Transfers to modified *Swift* BRT Green Line on-street.
- Some transfers may require crossing 132nd Street SW.

Quality of access for transit vehicles

- Most routes have moderate diversion down 4th Avenue W to access transit center. Significant diversion for *Swift* BRT Green Line off 128th Street SW to 132nd Street SW.
- Proximity of park-and-ride allows for efficient layover access.
- Transit center is located approximately a third of a mile southwest of the interchange, used by many routes.

Planned level of bus service

- Peak 88 buses/hour (weekday).

5.3.5 MAR-D (With)

The “With” background improvements scenario assumes the addition of a new multimodal bridge crossing over I-5 to the south of 128th Street SW to extend 130th Street SW to 8th Avenue W. This new connection would be utilized by bus routes traveling between the station and east of I-5, allowing buses to bypass congestion on 128th Street SW at the I-5 interchange.

Quality and capacity of transfers

- All routes serve station directly.
- All but *Swift* BRT Green Line are accessed via an off-street transit center.

Connectivity to high-capacity transit

- Transfers to modified *Swift* BRT Green Line on-street. Some transfers may require crossing 132nd Street SW.

Quality of access for transit vehicles

- Most routes have moderate diversion down 4th Ave W to access transit center. *Swift* BRT Green Line may be able to efficiently serve station by using 130th Street and continuing on new bridge across I-5.
- Proximity of park-and-ride allows for efficient layover access.
- Transit center located approximately a third of a mile southwest of the interchange, used by many routes.

Planned level of bus service

- Peak 88 buses/hour (weekday).

5.4 SR 99/Airport Road

5.4.1 AIR-A

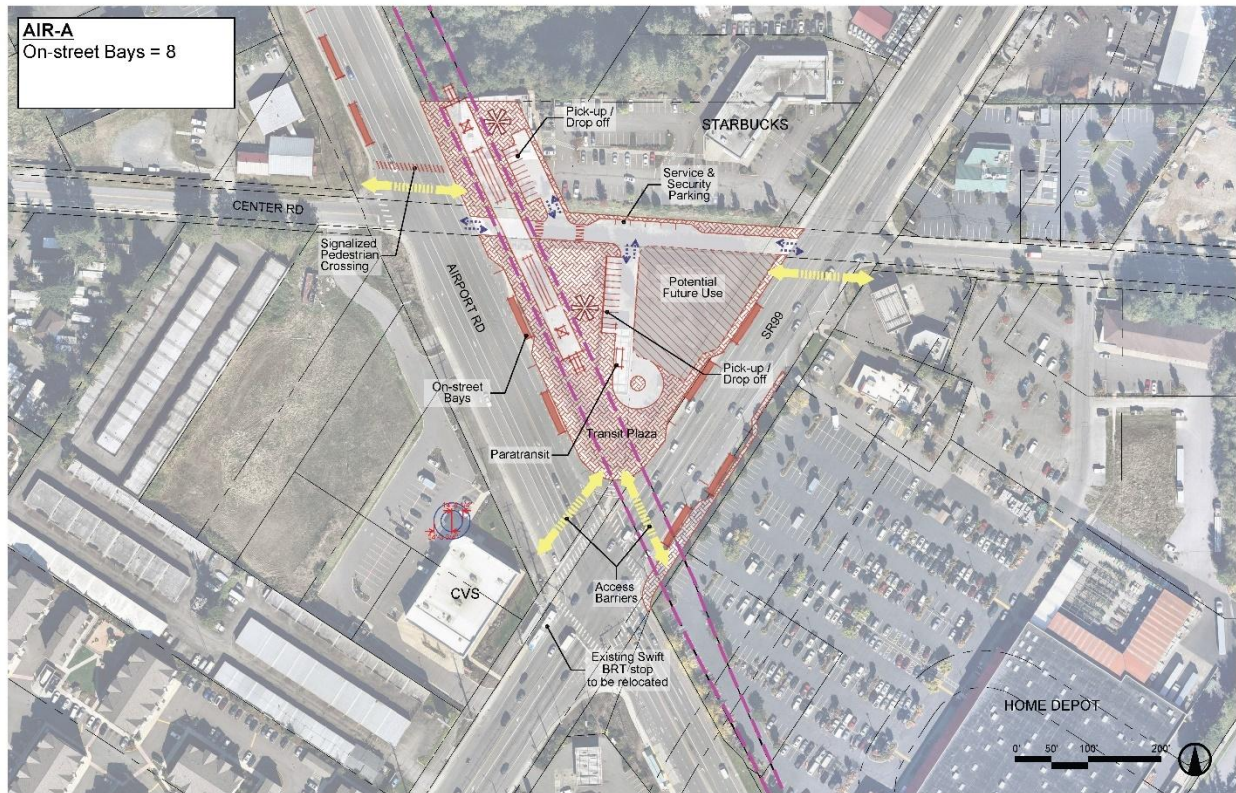


Figure 5-17 AIR-A Station Access Facility Concept Map

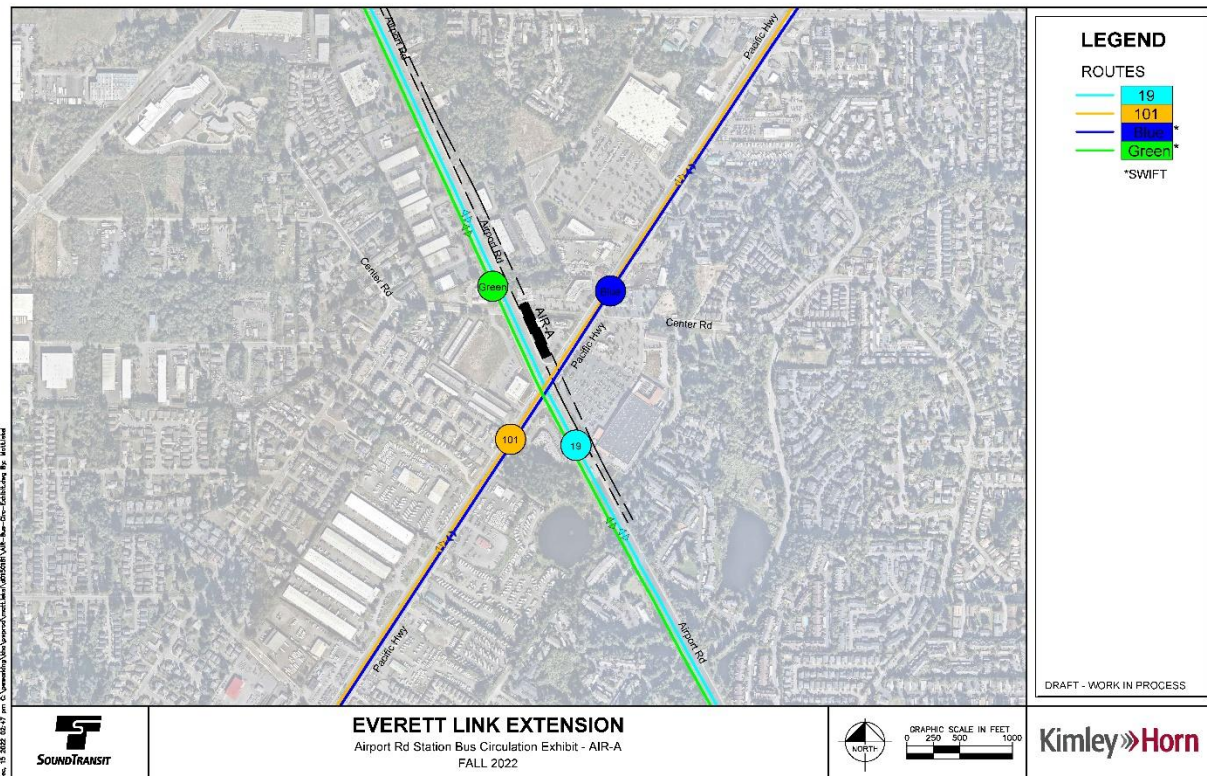


Figure 5-18 AIR-A Bus Routing Map

Quality and capacity of transfers

- Allows for connections to routes on both Airport Road and SR 99. Requires transfers across Airport Road or SR 99 for one direction of travel for all routes. No transfers require crossing both streets.
- Both arterial roadways are major barriers to access with long crossing distances.

Connectivity to high-capacity transit

- Direct connection to *Swift* BRT Green Line traveling northbound.
- Transfer for *Swift* BRT Green Line traveling southbound requires crossing SR 99 and Airport Road.
- Direct connection to *Swift* BRT Blue Line traveling southbound via relocated station, but northbound connections require crossing SR 99.

Quality of access for transit vehicles

- No deviation required.
- Stop placement impacted by intersection geometry.

Planned level of bus service

- Peak 38 buses/hour (weekday).

5.4.2 AIR-B

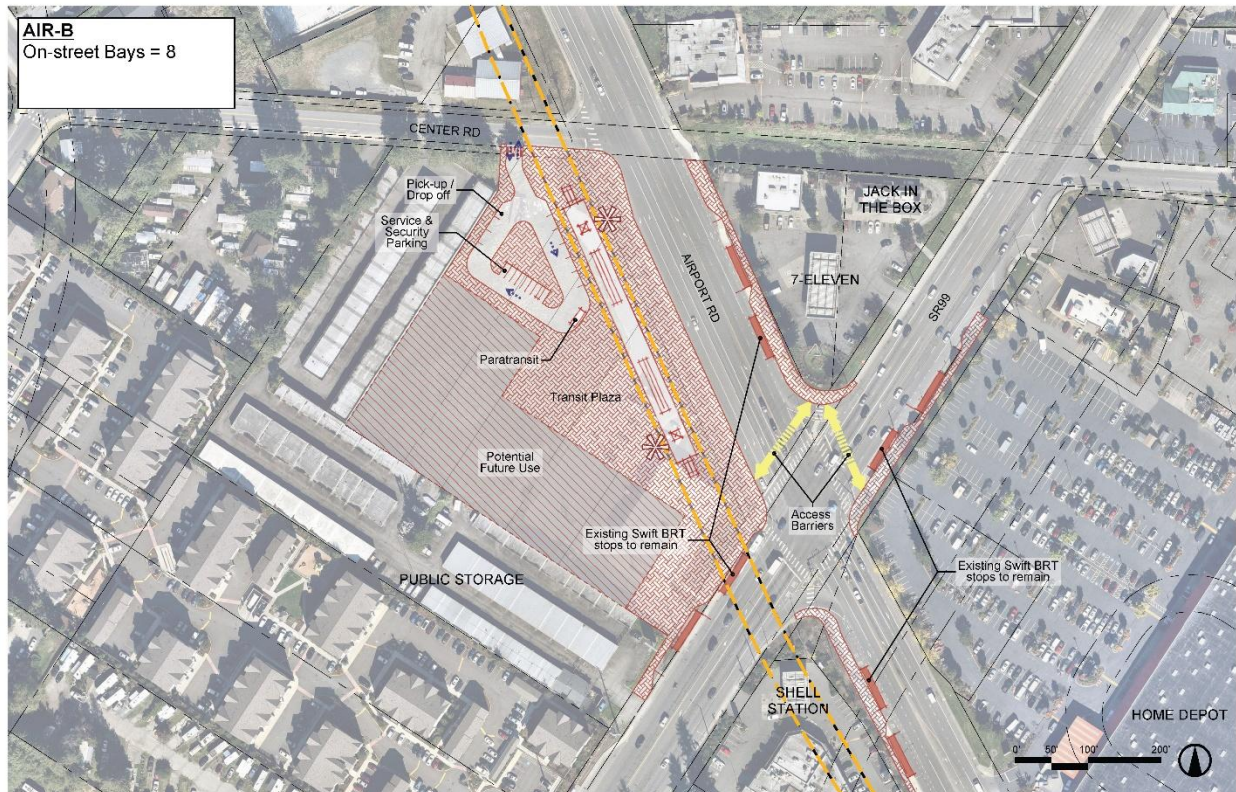


Figure 5-19 AIR-B Station Access Facility Concept Map

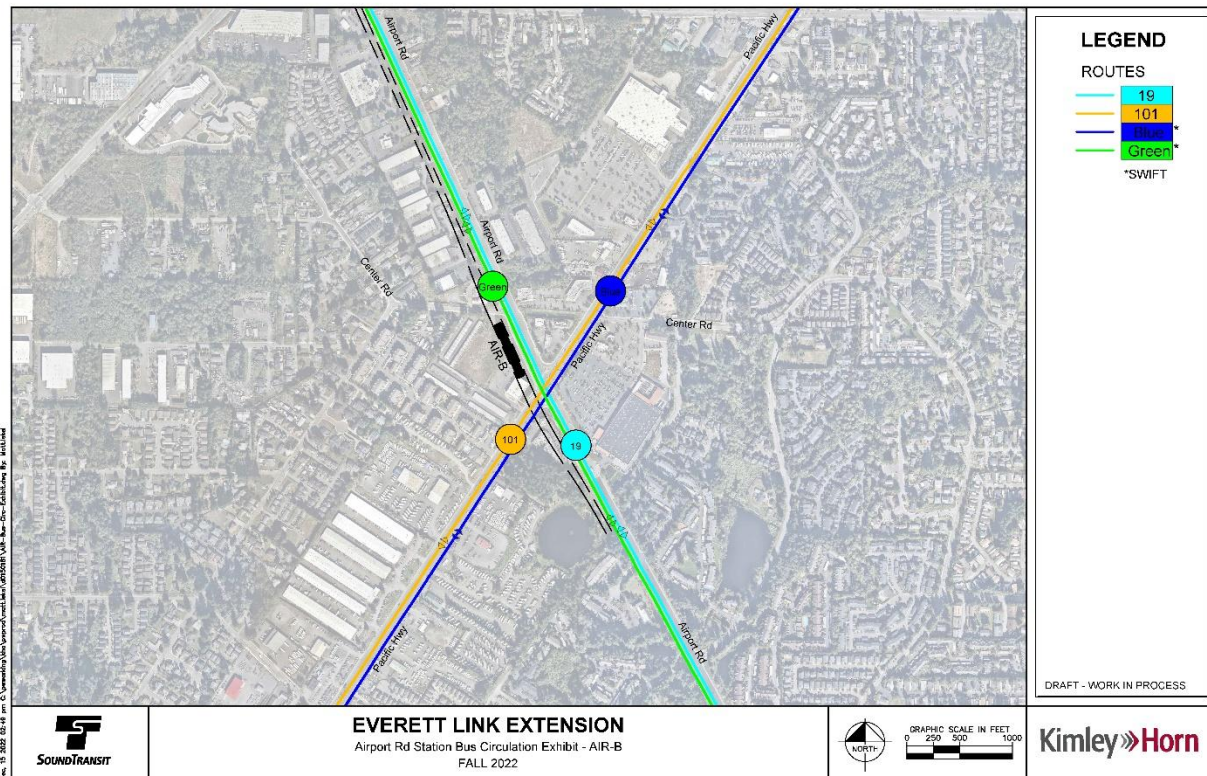


Figure 5-20 AIR-B Bus Routing Map

Quality and capacity of transfers

- Allows for connections to routes on both Airport Road and SR 99.
- Requires transfers across Airport Road and/or SR 99 for one direction of travel for all routes.
- Both arterial roadways are major barriers to access with long crossing distances.

Connectivity to high-capacity transit

- Transfer for *Swift* BRT Green Line traveling southbound requires crossing SR 99.
- Transfer to *Swift* BRT Green Line traveling northbound requires crossing Airport Road. Direct connection to *Swift* BRT Blue Line traveling southbound, but northbound connections require crossing Airport Road and SR 99.

Quality of access for transit vehicles

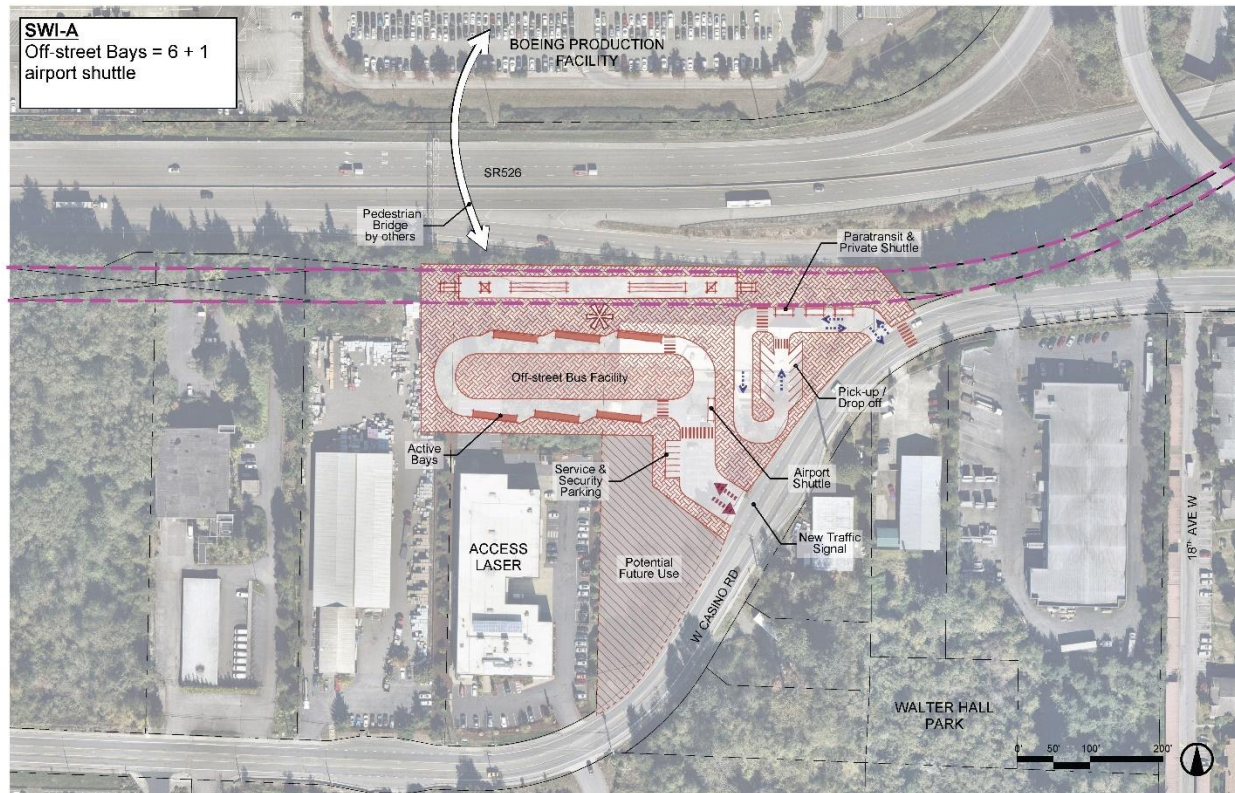
- No deviation required.

Planned level of bus service

- Peak 38 buses/hour (weekday).

5.5 SW Everett Industrial Center

5.5.1 SWI-A



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-21 SWI-A Station Access Facility Concept Map

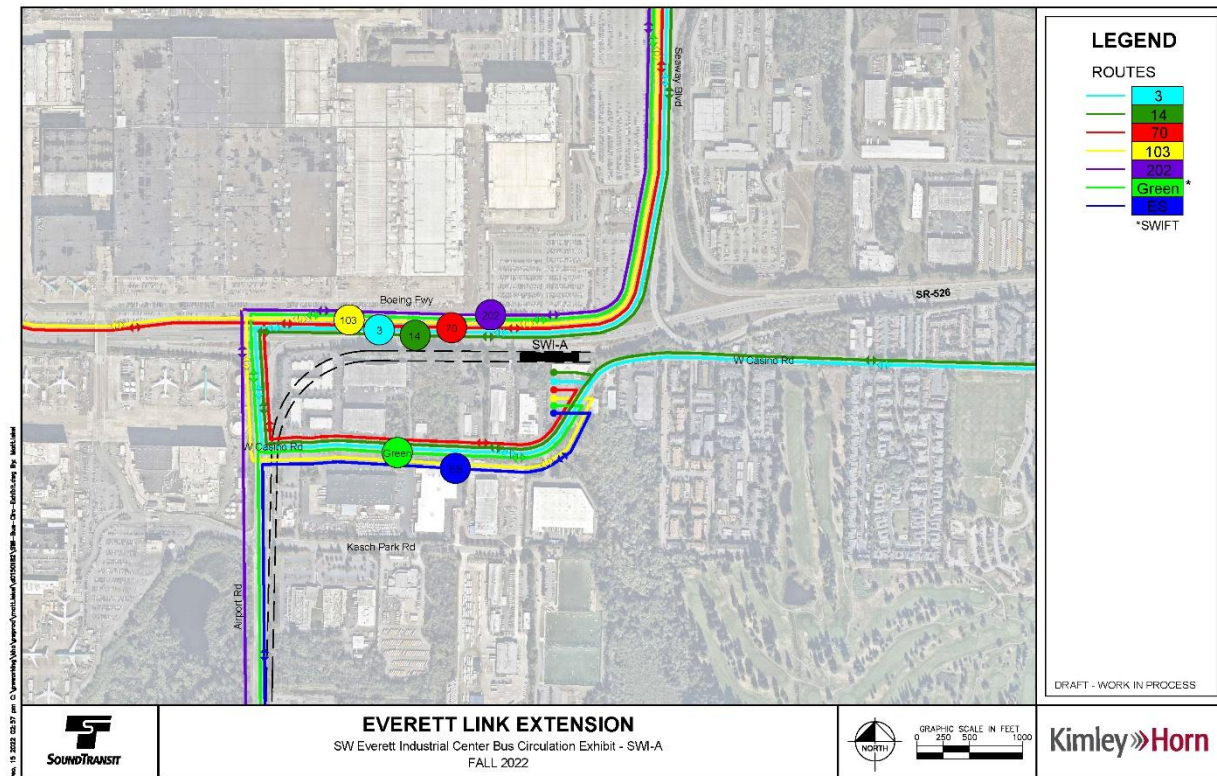


Figure 5-22 SWI-A Bus Routing Map

Quality and capacity of transfers

- Six routes serve station directly via an off-street transit center facility.

Connectivity to high-capacity transit

- Direct connection to modified *Swift* BRT Green Line service.

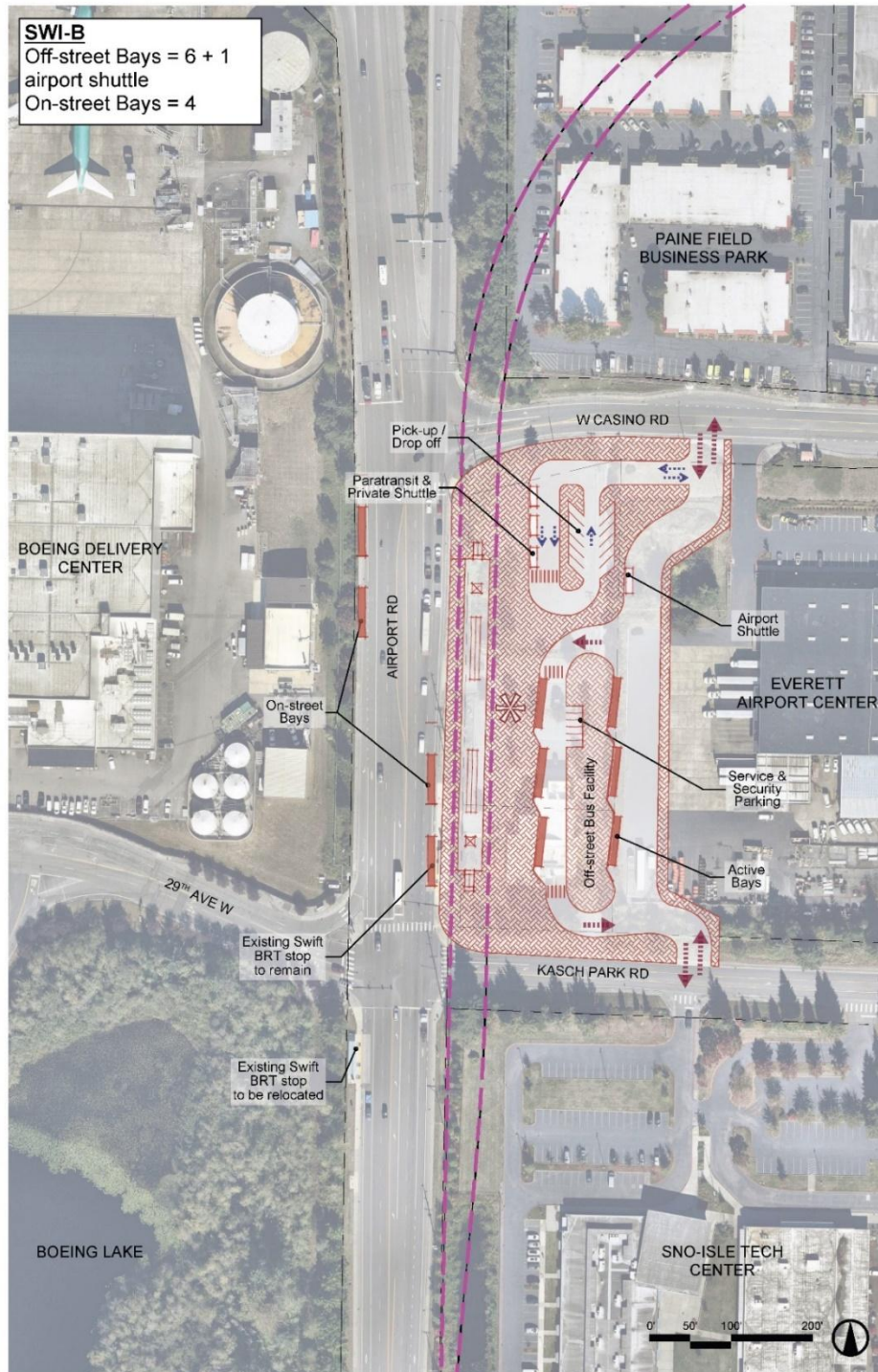
Quality of access for transit vehicles

- Significant diversion for most routes, including *Swift* BRT Green Line, from baseline to access station.
- Inefficient routing to access both this station and Seaway Transit Center.

Planned level of bus service

- Peak 39 buses/hour (weekdays) (excluding Boeing shuttles).

5.5.2 SWI-B



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-23 SWI-B Station Access Facility Concept Map

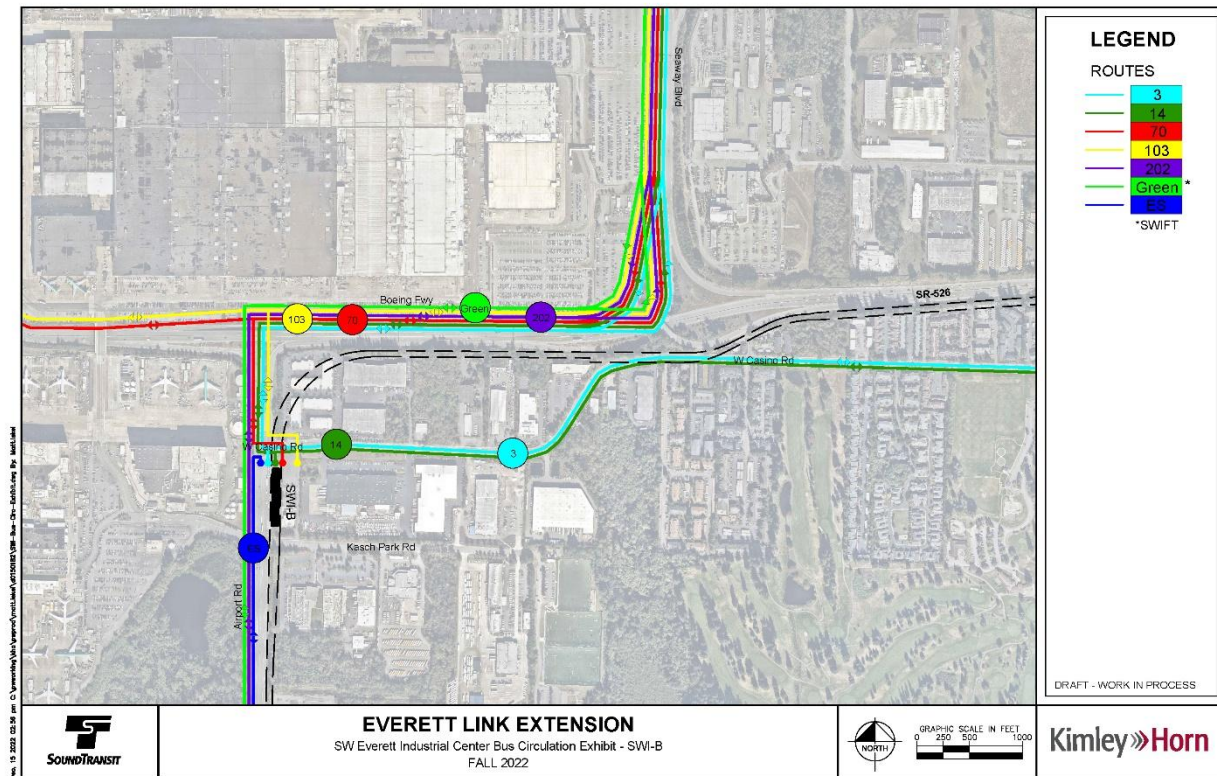


Figure 5-24 SWI-B Bus Routing Map

Quality and capacity of transfers

- Seven routes serve the station directly via an off-street transit center facility.

Connectivity to high-capacity transit

- Direct connection to *Swift* BRT Green Line service. Some transfers may require crossing Airport Road.

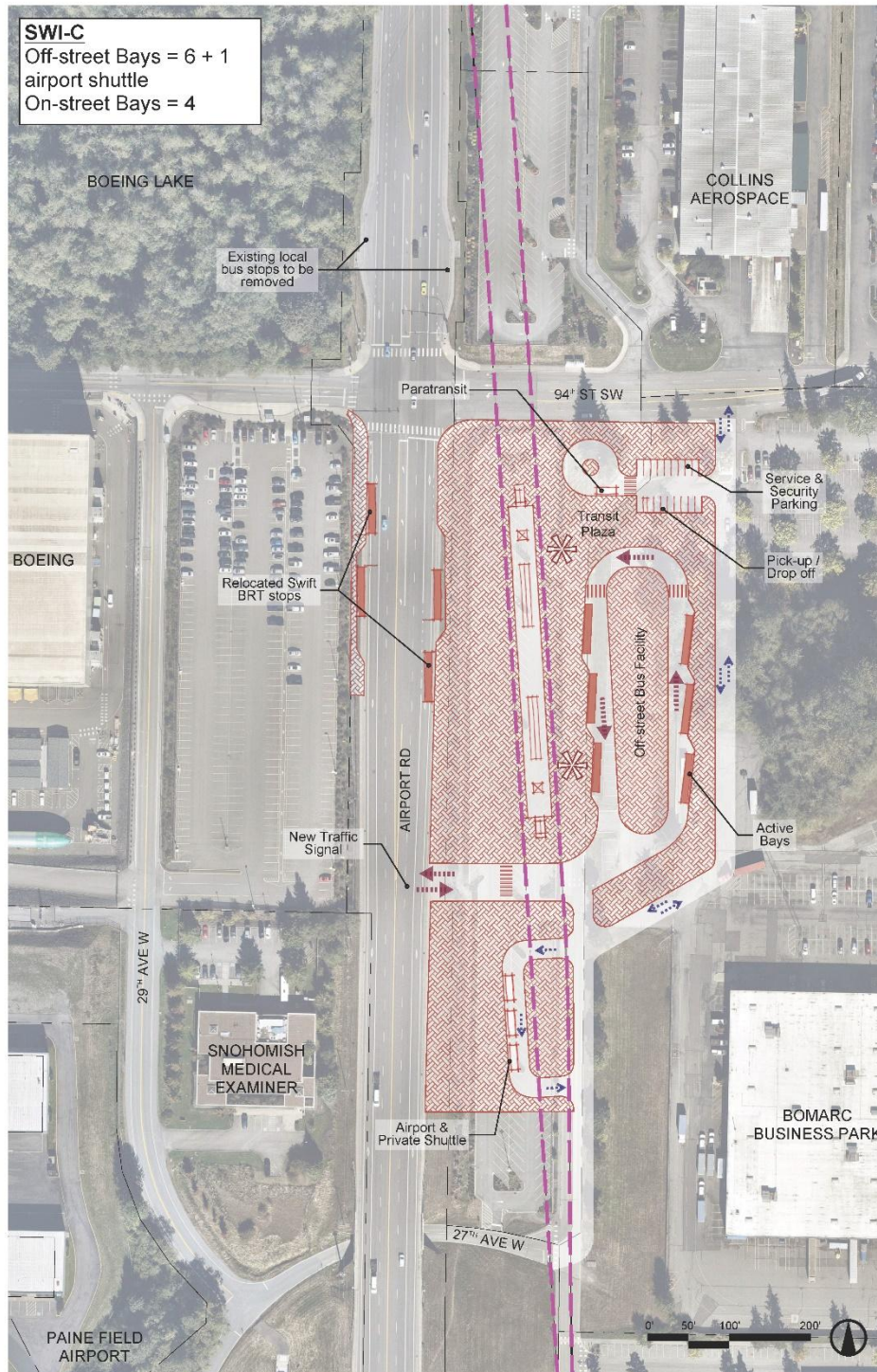
Quality of access for transit vehicles

- Moderate diversion for two routes from baseline to access station.
- Some routes could remain on Airport Road to minimize time penalty for serving station.

Planned level of bus service

- Peak 43 buses/hour (weekdays) (excluding Boeing shuttles).

5.5.3 SWI-C



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-25 SWI-C Station Access Facility Concept Map

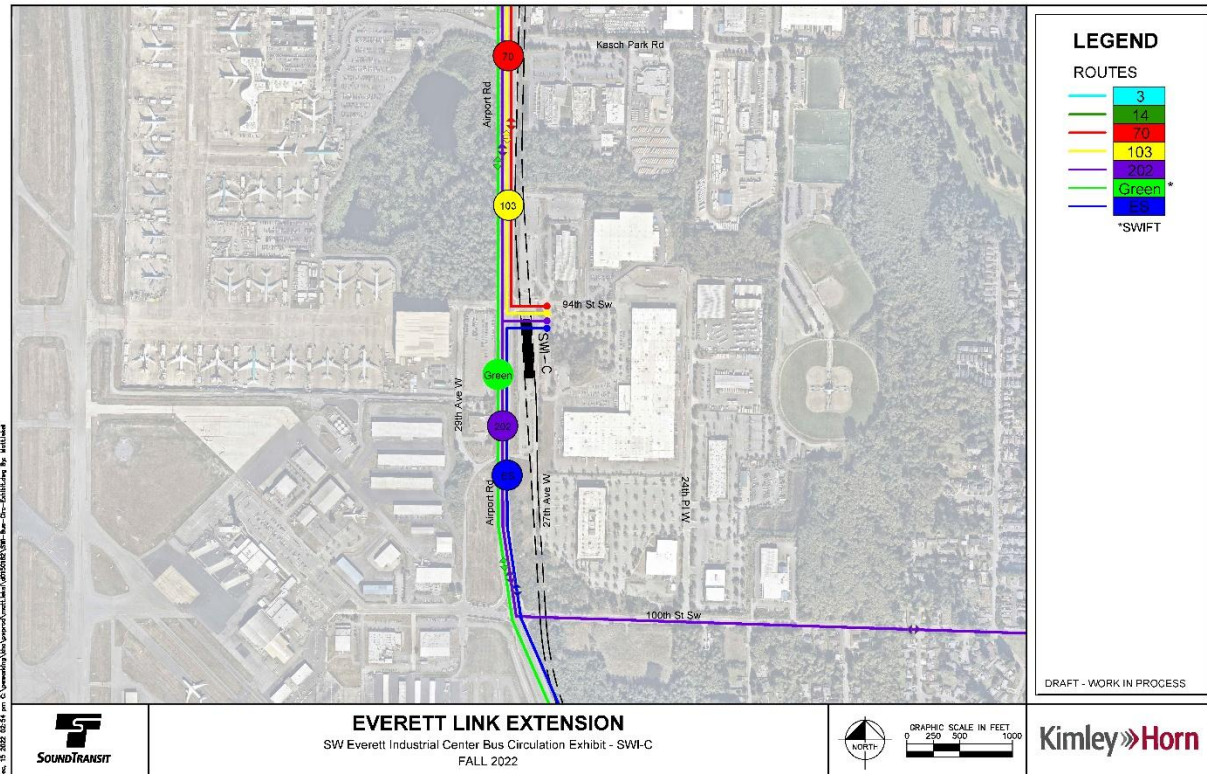


Figure 5-26 SWI-C Bus Routing Map

Quality and capacity of transfers

- Five routes serve station directly via an off-street transit center.

Connectivity to high-capacity transit

- Direct connection to *Swift* BRT Green Line service. Some transfers may require crossing Airport Road.

Quality of access for transit vehicles

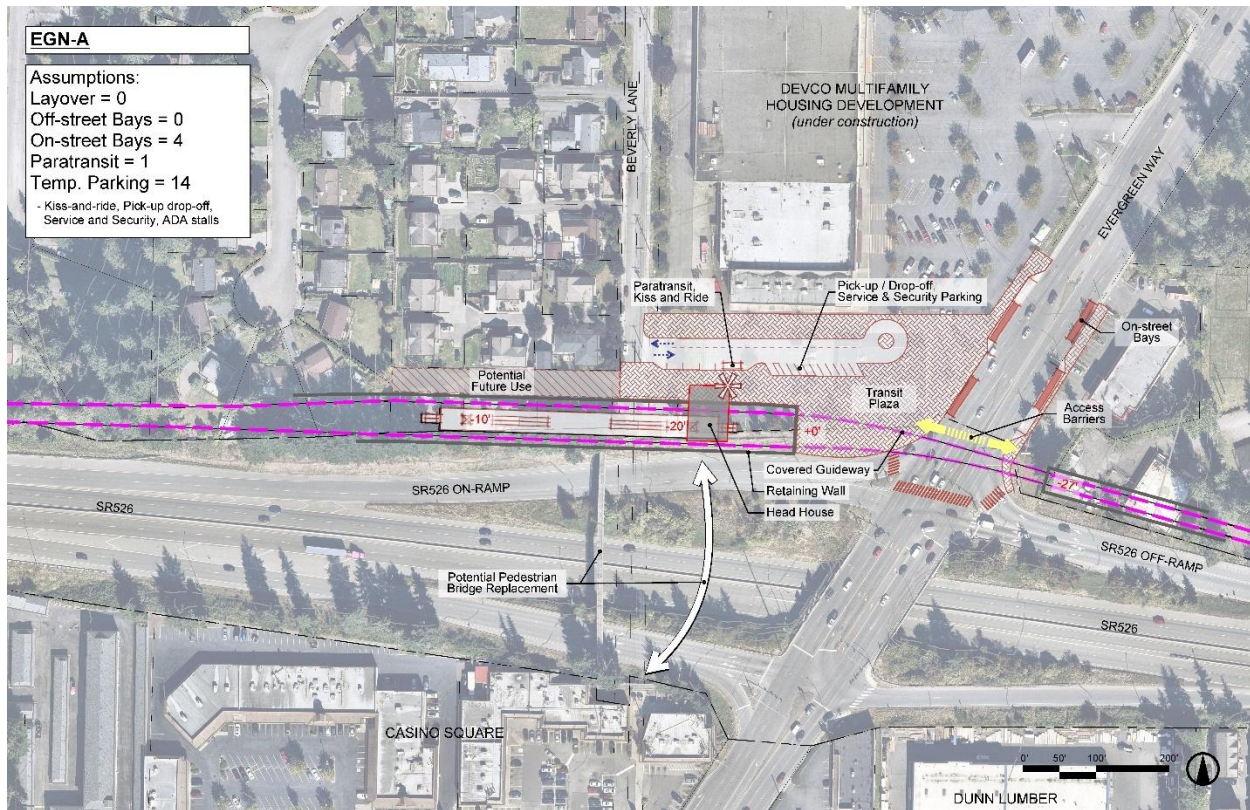
- Significant diversion for two routes from baseline to access station.
- Some routes could remain on Airport Road to minimize time penalty for serving station.

Planned level of bus service

- Peak 27 buses/hour (weekdays) (excluding Boeing shuttles).

5.6 SR 526/Evergreen

5.6.1 EGN-A



*Note: Additional bus bays (not depicted within figure viewport) along Casino Road
 Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.*

Figure 5-27 EGN-A Station Access Facility Concept Map

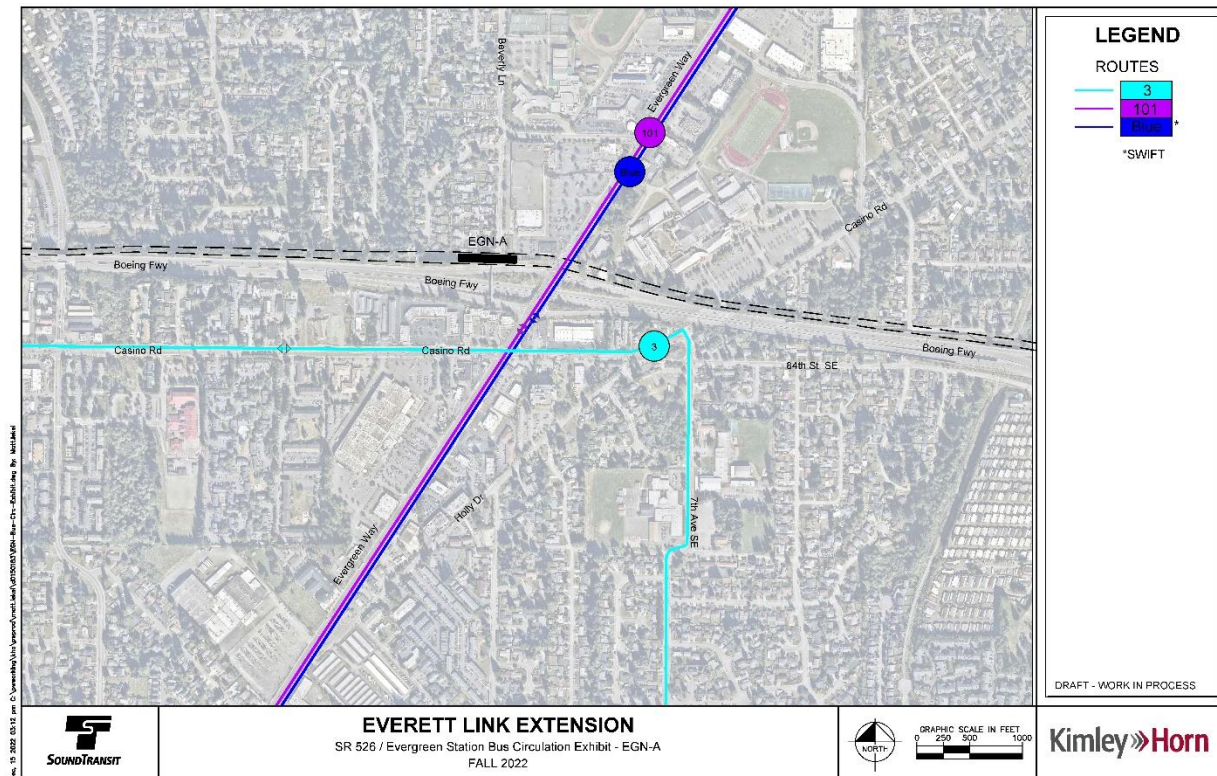


Figure 5-28 EGN-A Bus Routing Map

Quality and capacity of transfers

- Transfers to all routes require moderate to long walking distance.
- Some transfers require crossing SR 526 via pedestrian overcrossing.
- Evergreen Way is a major barrier to accessing northbound bus stops, including *Swift* BRT Blue Line.

Connectivity to high-capacity transit

- Connection to *Swift* BRT Blue Line on Evergreen Way.
- Requires crossing Evergreen Way to access northbound *Swift* BRT Blue Line station.

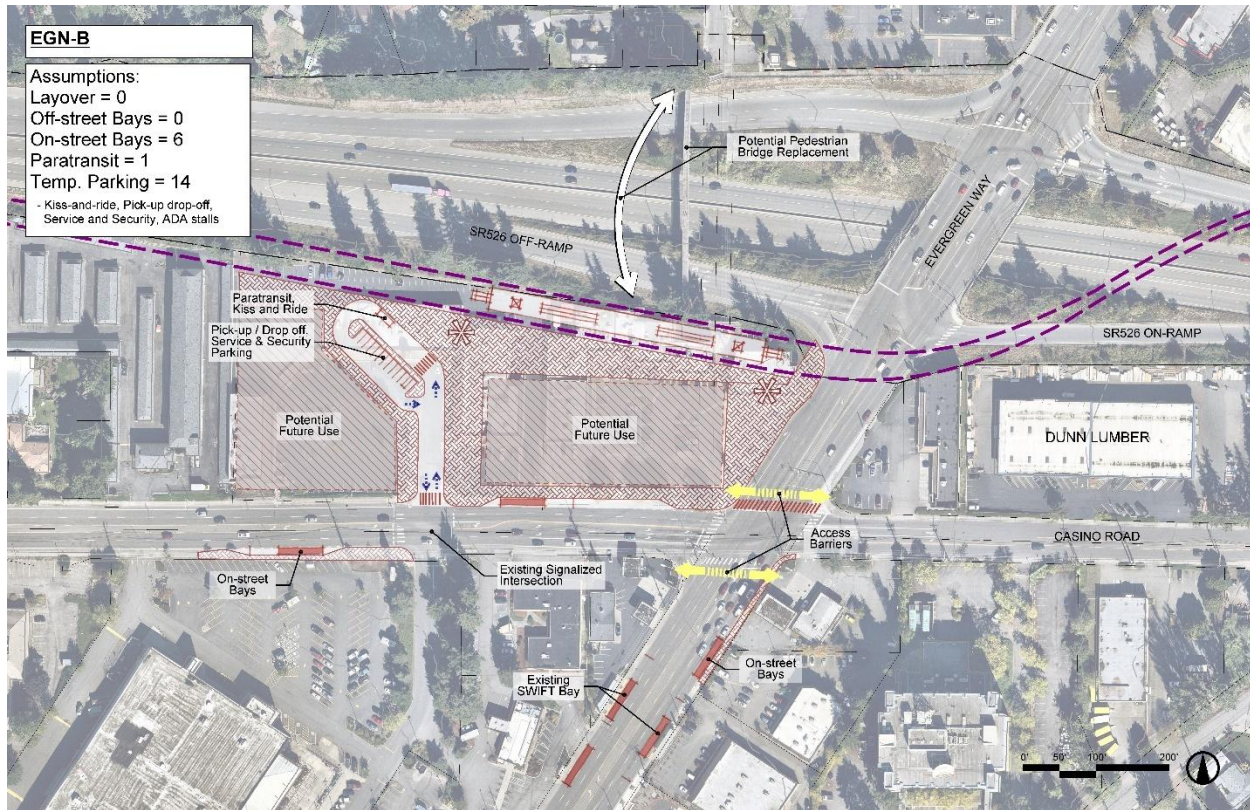
Quality of access for transit vehicles

- No route diversion proposed.
- Some stops would be relocated north of SR 526 to accommodate transfers.

Planned level of bus service

- Peak 28 buses/hour (weekday), including longer transfer distances.

5.6.2 EGN-B



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-29 EGN-B Station Access Facility Concept Map

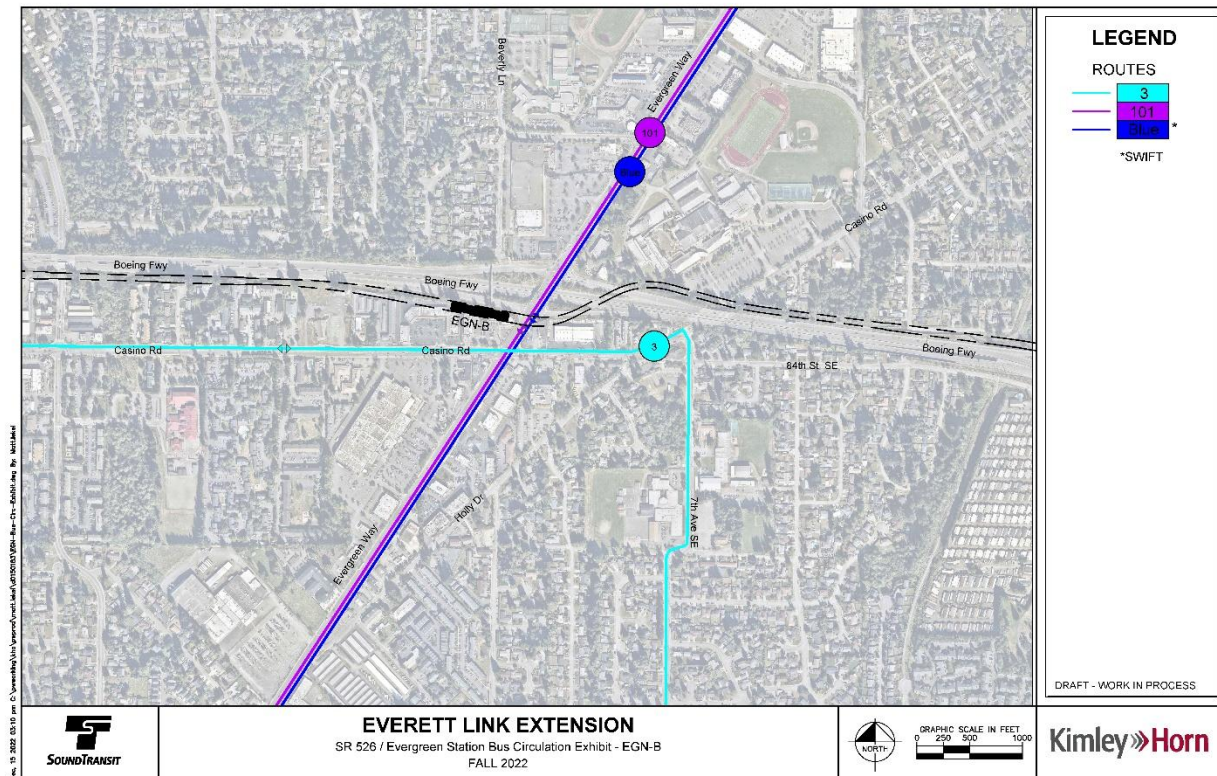


Figure 5-30 EGN-B Bus Routing Map

Quality and capacity of transfers

- Transfers to all routes on Evergreen Way require crossing Casino Road.
- Evergreen Way is a major barrier to accessing northbound bus stops, including *Swift* BRT Blue Line.

Connectivity to high-capacity transit

- Connection to *Swift* BRT Blue Line on Evergreen Way.
- Requires crossing Evergreen Way and Casino Road to access northbound *Swift* BRT Blue Line station and crossing Casino Road to access southbound *Swift* BRT Blue Line station.

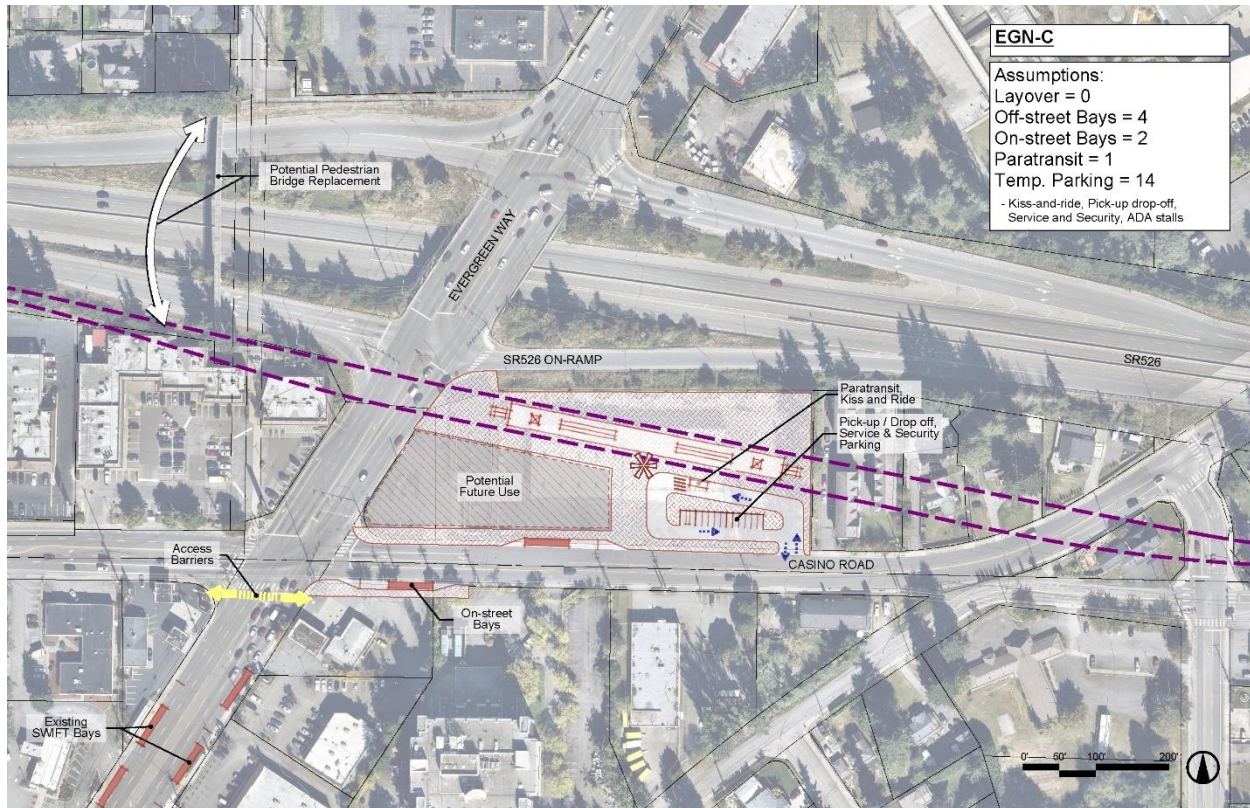
Quality of access for transit vehicles

- No route diversion proposed.
- No stop relocations.

Planned level of bus service

- Peak 28 buses/hour (weekday).

5.6.3 EGN-C



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-31 EGN-C Station Access Facility Concept Map

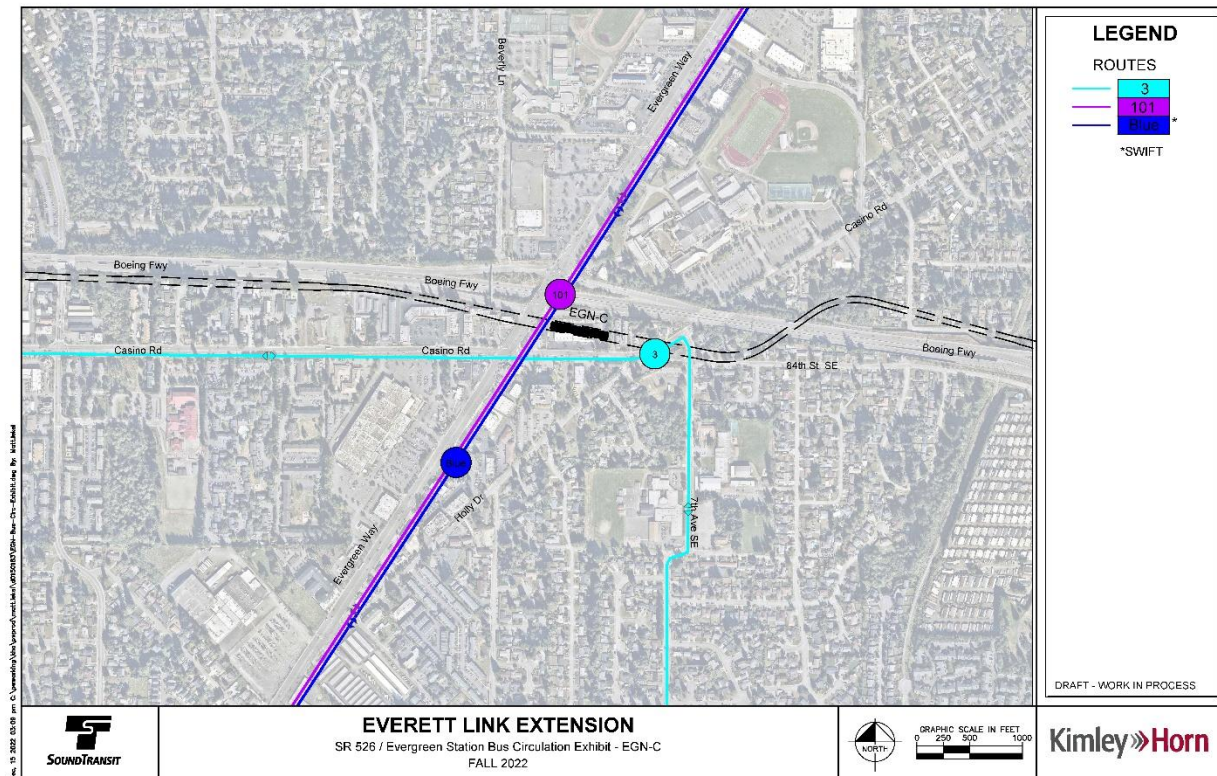


Figure 5-32 EGN-C Bus Routing Map

Quality and capacity of transfers

- Transfers to all routes on Evergreen require crossing Casino Road.
- Evergreen Way is a major barrier to accessing southbound bus stops, including *Swift* BRT Blue Line.

Connectivity to high-capacity transit

- Connection to *Swift* BRT Blue Line on Evergreen Way.
- Requires crossing Evergreen Way and Casino Road to access southbound *Swift* BRT Blue Line station and crossing Casino Road to access northbound *Swift* BRT Blue Line station.

Quality of access for transit vehicles

- No route diversion proposed.
- No stop relocations.

Planned level of bus service

- Peak 28 buses/hour (weekday).

5.6.4 EGN-D

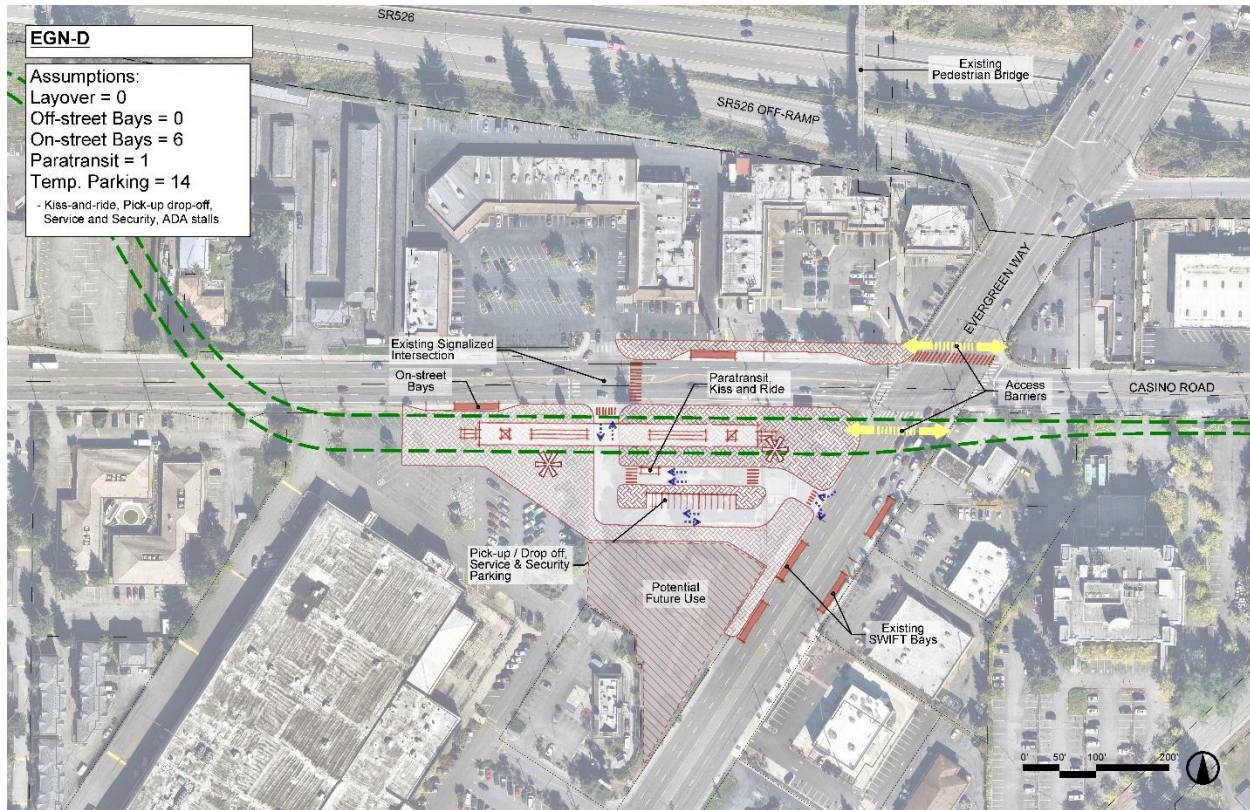


Figure 5-33 EGN-D Station Access Facility Concept Map

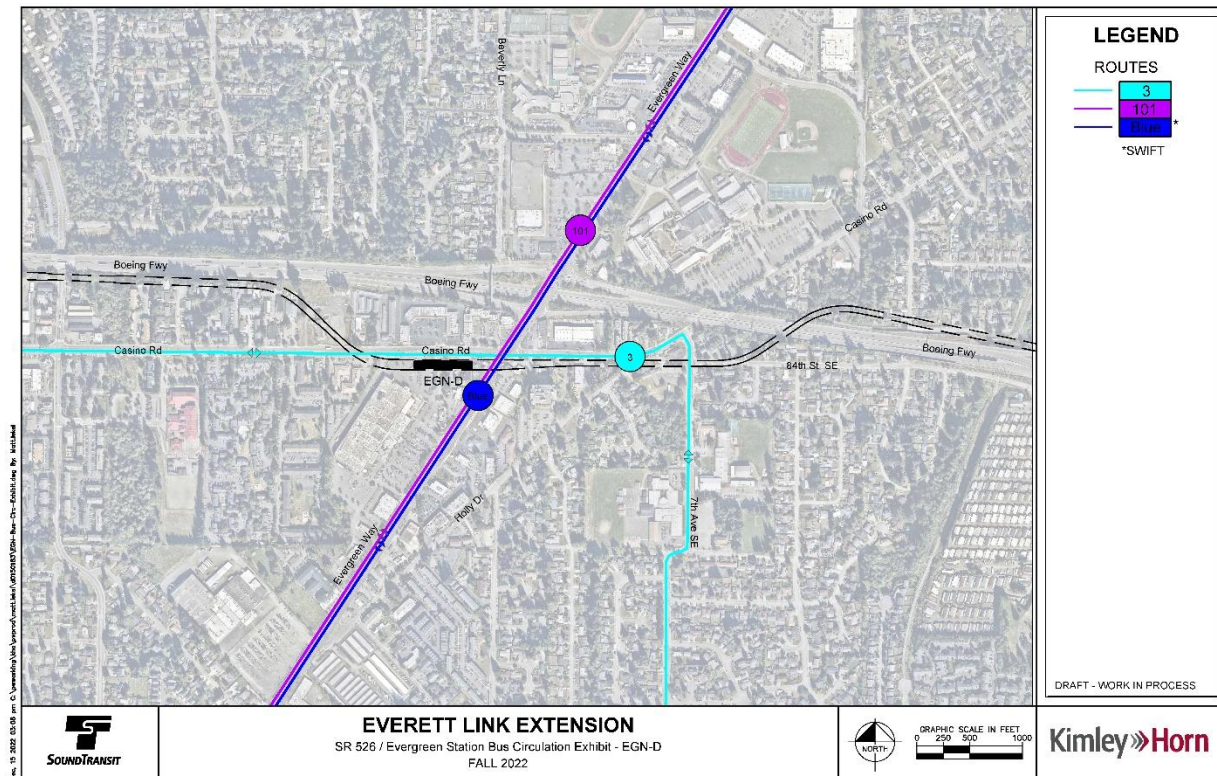


Figure 5-34 EGN-D Bus Routing Map

Quality and capacity of transfers

- Evergreen Way is a major barrier to accessing northbound bus stops, including *Swift* BRT Blue Line

Connectivity to high-capacity transit

- Connection to *Swift* BRT Blue Line on Evergreen Way.
- Requires crossing Evergreen Way to access northbound *Swift* BRT Blue Line station.

Quality of access for transit vehicles

- No route diversion proposed.
- No stop relocations.

Planned level of bus service

- Peak 28 buses/hour (weekday).

5.6.5 EGN-E

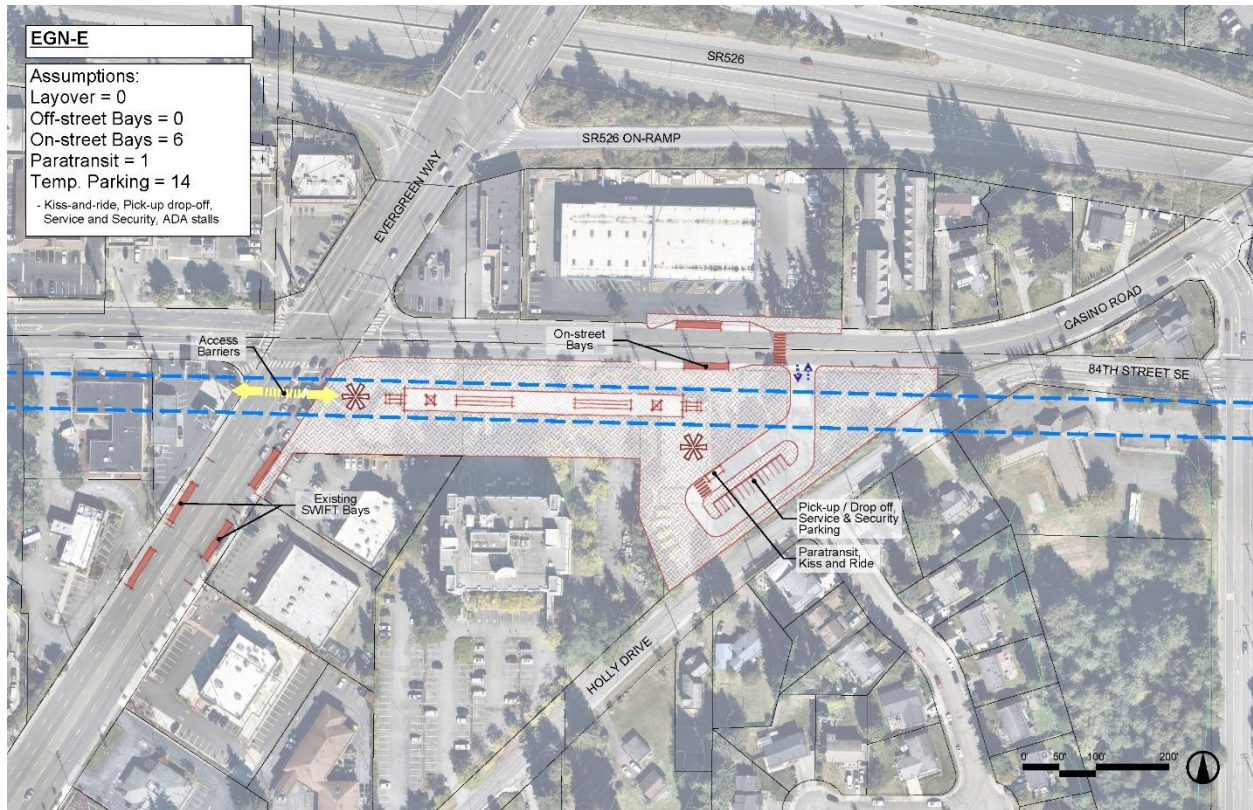


Figure 5-35 EGN-E Station Access Facility Concept Map

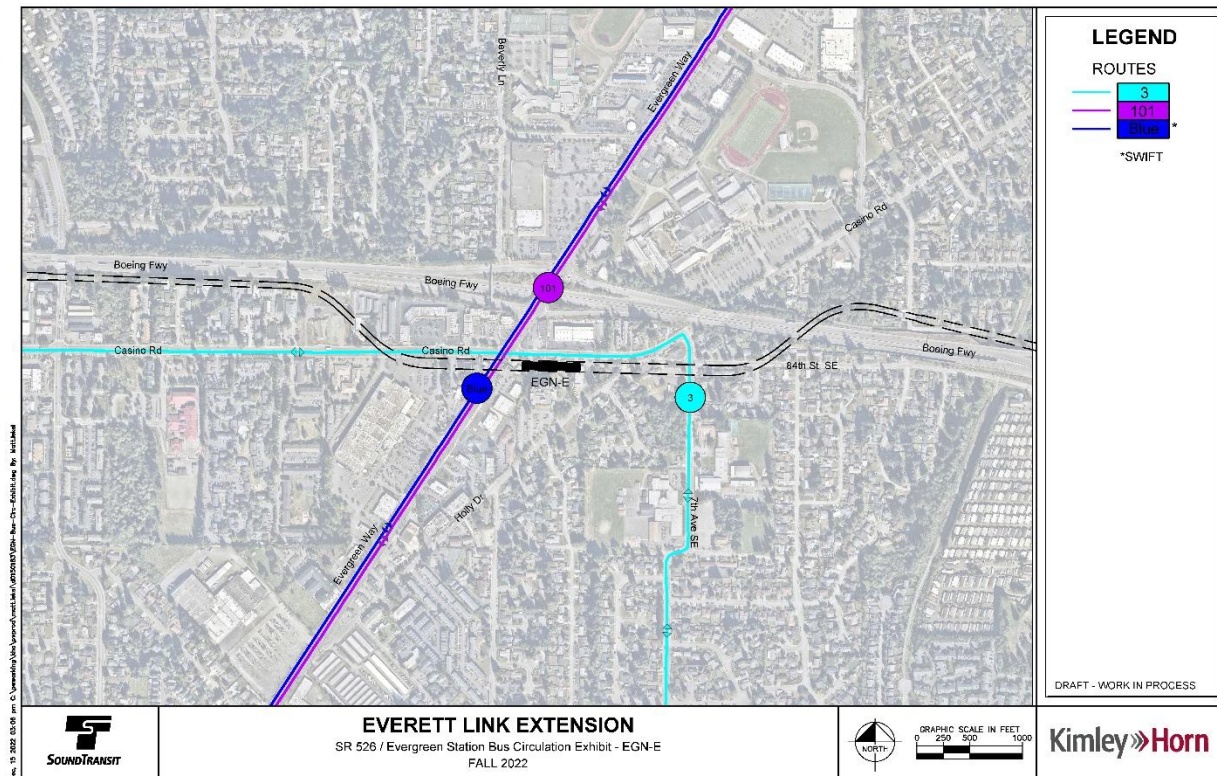


Figure 5-36 EGN-E Bus Routing Map

Quality and capacity of transfers

- Evergreen Way is a major barrier to accessing southbound bus stops, including *Swift* BRT Blue Line.

Connectivity to high-capacity transit

- Connection to *Swift* BRT Blue Line on Evergreen Way.
- Requires crossing Evergreen Way to access southbound *Swift* BRT station.

Quality of access for transit vehicles

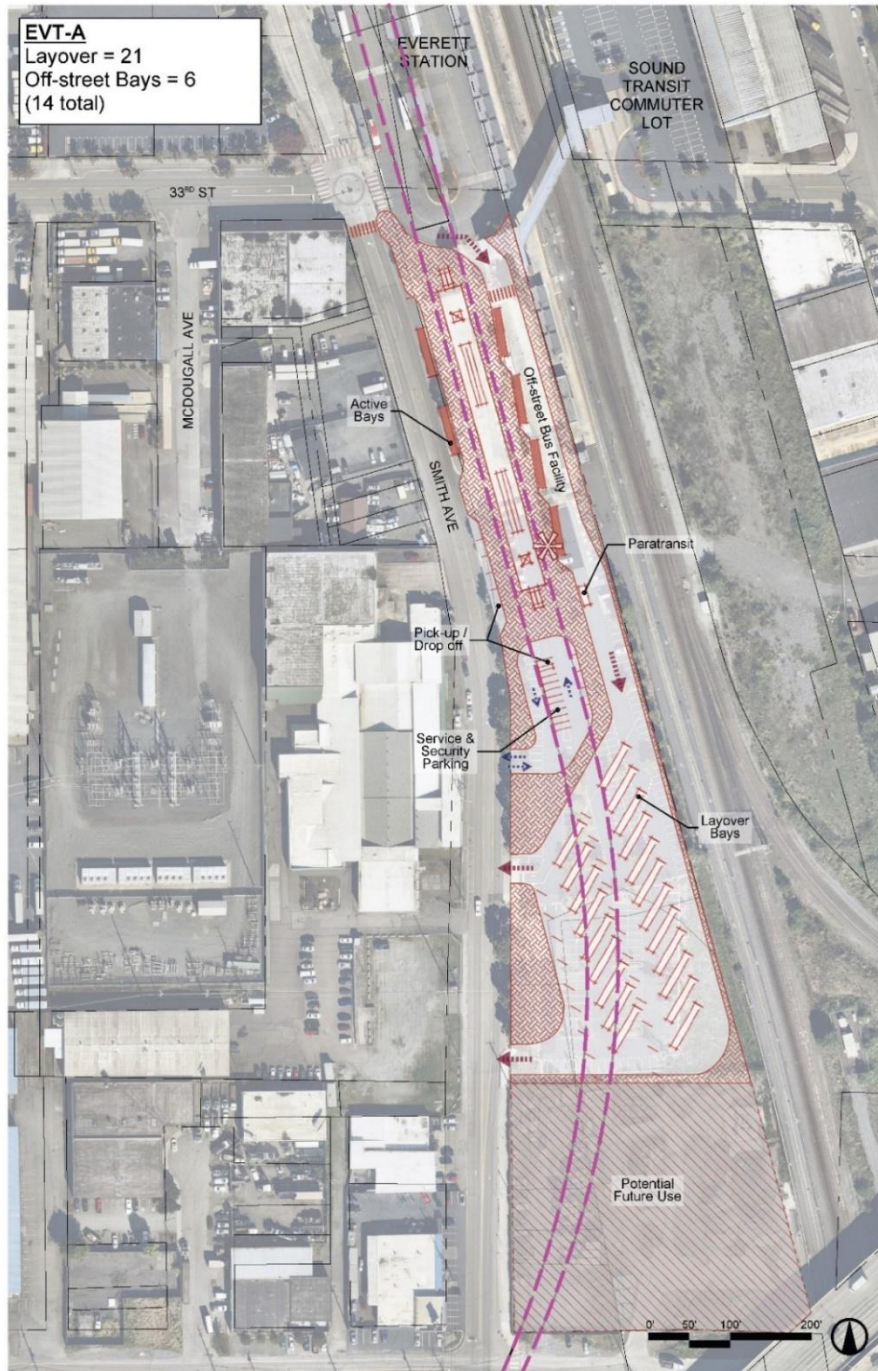
- No route diversion proposed.
- No stop relocations.

Planned level of bus service

- Peak 28 buses/hour (weekday).

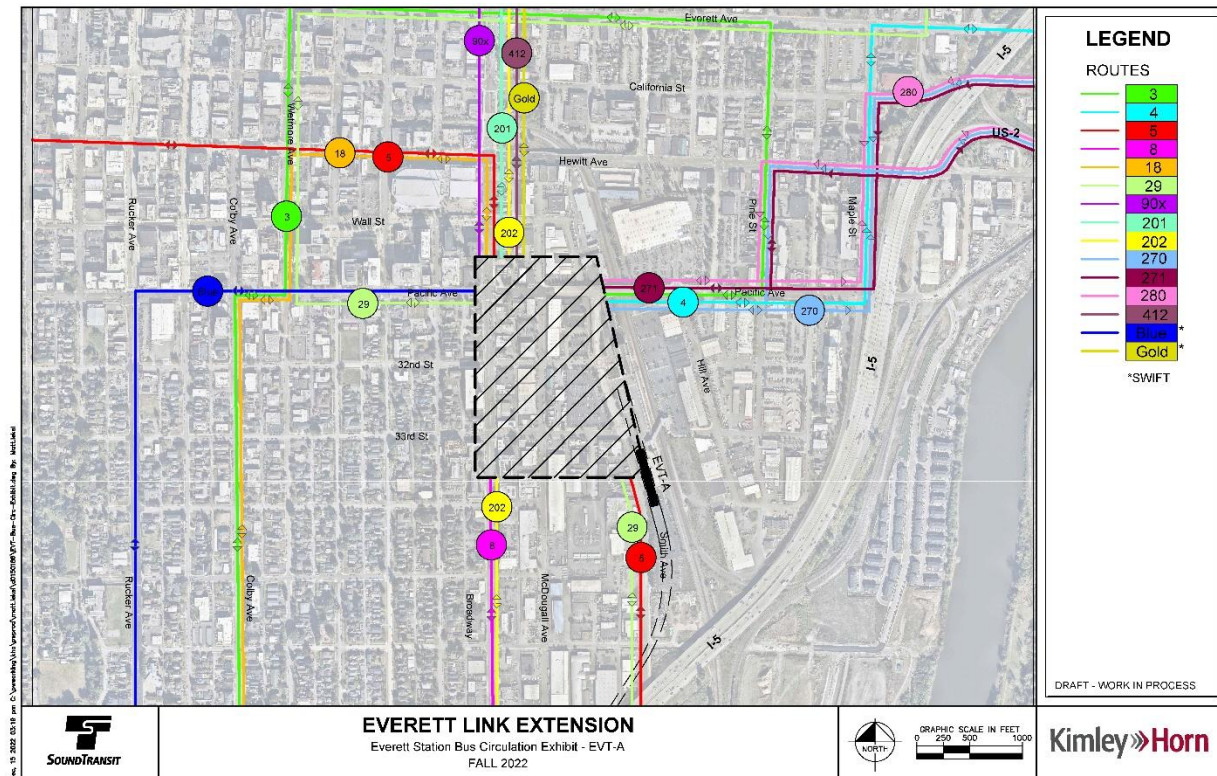
5.7 Everett Station

5.7.1 EVT-A



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2.

Figure 5-37 EVT-A Station Access Facility Concept Map



Note: Hatched area represents immediate station vicinity where bus routing is dependent on specific bay assignment, which is not yet determined

Figure 5-38 EVT-A Bus Routing Map

Quality and capacity of transfers

- All routes would stop at adjacent off-street transit center or adjacent on-street bays.
- Additional bus bay capacity would be added to existing facilities.

Connectivity to high-capacity transit

- Direct connection to the *Swift* BRT Blue Line and planned *Swift* BRT Gold Line.
- Direct connection to Sounder and Amtrak at Everett Station.

Quality of access for transit vehicles

- Similar to the existing bus terminal at Everett Station with no new diversions.
- Existing bus terminal access at Everett Station allows for easy access and circulation for transit vehicles.

Planned level of bus service

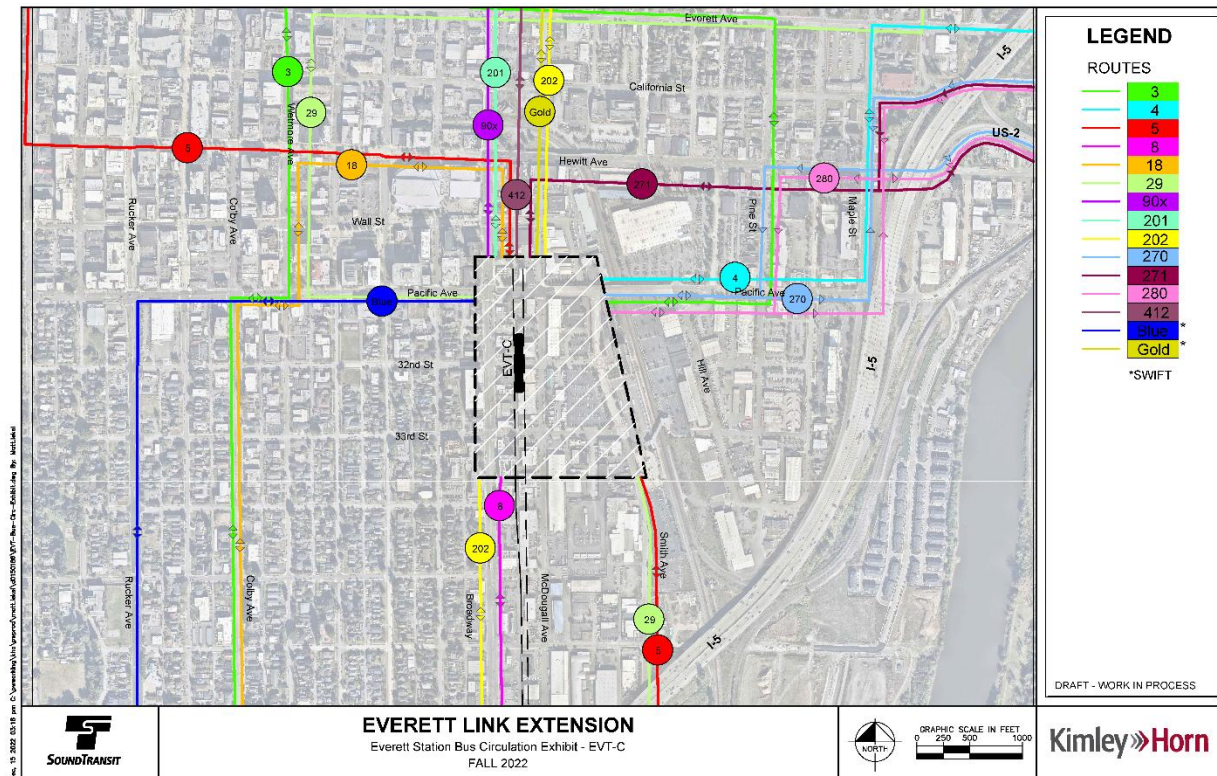
- Peak 49 buses/hour (weekday).

5.7.2 EVT-C



Figure 5-39

EVT-C Station Access Facility Concept Map



Note: Hatched area represents immediate station vicinity where bus routing is dependent on specific bay assignment, which is not yet determined

Figure 5-40 EVT-C Bus Routing Map

Quality and capacity of transfers

- Routes would stop at nearby bus stops located on-street or at nearby curbside bays.
- Many transfers would need to cross local streets, such as McDougall Avenue and/or 32nd Street.

Connectivity to high-capacity transit

- Direct connection to the *Swift* BRT Blue Line and planned *Swift* BRT Gold Line.
- 750 ft walk to Sounder and Amtrak at Everett Station.

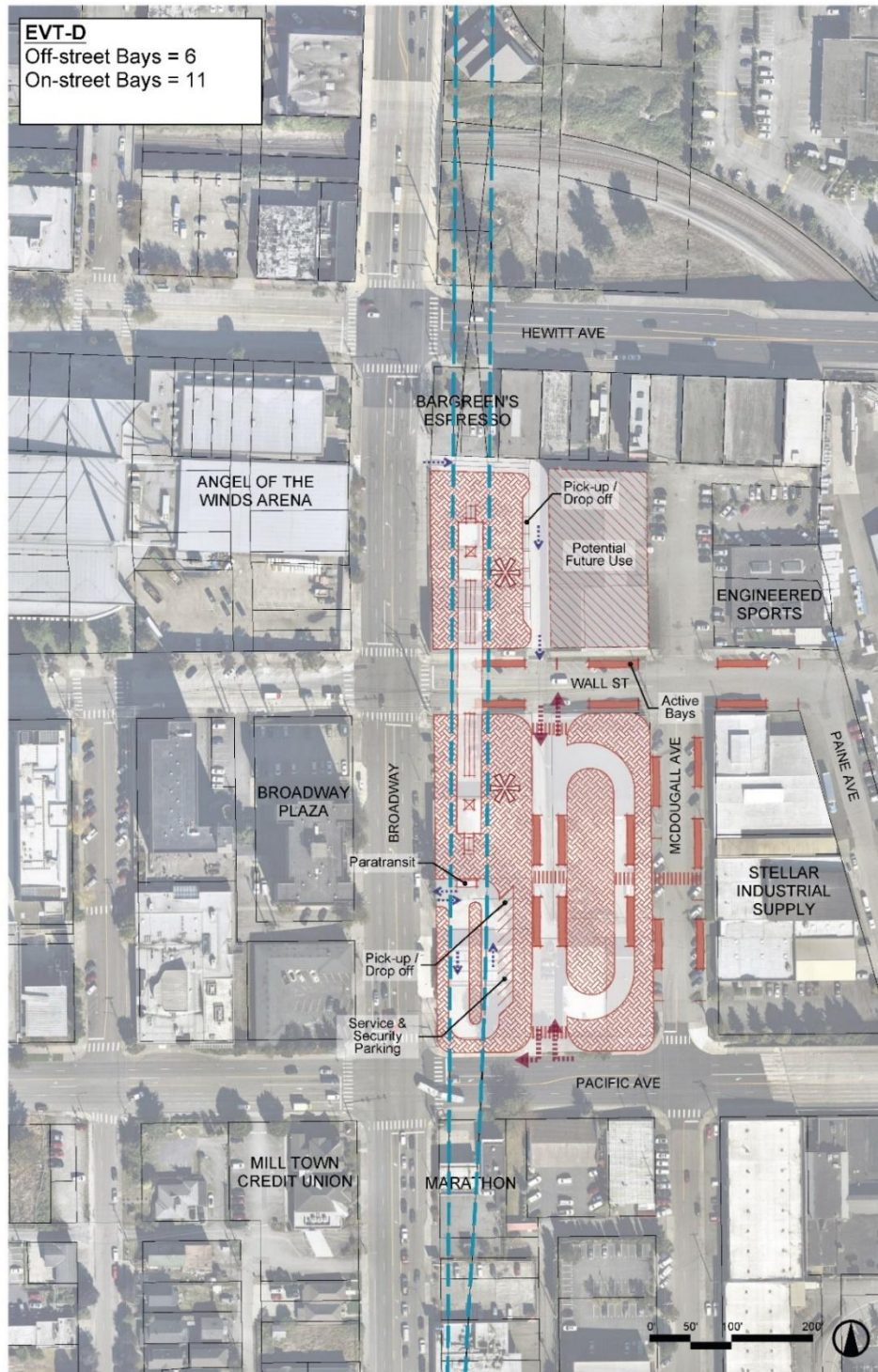
Quality of access for transit vehicles

- May be complex routing for most routes to serve both station alternative EVT-C and existing Everett Station.
- No layover bays planned at station. Layover assumed to occur at Everett Station.

Planned level of bus service

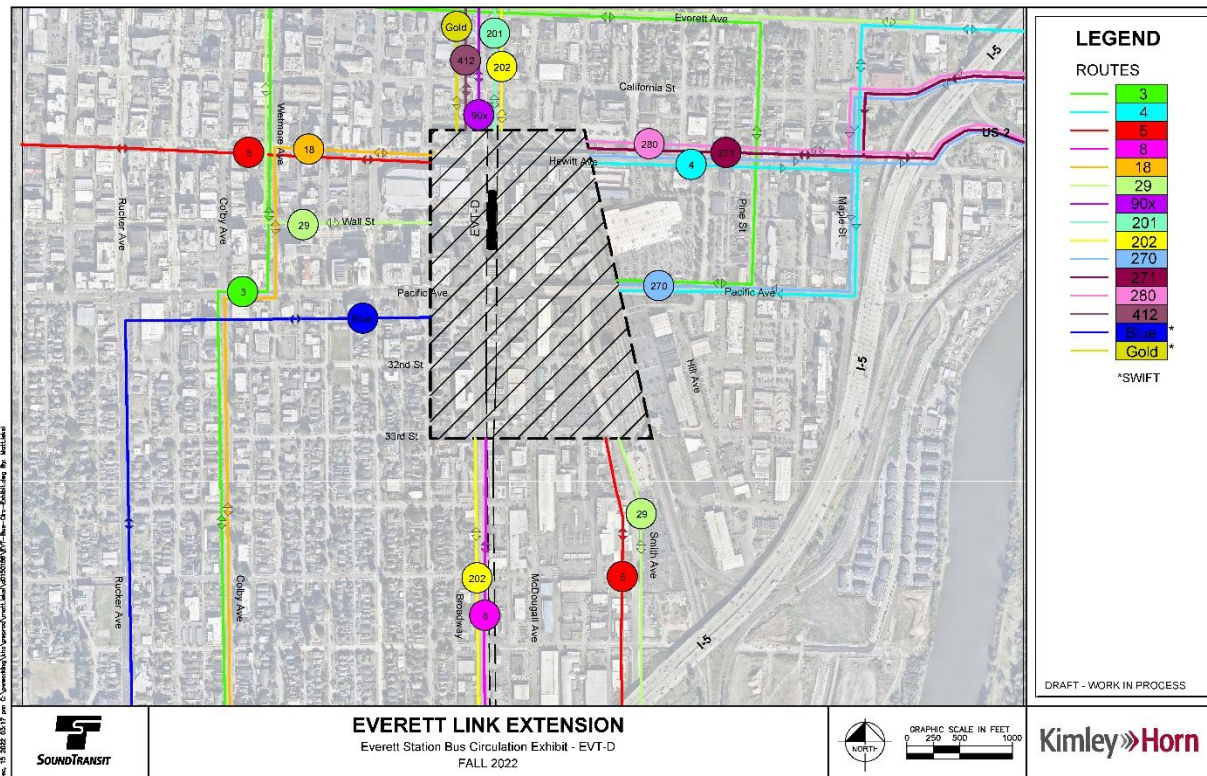
- Peak 89 buses/hour (weekday) (additional buses associated with bi-directional, non-terminal service).

5.7.3 EVT-D



Note: Minor inconsistency between bay requirements in Table 4-2 and concept will be addressed along with further refinement of bus network assumptions if the alternative is advanced to Phase 2

.Figure 5-41 EVT-D Station Access Facility Concept Map



Note: Hatched area represents immediate station vicinity where bus routing is dependent on specific bay assignment, which is not yet determined

Figure 5-42 EVT-D Bus Routing Map

Quality and capacity of transfers

- Routes would stop at nearby bus stops located on-street or at nearby curbside bays.
- Many transfers would need to cross local streets, such as McDougall Avenue and/or Wall Street.

Connectivity to high-capacity transit

- Direct connection to the *Swift* BRT Blue Line and planned *Swift* BRT Gold Line.
- 1500 ft walk to Sounder and Amtrak at Everett Station.

Quality of access for transit vehicles

- May be very complex and circuitous routing for most routes to serve both station alternative EVT-D and existing Everett Station.
- No layover bays planned. Layover at Everett Station assumed.

Planned level of bus service

- Peak 89 buses/hour (weekday) (additional buses associated with bi-directional, non-terminal service).

6 SUMMARY

During Phase 1 - Screening, Level 1, and Level 2, station area alternatives were assessed based on compatibility with project goals and performance relative to each other, with lower-performing alternatives removed at each step and higher-performing alternatives preserved for further analysis. Based on the transit integration assessment factors considered, each station area alternative was given a consolidated transit integration rating based on the assessment metrics and measures. These ratings are presented in Table 6-1 (Consolidated Ratings by Station Area Alternative).

The transit integration analysis is one piece of a larger alternatives analysis process with numerous other metrics and measures, including technical and engineering factors, ridership, bike and pedestrian access, demographic conditions, and equity considerations. While station area alternatives may have received a poor (1) or excellent (5) rating for other measures, none scored this low or this high for transit integration factors. This is generally considered an indication that there are fewer distinctive transit integration attributes that separate the station alternatives in the Level 2 evaluation. In combination with other analysis factors, these results will contribute to the future selection of a Preferred Alternative to move forward into the environmental and conceptual design process during Phase 2.

Table 6-1 Consolidated Ratings by Station Area Alternative

Station Area	Consolidated Rating
West Alderwood	
ALD-B	2
ALD-D	4
ALD-F	3
Ash Way	
ASH-A (without)	3
ASH-A (with)	3
ASH-D (without)	2
ASH-D (with)	3
Mariner	
MAR-A (without)	3
MAR-A (with)	3
MAR-B (without)	3
MAR-B (with)	3
MAR-D (without)	3
MAR-D (with)	4
SR 99/Airport Road	
AIR-A	3
AIR-B	2
SW Everett Industrial Center	
SWI-A	3
SWI-B	4
SWI-C	3
SR 526/Evergreen	
EGN-A	2
EGN-B	3
EGN-C	3
EGN-D	4
EGN-E	4
Everett Station	
EVT-A	4
EVT-C	3
EVT-D	2



Everett Link Extension

APPENDIX B

Sound Transit's Transit Ridership Forecasting Methodology Report

Transit Ridership Forecasting Methodology Report



401 South Jackson Street
Seattle, WA 98104-2826

March 2018

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Appendixes

Appendix A: Maps

Forecasting Analysis Zones (FAZ)

Alternative Analysis Zones (AAZ)

10 and 26 Districts

Appendix B: ORCA, Surveys and Google Travel Time Data

Appendix C: Highway Model

Overview

Network Refinements

Model Results

Appendix D: Procedures for Transit Network Preparation

Development of the Base Network

Coordinate System

Bus Speed from AVL Data

Bus Speed Degradation Procedures

Acronyms and Abbreviations

AAZ	Alternatives Analysis Zones
ACS	American Community Survey
APC	Automatic Passenger Count
AVL	Automatic Vehicle Locator
CT	Community Transit
CTR	Commute Trip Reduction
DRAM	Disaggregated Residential Model
EIS	Environmental Impact Statement
EMPAL	Employment Allocation Model
FAZ	Forecast Analysis Zone
FTA	Federal Transit Administration
IIA	independence from irrelevant alternatives
JTW	journey-to-work
KCM	King County Metro
PSRC	Puget Sound Regional Council
PT	Pierce Transit
RTA	Regional Transit Authority
RTP	Regional Transit Project
ST	Sound Transit
WSDOT	Washington Department of Transportation

1 Introduction

This report summarizes the methods used in the current Sound Transit (ST) incremental model to produce ridership forecasts in support of the ongoing project planning and development activities. It describes reliance on the new and emerging data that were not previously available. This includes data from the ORCA smart cards,¹ recent surveys, actual point-to-point speeds² and detailed ridership counts. The current model benefited profoundly from the new data - particularly, from the ORCA data which:

- Is rich and internally consistent with a statistically acceptable 30% representation of transit travel at origin-to-destination level and by time of day;
- Provides realistic transit trip length distribution as well as transfer rates for each time period; and
- Is a significantly improved alignment of the transit travel patterns (represented by the seed matrix) to the actual counts data that results in a more accurate Base Year transit demand.

The current (2017) version of the ST ridership model was developed using analytical ridership forecasting procedures refined over three decades of incremental methods applications. Over this time period, the methods have been subjected to substantial external review, including three independent Expert Review Panels, and four cycles of review by the Federal Transit Administration (FTA) over the course of New Starts grant applications for Link light rail projects. The fourth review cycle is still ongoing, in support of the proposed New Starts grant for the Federal Way Link Extension.

These reviews have included comments FTA provided with respect to the ST incremental modeling procedures and assumptions described in earlier versions of this report. This report incorporates changes reflecting all of FTA's comments. The following presents a brief history of ST transit ridership forecasting.

1.1 History of transit forecasting at Sound Transit

The history of transit forecasting analysis at ST began at Seattle Metro (now King County Metro) in 1986. Work by Brand and Benham³ led to Metro's consideration of "a quick-responsive incremental travel demand forecasting method," based on the concept of staged forecasting analysis. In 1986, Metro developed and applied "logit mode-choice equations for pivot-point analysis"⁴ (as described by Ben-Akiva and Atherton;⁵ Koppelman;⁶ Nickesen, Meyburg and Turnquist;⁷ and many others) on EMME software. In 1988, Metro staff highlighted the relationship⁸ between Metro's transit forecasting methods and the Puget Sound Council of Governments regional model.

The Regional Transit Project, incorporated as Sound Transit in 1993, further developed forecasting analysis procedures using incremental methods in the early 1990s, prior to the November 1996 voter

¹ ORCA smart card is the primary fare medium for all transit operators in the Puget Sound region.

² Actual Vehicle Locator (AVL) provides point-to-point actual speed data.

³ Brand, D., and J.L. Benham, "Elasticity-Based Method for Forecasting Travel on Current Urban Transportation Alternatives," Transportation Research Record No. 895, 1982.

⁴ Harvey, R., "Pivot-Point Analysis of Transit Demand Using EMME/2," an Internal Paper, Municipality of Metropolitan Seattle, May 1986.

⁵ Ben-Akiva, M., and T. Atherton, "Methodology for Short-Range Travel Demand Predictions," Transportation Economics and Policy, v.7, 1977.

⁶ Koppelman, F., "Predicting Transit Ridership in Response to Transit Service Changes," ASCE 109, 1983.

⁷ Nickesen A., A. Meyburg, and M. Turnquist, "Ridership Estimation for Short-Range Transit Planning," Transportation Research B, v.17B, 1983.

⁸ Harvey, R., "Comparison of Metro and PSCOG Modeling," a Memorandum to File, March 7, 1988.

approval of *Sound Move: The Ten-Year Regional Transit Plan*. An Expert Review Panel—formed in 1990 under the auspices of the Legislative Transportation Committee, the Secretary of Transportation, and the Governor—oversaw development of the first generation of the ST incremental model. This model is described in the November 1993 *Travel Forecasting Methodology Report* published by the Regional Transit Project.

The ST model was updated in the late 1990s in support of the Central Link Light Rail Transit Project Environmental Impact Statement (EIS) and the North Link Light Rail Transit Project Supplementary EIS, including respective Full Funding Grant Agreements with FTA. The underlying ST model procedures used to perform transit ridership forecasting analysis in support of the North Link Light Rail Projects were documented in the *Transit Ridership Forecasting Technical Report*, issued in November 2003 by ST. The ST model was further updated in the mid-2000s in support of the ST2 transit system expansion program and subsequently in 2012 for the EIS phases of the Lynnwood Link Extension and in 2014 for the ST3 system planning work.

The ST model has now been updated again in 2017 in support of the ST3 project planning and development activities and this report describes this latest update. Table 1-1 illustrates more clearly the historical development of the current model, showing refinements in both data sources and structure over the past two decades.

1.2 Report organization

This report contains three chapters and four appendixes. Chapter 1 summarizes the methods used to produce ridership forecasts for ST and discusses important methodological considerations. Chapter 2 describes the individual methods used for each step of the ridership forecasting process. Chapter 3 describes validation of the ST model to 2016 conditions. The current model validation exercise has two purposes: (1) to highlight problems with past forecasting process that might have otherwise been overlooked and (2) to incorporate changes that could improve the forecasting results.

1.3 Sound Transit incremental transit model

The ST incremental model has been updated to a new base year (2016). Development of the base-year transit-trip tables involved a rigorous analysis of actual ridership volumes along each transit route and a realistic simulation of observed transit service characteristics for peak and off-peak periods.

For future year forecasts, external changes in demographics, highway travel time, and costs are distinctly incorporated into the process in stages, prior to estimating the impacts of incremental changes in transit service. In the first stage of ridership forecasting analysis, only changes in Puget Sound Regional Council (PSRC) land use forecasts are considered. In the second stage, other external non-transit changes, such as highway travel time (congestion) and costs (including parking costs) are taken into consideration. For forecasts of external changes, the ST model relies on the version of the PSRC regional model in current use by the Washington State Department of Transportation (WSDOT) on major highway projects. The first two stages of ridership forecasting analysis result in a forecast of future year zone-to-zone transit trips within the Regional Transit Authority (RTA) district boundaries, absent any changes in the transit system itself. For current year analyses, these first two stages are not necessary.

Table 1-1. Sound Transit incremental models history

	Survey based model (1992 to 2004)	Counts based model (2005 to 2011)	Counts based model (2012 to 2016)	Counts based model (2017 to present)
Data Sources	1992 on-board surveys, collected by bus drivers on all transit lines - Lumpy 36% one-day sample of inbound trips (mostly AM), or about 18% of daily trips - Peak and off-peak line boardings control totals for survey expansion 1990 U.S. Census Journey-to-Work (JTW) used for base transit shares - No reliable data for transfer rates, checked against 1992 surveys - Sparse on-board survey data used for auto-access shares - After 2000: 1992 survey demand adjusted with about 100 screen-line segment 1999 ridership counts on select locations around the region	1,700 line-segment ridership counts for each time period for all lines, mostly collected by validated Automatic Passenger Count (APC) systems (2004 average weekday) 2000 U.S. Census JTW for base transit shares 2004 ST on-board surveys - PSRC modeled transit trip distribution to open additional non-zero cells - Little reliable data for transfer rates, checked against 1992 and 2004 surveys - Sparse on-board survey data for peak auto-access shares	1,800 line-segment ridership counts for each time period for most routes, collected by most transit agencies by validated APC systems (2011 average weekday) - Washington Commute Trip Reduction Surveys (CTR) 2007 to 2014 data and American Communities Survey (ACS) 2010 data used for base transit shares 2009, 2011, and 2012 ST on-board surveys added to base year matrix development 2007 to 2014 CTR Survey transit trip patterns added to base year matrix development - Transfer rate estimates validated against PSRC Travel Diary Survey (2006) and ST on-board surveys (2004–2012) - Relied on segment counts near park-and-ride lots for peak auto-access shares	2,400 bus line-segment ridership counts for combined time periods and for all lines, collected by all transit agencies by validated APC systems (2016 average weekday) - Stop-level boarding and alighting ridership counts for each period and for Link, Sounder and high ridership bus routes collected by all transit agencies by validated APC systems (2016 average weekday) 2016 ORCA smart card database data was primarily used to create peak and off-peak seed matrices. 2011-2016 ST on-board and CTR surveys were incrementally added to open new cells. 2011-2016 CTR Surveys data and most recent available American Communities Survey (ACS) data used for base transit shares 2016 ORCA smart card database provided actual transfer rates - Relied on segment counts near park-and-ride lots for peak auto-access shares - Actual Vehicle Locator (AVL) database was used to develop base year (2016 actual transit speed on each link for peak and off-peak

Table 1-1. Sound Transit incremental models history (continued)

	Survey based model (1992 to 2004)	Counts based model (2005 to 2011)	Counts based model (2012 to 2016)	Counts based model (2017 to present)
Structure	737 zones - FAZ demographics from 2002 PSRC model DRAM/EMPAL + negotiation with locals - Highway skims via blind adoption of PSRC matrices created with erroneous cost coefficient - structural error - Use of eight transit trip classes forced very thin demand matrices (not technically a structural error, but generally a poor practice) - PM time periods: 3-hour peak and ½ day off-peak - Trip purpose: commute and non-commute - Mode of access: walk and auto for peak and off-peak - Transit Trip Tables - Base year demand derived directly from on-board surveys - Non-zero cells only 0.05% to 2% across the eight trip tables - After 2000: single-step Matrix Adjustment on non-zero cells of 0.5% to 3% for eight trip tables - Fares in 2nd stage with auto-mode equation	780 zones (splits near rail stations) - FAZ demographics from 2006 PSRC model DRAM/EMPAL - Highway skims prepared directly by project team using a current PSRC model - Used a validated model that has been refined in major WSDOT projects - Aligned transit service levels in the PSRC model with those assumed in the ST model - Rigorous convergence criteria - Use of only three transit trip classes allowed very robust demand matrices - Time periods: 6-hour peak and 18-hour off-peak with 24-hour daily counts as control totals - Mode of access: walk and auto for peak-period and walk only for off-peak - Transit Trip Tables - Base year demand derived directly from detailed ridership counts by route segment, time-period, and direction - Single-step Matrix Estimation on non-zero cells of 15% for peak and 17% for off-peak - Fares in 2nd stage with non-transit-mode equation	785 zones (splits for Ballard study) - FAZ demographics from PSRC 2013 Land Use Targets and 2016 Vision I Forecasts - Highway skims prepared directly by project team using a current PSRC model - Used a recent model version refined and validated for major WSDOT projects - Aligned transit service levels in the PSRC model with those assumed in the ST model - Rigorous convergence criteria - Use of only three transit trip classes allowed very robust demand matrices - Time periods: 6-hour peak and 18-hour off-peak with 24-hour daily counts as control totals - Mode of access: walk and auto for peak-period and walk only for off-peak - Transit Trip Tables - Base year demand derived directly from detailed ridership counts by route segment, time-period, and direction - Five-step Matrix Estimation - Fares in 3rd stage with transit-mode equation - In transit assignment, used logit function on connectors to improve distribution of zone access.	807 zones (splits near Capitol Hill, SW Everett, Federal Way, Fife, Issaquah) - FAZ demographics from PSRC 2017 Land Use Vision II Forecast - Highway skims prepared directly by project team using a current PSRC trip-based model - Used a recent model version refined and validated for major WSDOT projects - Aligned transit service levels in the PSRC model with those assumed in the ST model - Rigorous convergence criteria - Use of only three transit trip classes allowed very robust demand matrices - Time periods: 7-hour peak and 17-hour off-peak with 24-hour daily counts as control totals - Mode of access: walk and auto for peak-period and walk only for off-peak - Transit Trip Tables - Base year demand derived directly from detailed ridership counts by route segment, time-period, and direction, plus stop-level boardings and alightings for major routes. - Six-step Matrix Estimation - Fares in 3rd stage with transit-mode equation - In transit assignment, used logit function on all connectors to improve distribution of zone access.

In the third and final stage, incremental changes in the transit level of service (e.g., access, wait, and ride travel times) and user costs (i.e., fares) are considered, resulting in final transit demand estimates for each transit network alternative under consideration.

Like all travel forecasting models, the ST model has some limitations. Because it uses average daily ridership, it is not particularly strong at assessing the effects of weekend special events, such as sporting events or major festivals. Furthermore, the ST model is ill-suited for analyzing structural changes in regional land use beyond those already included in PSRC demographic forecasts or for forecasting in outlying areas of the three-county region where there is minimal existing transit service.

1.4 Important considerations and constraints

This section discusses six important considerations and constraints in travel forecasting methods. Most of these are derived from many years of FTA guidelines on transit project planning that culminated in the current policy guidance.⁹ The following considerations reemphasize the use of best professional practice:

- Careful standards for validation
- Consistent application of policy assumptions across alternatives
- Use of identical land use plans and constant overall travel demand patterns across alternatives
- Generic attributes of modes
- Analysis of service levels and travel forecasts for reasonableness
- Maximum possible reliance on detailed data rather than output from other models

1.4.1 Careful standards for validation

Validation is a vital component of any travel forecasting effort. It demonstrates that the forecasting procedures can replicate observed travel patterns in a region to support reliable forecasts of future travel patterns. The ST model primarily relies on the ORCA fare card data and detailed ridership counts to establish current transit travel patterns. In project planning, travel forecasting methods are expected to predict changes in travel patterns that are caused by general changes between the base year and a forecast year and by specific transit service changes introduced by each alternative.

1.4.2 Consistent policy assumptions across alternatives

A large number of inputs to the travel forecasting process are at least partially subject to the policy decisions of local and state agencies. To isolate the differences generated by a specific proposed project (e.g., a fixed guideway rail transit system), all conditions that are not directly attributable to the proposed project must be held constant. It is therefore required that the forecasts hold the policy setting constant across all alternatives evaluated. These policies include:

- Fare level and structure
- Levels of service provided by the background transit system
- Zoning policies
- Parking policies and prices

⁹ Final Interim Policy Guidance—FTA Capital Investment Grant Program (June 2016).

This constraint means that forecasts prepared for FTA evaluation and EIS documentation should only contain differences between alternatives that are primarily caused by the transit alternatives themselves. For example, service levels on feeder buses should reflect a general service policy and investment level that is applied consistently across alternatives. Assumptions on all external inputs—land use, regional income, parking costs, and other external variables—should also be held constant.

1.4.3 Constant travel patterns across alternatives

Forecasts of the overall travel demand for which transit competes can involve confounding factors. The FTA guideline that land-use policies be consistently applied removes some sources of variability in population and employment forecasts. In basic forecasts for modes that have differing degrees of grade separation, it eliminates guessing about the extent to which a particular alternative might shift residential and commercial development. Note that the forecasts provided to FTA by ST hold travel patterns constant. Supplementary analyses external to the modeling process are used to address potential development changes related to the various transit investment proposals.

1.4.4 Generic attributes of modes

It is widely acknowledged that perceived differences between transit technologies, independent of travel time and cost, may contribute to choice of mode. These differences are often discussed in terms of comfort, security, reliability, legibility, and other characteristics that are difficult to quantify. Data to support direct inclusion of these variables in the analysis is limited. The ST model uses a conservative assumption and, for the most part, treats transit modes generically. Current FTA guidance on methods indicates that FTA will accept forecasts that account for measurable differences in some of these attributes, such as reliability between modes (e.g., bus and rail).

The ST model includes small quantified mode-specific variations in the perception factors (i.e., weights) for transit line boarding and waiting times (see Table 3-2 in Chapter 3).

1.4.5 Analysis of transit service levels and travel forecasts

The development of forecasts results in the production of a variety of additional types of information beyond ridership volumes. Examples include ridership changes in specific subareas, changes in roadway congestion levels, travel time savings created by new transit investments, and transit's share of various travel markets. All of these needs careful review for quality control purposes, as well as an understanding of what the forecasts reveal about changes between the present and the future and differences among the transit alternatives.

1.4.6 Reliance on data

This model version increases the reliance on detailed data by incorporating newly available data detail. Major new sources of data include ORCA fare card boarding and alighting data, Google highway travel time data, Automatic Vehicle Locator (AVL) data, and additional Automatic Passenger Count (APC) data on passenger activity at major stops. All of these data source additions reduce dependence on inputs from external models.

2 Procedures for Travel Forecasting

This chapter describes the methods and procedures used in the ST transit forecasting model, including the input data required by the ST model and its relationship to the PSRC model.

Section 2.1 describes the methodology used to develop transit forecasts, the data requirements, and the data available. Section 2.2 describes the relationships between the ST and PSRC models. For instance, this section provides an overview of the methodology used by PSRC to produce land use forecasts that are critical to any future year ridership forecasting analysis. The transportation analysis zone system is described in Section 2.3. The mode choice model structure, specification, and coefficients are presented in Section 2.4. Summary descriptions of the process used to develop base-year transit-trip tables are provided in Section 2.5. Possible changes in population and employment, highway congestion, and cost (i.e., the application of the staged build-up forecasting analysis) are discussed in Sections 2.6 and 2.7. A discussion on changes in transit service is included in Section 2.8.

2.1 Methodology

2.1.1 Incremental vs. synthetic methods

There are two different approaches to developing transit forecasts: synthetic methods and incremental methods. Synthetic methods estimate existing transit travel patterns by using separate sequential models to estimate

- An allocation of regional population and employment projections to zones
- The total number of trips to and from these zones
- The origin/destination patterns of these estimated trips
- The travel mode share likely for each estimated origin/destination pattern
- Which specific links and lines in the highway and transit systems are used by these synthesized trips

Incremental methods are simpler and more efficient for transit ridership forecasting and analysis because they

- Are directly based on observed (rather than estimated) baseline travel patterns of transit users
- Allow for concentrating efforts on transit network analysis, for studies whose primary goals are answering questions about alternative transit networks
- Are more conducive to the separate and transparent evaluation of population and employment changes, highway congestion and cost, and transit services through the three stages of the forecasting process
- Focus on direct comparisons related to specific changes rather than on complete simulations of travel behavior
- Are more usable for intermediate evaluation and error identification
- Eliminate the often laborious and time-consuming calibration of sub-choice models, since they do not require replication of base-year travel patterns for these markets.

The FTA guidelines on transit project planning have identified three strong characteristics of the incremental approach that make it attractive for many applications. According to FTA, the incremental method “is well grounded in the reality of baseline travel patterns; it deals only with marginal changes; and it focuses attention on the changes in land-use and transportation that drive the evolution of travel patterns over time.”¹⁰

One limitation that could render incremental methods less desirable in some situations is their weakness in estimating future transit markets in locations where there is no existing transit market from which to build estimates. This is not an issue within the ST RTA district, since both ridership and transit service coverage within the district are highly developed. The use of incremental methods would only have limitations if applied to exurban or rural areas beyond the district boundary.

Incremental methods rely on data collection, not travel demand theory, to describe base-year travel patterns. In recent years, data availability has increased dramatically, with large quantities of revealed preference data no longer requiring expensive surveys or special counts. The ORCA smart card data, coupled with the detailed route-level data by time-of-day from the ridership counts from each transit agency now available, provide complete observed baseline travel patterns within the RTA district.

In the incremental model approach, the coefficients and sensitivities are the same as in the synthetic approach. The incremental methods are mathematically derived from and parallel to the synthetic methods and are applied at the same level of network detail that would be used in a synthetic approach.

2.1.2 Data available for Sound Transit planning

The key sources of data available for ST planning include

- PSRC land use forecasts
- PSRC regional travel model version adopted by WSDOT for major highway projects
- Service levels and detailed route-level counts from transit operators in the three-county area—Sound Transit, King County Metro, Pierce Transit, Community Transit, and Everett Transit
- ORCA smart card database
- Automated Vehicle Locator (AVL) speed data
- Location-to-location highway travel time from the Google Distance Matrix database
- Sound Transit Surveys (2011–2016)
- Commute Trip Reduction surveys (2011–2016)
- Most recent available American Community Surveys
- The National Transit Database (2016)
- State and local agencies

¹⁰ Procedures and Technical Methods for Transit Project Planning, Federal Transit Administration, 2004.

PSRC's land use forecasts are key input to the modeling effort for future years. The ST model uses the most current land use forecasts available from PSRC at the start of a project. The PSRC regional forecasting model, the version used by WSDOT for travel forecasting in support of major capital projects and tolling analysis, provides changes in highway travel times for past and future years. This WSDOT highway model also provides changes in traffic volumes on regional highway facilities for traffic impact analysis, and local jurisdictions provide traffic counts on local arterials for station impact analysis, as required.

The following sections discuss how these various databases were developed and include more detail on how they are being used.

2.2 Relationship to PSRC modeling

2.2.1 Summary comparisons of the PSRC travel demand model and the ST transit ridership model

PSRC maintains a four-step conventional synthetic travel-demand modeling system consisting of trip generation, trip distribution, mode choice, and trip assignment models.¹¹ Zonal trip ends are estimated using a set of trip rates classified by home-based work, home-based college, home-based shop, home-based other, home-based school, non-home-based work, non-home-based other, and three truck types. Trip distributions are estimated using a traditional "gravity" model. The PSRC mode-choice model structure is a logit-based model comprised of two transit modes, three auto modes, and two non-vehicle modes.

The ST and PSRC modeling procedures are closely inter-related and highly complementary. The ST model uses measures of regional change in travel demand and highway congestion derived from the PSRC model. Summary comparisons and interrelationships of the PSRC and ST modeling procedures are highlighted below:

- The PSRC model is a four-county synthetic modeling system comprising land use, trip generation, trip distribution, modal split, and assignment models. It also includes several feedback loops based on intra-regional accessibility.
- The ST model is a three-county, three-stage, fully incremental system purposely designed for detailed corridor-level transit planning and transit ridership forecasting.
- PSRC's regional population and employment forecasts are used to predict travel demand growth for future years.
- ST uses an incremental mode choice procedure that is consistent with PSRC's multinomial logit mode choice model.
- The current PSRC model version used by WSDOT for travel and toll forecasting in support of major highway projects is adopted for interface with the ST model. This highway model has been recently refined and validated for use on several WSDOT tolling analyses. Figure 2-1 highlights the relationship between the PSRC and ST models.

¹¹ Puget Sound Regional Council, 4K Travel Model Documentation, June 2015.

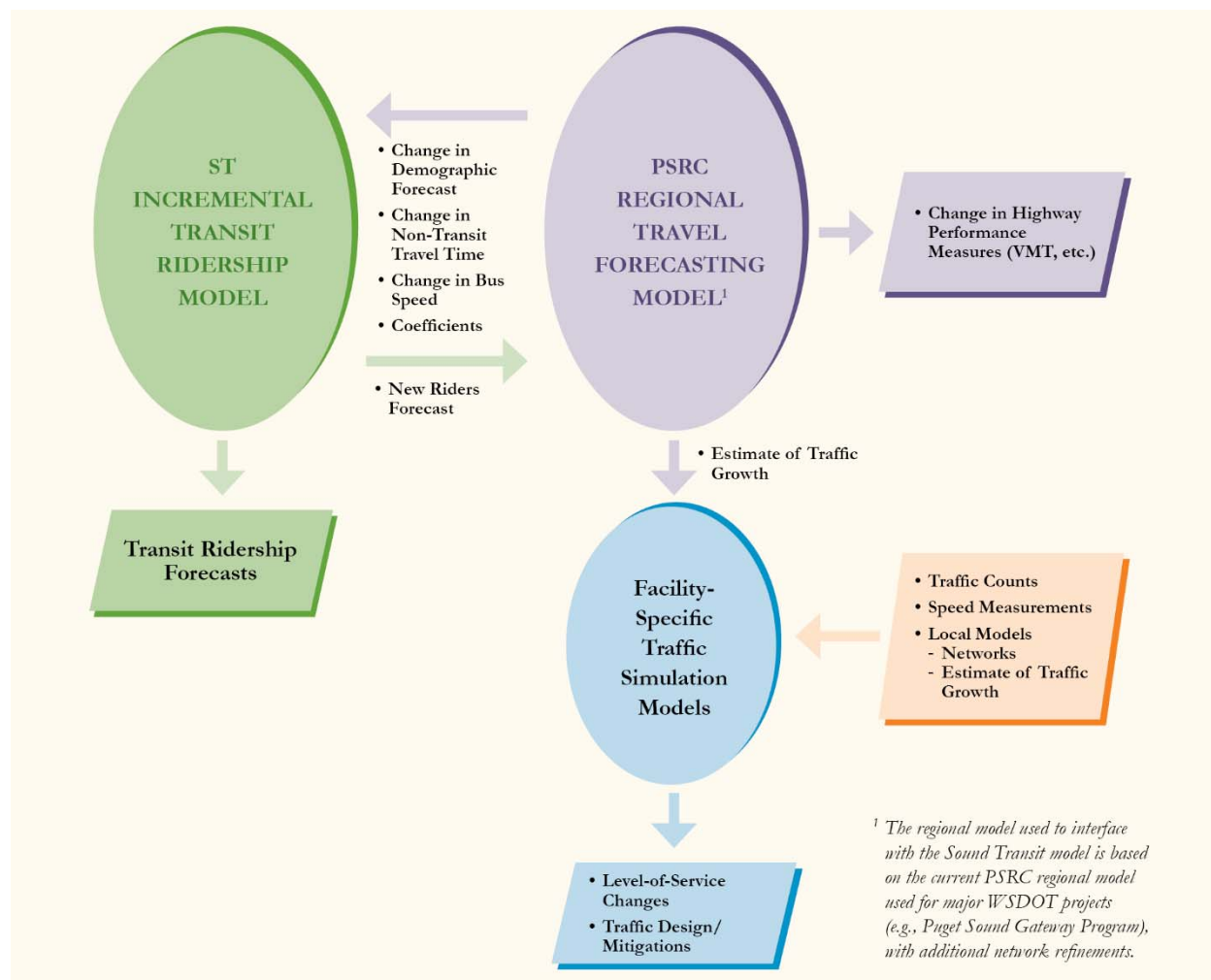


Figure 2-1. ST incremental transit ridership and PSRC regional models relationship

2.2.2 Preparation of demographic forecasts

This section summarizes the procedures used by PSRC to forecast regional population and employment. The current demographic forecasts are referred to as Land Use Vision (LUV). The development of demographic forecasts process is described by PSRC in the *Land Use Vision (LUV) Dataset Metadata Documentation* (May 2017).

Land Use Vision Development Process

The LUV projects growth for places in the Central Puget Sound region in 5-year increments, 2015–2040. The process includes four general steps (Figure 2-2). The regional totals for population, households, and jobs come from the PSRC Regional Macroeconomic Forecast. PSRC has used numeric policy guidance from the VISION 2040 Regional Growth Strategy and adopted local growth targets to apportion the Regional Forecast to cities and unincorporated areas to create annual control totals. Resulting control totals are then used in the PSRC’s land use simulation model, UrbanSim, to distribute projected growth on developable land.



Figure 2-2. Land use vision development process

The UrbanSim model results are reported at different geographies, including at the forecasting analysis zone (FAZ) level for review and consultation feedback by local jurisdictions. These forecasts are also circulated for review by a wide variety of public and private organizations. After the review process is completed, these forecasts and allocations are widely used by the state as well as by local governments, public agencies, and private organizations.

2.3 Development of zone and district systems

The ST travel forecasts are produced for an 807-zone system of Alternatives Analysis Zones (AAZ) developed specifically for the ST model but based directly upon PSRC’s current zonal system. Summaries of inputs and forecasts are prepared using 26 summary districts or other levels of aggregation (e.g., by corridor or by county) as needed. Zone and district maps are shown in Appendix A.

2.3.1 Forecast analysis zone and traffic analysis zone systems

PSRC’s FAZ structure is the basic land-use zone structure and consists of 219 FAZs that cover all the land area within the four-county region. It is usually at this level of detail that local jurisdictions, through PSRC, agree upon allocations of future population and employment throughout the region.

2.3.2 Alternatives analysis zone system

The AAZ system used to produce the ST travel forecasts is based on the zones maintained by PSRC for regional forecasts of travel demand within the four-county central Puget Sound region. The ST zone system differs from PSRC’s system in two aspects.

Most importantly, the ST system does not have the same geographic boundary as the PSRC system. Whereas PSRC includes a four-county region (Snohomish, King, Kitsap, and Pierce Counties), the 1993 state-established RTA excludes the largely rural areas of North and Northeast Snohomish, South and Southeast Pierce, and East King Counties, as well as all of Kitsap County, Vashon Island, and the Gig Harbor peninsula. Areas outside the RTA district are external to the ST model. The 807-zone system

includes smaller zones within transit corridors of interest, especially around potential station locations, as well as 17 external zones to represent highway connections outside the RTA boundaries.

Keeping the PSRC and ST zone structures as similar as possible reduces the level of data manipulation required for interface between the two models.

Summary districts were created from the AAZ system in order to

- Provide a consistent basis for aggregation of certain model inputs, when such aggregation is appropriate
- Calculate the modal shares required in the model validation and application phases
- Prepare summary reports on trip tables and travel time skims

These districts were carefully constructed to provide distinctive summary travel patterns by geographical area and corridor.

2.4 Sound Transit mode choice model methodology

2.4.1 Model structure

The ST mode-choice model structure, which is an incremental logit model, uses a pivot approach in the development of forecasts and uses the PSRC regional mode choice coefficients.

Incremental logit model

The incremental approach predicts changes in travel behavior based on existing travel behavior and changes in level of service. The incremental form of the logit model is derived from the standard logit formulation, which is¹²

$$(1) \quad S_i = \frac{\exp(V_i)}{\sum_j^m [\exp(V_j)]}$$

Where

- V_i = utility of mode i in choice set m ($j=1,2,3, \dots, i, \dots, m$)
Contains measurable components of transportation systems such as travel time and cost as well as socio-economic attributes of trip makers.
- S_i = share of demand using mode i

¹² Domenich, T., and D. McFadden, "Urban Travel Demand—A Behavioral Analysis," North Holland, Amsterdam, 1975.

Ben-Akiva and Lerman indicate that “using elasticities is one way to predict changes due to modifications in the independent variables. For the linear-parameters multinomial logit model, there is a convenient form known as the incremental logit model which can be used to predict changes in behavior on the basis of the existing choice probabilities of the alternatives plus changes in the independent variables.” The incremental form of the logit model is¹³

$$(2) \quad S_i^f = \frac{S_i \times \exp(\text{DIFF } V_i)}{\sum_j^m [S_j \times \exp(\text{DIFF } V_j)]}$$

where

$$\begin{aligned} S_i &= \text{base-year observed probability of using mode } i \text{ from choice set } m \\ S_i^f &= \text{new share (i.e., forecast year) of using mode } i \text{ (interzonal average)} \\ \text{DIFF } V_i &= \text{change in utility of mode } i \text{ (interzonal average)} \\ &= V_i^f - V_i = (\text{DIFF CONST}_i) + B_k \times (\text{DIFF VAR}_{i,k}) \end{aligned}$$

and

$$\begin{aligned} \text{DIFF CONST}_i &= \text{difference (future vs. base) in mode-specific constant for mode } i, \\ B_k &= \text{coefficient for attribute } k \\ \text{DIFF VAR}_{i,k} &= \text{difference in numeric variable VAR } k \text{ of alternative } i \\ f &= \text{variable with superscript “f” represents value in forecast year.} \end{aligned}$$

All transportation models, including the PSRC synthetic model, assume that the difference between the unmeasured attributes (e.g., comfort and image) between transportation systems in the base year and future years is negligible. As a result, the term representing the difference in mode-specific constants (i.e., DIFF CONST_i) falls out of the computations. The only terms remaining in Equation 2 pertain to those attributes (e.g., travel times and costs) for which a measured change might occur, as well as Equation 3:

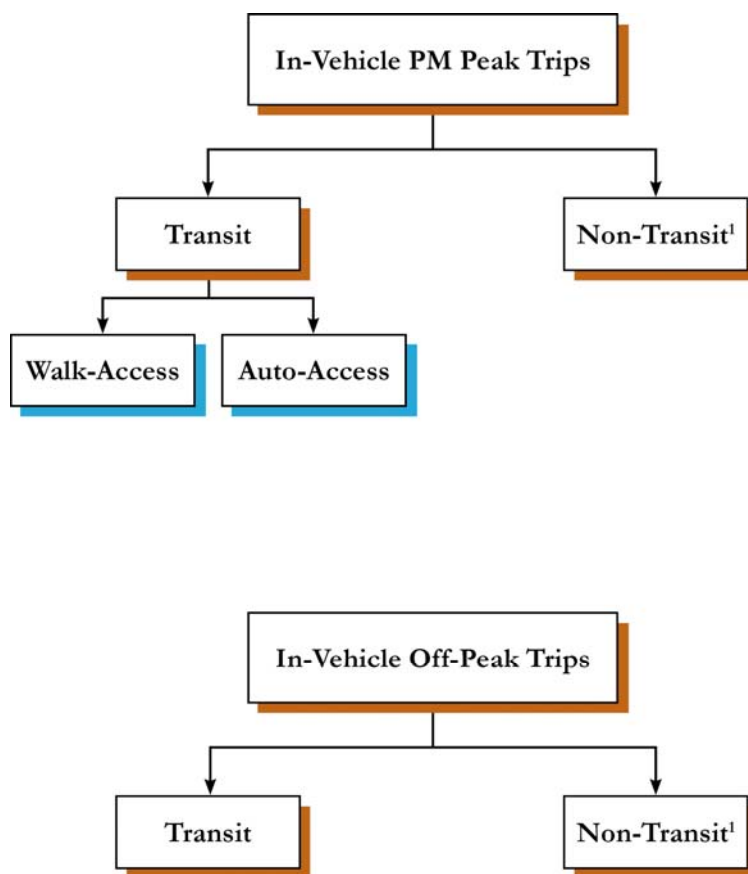
$$(3) \quad \text{DIFF } V_i = B_k \times \text{DIFF VAR}_{i,k}$$

The mode-specific constants in a synthetic model theoretically represent the effects of unmeasured attributes and often account for over half of the explanatory power in synthetic mode choice models. In practice, these constants are quite large and compensate for all types of errors in synthetic models, even network coding idiosyncrasies. They are used as overall adjustment factors to move the base year model results closer to targeted base year totals. Mode-specific constants are not present in incremental logit equations.

¹³ Ben-Akiva, M., and S.R. Lerman, “Discrete Choice Analysis Theory and Application to Travel Demand,” The MIT Press, Cambridge, MA, 1985.

Nested logit model

According to the independence from irrelevant alternatives (IIA) assumption, logit models require that all of the modes defined in the choice set m (for travelers) be independent of one another. However, the IIA requirement is usually difficult to maintain in a simultaneous structure. In practice, a sequential (or nested) logit model that is less restrictive than the simultaneous form is often used. The nested logit model groups appropriate submodes under the primary modes (i.e., transit), as shown in Figure 2-3. For peak trips, the transit mode in the ST model, the sub-choice is between access to transit by walking or by automobile. Suggestions from FTA on the appropriateness of nesting can be found in the FTA presentation by Jim Ryan at the January 2004 Transportation Research Board Annual Meeting.¹⁴



¹ Non-transit includes all travel in vehicles other than public transit buses and trains.

Figure 2-3. Incremental mode choice model structure

¹⁴ Travel Forecasting for New Starts Projects, Transportation Research Board 83rd Annual Meeting, Session 501, January 13, 2004.

The natural logarithm of the denominator of a logit model (Equation 1) is a single “inclusive” index I_m ¹⁵ indicating the desirability of the main mode m and taking into account the attributes of access modes. This index is often called “LogSum” and calculated from

$$(4) \quad \text{LogSum} = \ln \{ \sum_j^m [\exp(V_j)] \}$$

where

V_j was defined before for Equation (1)

McFadden¹⁶ has identified the coefficients K for the LogSum variable as indices of similarity among the sub-mode choices comprising the overall price or cost.

For the transit, lower level, the composite disutility of the sub-modes (walk- and auto-access) represents transit to the upper level choice. For transit mode t , the LogSum is

$$(5) \quad \text{LogSum}^t = \ln [\exp(V_{\text{walk}}) + \exp(V_{\text{auto}})]$$

where

V_{auto} = utility of the auto-access mode
 V_{walk} = utility of the walk-access mode

The structure for PM peak period shown in Figure 2-3 is fully incremental¹⁷ because it uses the incremental logit model at both the lower-level and upper level nests. The incremental form is highly desirable because it relies on observed data that describes current conditions, rather than using models to estimate these current conditions.

Derivation of changes in LogSum variable

In the fully incremental ST mode choice model, the changes in ridership between future and base-year conditions are calculated based on the incremental logit formulation (Equation 2) both at the primary level of hierarchy (i.e., transit vs. non-transit) and at the lower level (i.e., mode of access).

Because the incremental model requires the difference in the values of LogSum variable (i.e., DIFF LogSum^t for the mode of access), the underlying components of this difference need to be spelled out first within the context of standard logit formulation (Equation 1). The derivation process starts by using the definition of difference in the LogSum values and ends up with a simple formula consisting of the logarithmic summation of the exponential difference in the utility of each mode (i.e., future minus base year), weighted by the respective base year observed share. The mathematical derivation is presented below.

¹⁵ McFadden, E., A. Talvitie and Associates, “Demand Model Estimation and Validation, Urban Travel Demand Forecasting Project (UTDFP) Final Report,” Vol. V, University of California, Berkeley, CA, 1977.

¹⁶ McFadden, E., A. Talvitie and Associates, “Demand Model Estimation and Validation, Urban Travel Demand Forecasting Project (UTDFP) Final Report,” Vol. V, University of California, Berkeley, CA, 1977.

¹⁷ Dehghani, Y., and R. Harvey, “A Fully Incremental Model for Transit Forecasting: Seattle Experience,” Transportation Research Board, Record #1452, 1994.

Incremental change in LogSum^t of Equation 5 can be represented by

$$(6) \quad \text{DIFF LogSum}^t = \text{Ln}[\exp(V_{\text{walk}}^f) + \exp(V_{\text{auto}}^f)] - \text{Ln}[\exp(V_{\text{walk}}^b) + \exp(V_{\text{auto}}^b)]$$

Incremental change in LogSum for mode *m* (i.e., transit or auto), representing the upper-level of the nested logit structure, can be written as

$$(7) \quad \text{DIFF LogSum}^m = \text{Ln} \{ \text{Sum}_i^n [\exp(V_i + \text{DIFF } V_i)] \} - \text{Ln} \{ \text{Sum}_i^n [\exp(V_i)] \}$$

or

$$\begin{aligned} &= \text{Ln} \left[\frac{\text{Sum}_i^n [\exp(V_i + \text{DIFF } V_i)]}{\text{Sum}_i^n [\exp(V_i)]} \right] \\ &= \text{Ln} \left[\frac{\text{Sum}_i^n [\exp(V_i) \times \exp(\text{DIFF } V_i)]}{\text{Sum}_i^n [\exp(V_i)]} \right] \\ &= \text{Ln} [\text{Sum}_i^n (S_i \times \exp(\text{DIFF } V_i))] \end{aligned}$$

where

DIFF LogSum ^t	=	difference in LogSum term for transit mode <i>t</i> (future–base year)
$V_{\text{walk}}^f, V_{\text{auto}}^f$	=	the utility of walk and auto access modes in future
$V_{\text{walk}}^b, V_{\text{auto}}^b$	=	the utility of walk and auto access modes in the base year
DIFF LogSum ^m	=	difference in LogSum term for mode <i>m</i> (e.g., auto or transit) in the upper level of the nested structure (future–base year)
V_i	=	the utility of submode <i>i</i> (e.g., walk or drive access attributes) under nest <i>n</i> (e.g., transit)
S_i	=	base-year observed share of using submode (e.g., walk or drive access) under nest <i>n</i>
DIFF V_i	=	difference in the utility (e.g., travel time) of submode <i>i</i> under nest <i>n</i> (future–base year).

The coefficients of variables (e.g., travel time) included in the utility of a sub-mode *i* are equal to comparable mode-choice coefficients from the upper-level nest for the same variables (e.g., travel time), scaled by the corresponding LogSum coefficient (*K*).

Values for DIFF LogSum variables resulting from Equation 7 are used in the incremental logit formulation (Equation 2) to estimate new interzonal modal shares. Nesting coefficients vary between 0.0 and 1.0 and measure the degree of similarity and dissimilarity of a group of sub-modes from other modes in the upper-level nest. For example, a nesting coefficient (*K*) of 1.0 on the transit nest of Figure 2-3 would indicate that auto- and walk-access sub-modes are dissimilar (independent) from each other, implying that they should have been structured simultaneously instead of within a nested form. In the absence of any information to inform the selection of a nesting coefficient, an assumption of 0.50 is neutral. This nesting coefficient of 0.50 is used for the PM peak mode-of-access nest in the ST model.

2.4.2 Model specification and coefficients

As indicated in the previous section, since the mode-choice model structure is fully incremental, the mode-specific constants fall out of the computations. Therefore, it is not necessary to estimate values for modal constants. The model includes

- Travel time and cost variables in the utilities of the transit sub-modes, walk and drive access (e.g., in-vehicle, out-of-vehicle times, transit fares)
- Travel time and cost variables in the utility of non-transit mode representing all travel in vehicles other than public transit buses and trains.

The travel time and cost coefficients used in the ST model include the following:

- -0.025 for in-vehicle travel time (which falls within the FTA's recommended range of -0.02 to -0.03 and is also used in the PSRC mode choice model) with a relative ratio of 1.5 for out-of-vehicle over in-vehicle transit travel times, as derived from the base year (2016) model validation analysis.
- -0.00075 for travel cost (in 2016 dollars).

These coefficients imply a value of in-vehicle time of \$20 (in 2016 dollars), which is about two-thirds of average hourly wage rate for the Puget Sound Region. This value of travel time is also compatible with values used over the last decade for tolling analysis on major WSDOT projects such as SR 520,¹⁸ SR 99, and Puget Sound Gateway.

2.4.3 Base year mode shares

Equation 2 illustrates the need for a reasonable estimate of S_i (the existing shares for transit relative to alternative modes), including existing mode-of-access shares. Development of these base shares, used in the ST incremental model, is described below.

Transit shares

For the 2017 ST model version, a combination of data from the Washington Commute Trip Reduction (CTR) Act surveys and the American Communities Survey (ACS) is used to establish base year transit shares.

The State of Washington passed the CTR Law in 1991 to encourage commuters to consider transportation alternatives to driving alone. Under this law, employers with 100 or more employees are required to conduct a survey once every two years to record the commute options used by their employees. The ACS is conducted on an on-going basis in order to provide up-to-date information for planning. Further information about the CTR surveys and the ACS is provided in Appendix B.

The CTR (2011-2016) surveys provide transit shares at the zonal level with some limitations. These limitations include an over-representation of transit users, related to employer size because the sample excludes small employers.

The ACS data also has some limitations as it represents a sample of residences—only about 1 in 40 households annually. The Census Bureau produces three ACS data series: *one-year*, *three-year*, and

¹⁸ SR 520 Bridge Investment Grade—Traffic and Revenue Study Report, August 29, 2011.

five-year estimates. Five-year estimates of ACS home-to-work flow by mode are currently available at the County or Census Place geographies. To address the ACS data limitations, transit shares were aggregated at the 6-district level for maintaining statistical confidence in the share values.

A 6-district level summary comparison of transit shares in the ST service area indicated that

- As expected, CTR transit shares are higher than those obtained from the ACS
- Most recent available ACS shares are slightly higher than those obtained from the 2000 U.S. JTW data

Based on the findings from the above analysis, it is reasonable to adjust CTR transit shares relative to ACS shares in the following manner in order to retain the CTR geographic detail:

- Aggregate CTR 2011-2016 surveys to the 26 districts at the work ends and 26 districts at the home end and calculate transit shares accordingly. Calculating the shares at this level (i.e., 26-district to 26-district) preserves the variation in current mode-choice behavior for PM peak and, therefore, the elasticities in the incremental logit model.

Adjust 26-district-to-district base transit shares based on using the 6-district-to-6-district transit shares calculated from the most recent ACS five-year estimates as follows:

- Since the aggregated CTR shares are higher than the ACS shares at the 6-by-6-district level, reduce the CTR shares proportionately using the ratio of the ACS share to the aggregated CTR share.

For calculating off-peak base shares, a procedure similar to the one described above was used with the following exceptions:

- Aggregate CTR surveys at 26-district-to-26-district level and calculate shares accordingly
- Adjust CTR shares based on using 6-district level ACS shares similar to the method for peak shares.
- Balance the resulting 26-district-to-26-district share matrix by adding its transpose and dividing by 2
- Apply a factor of 0.5 to reflect the difference in base off-peak transit share relative to peak—this factor was calculated based on recent ST 2011 through 2016 small-sample transit on-board survey data.

Access shares

The 2017 ST model version relies on a matrix estimation process for the development of base-year trip tables that is based on using a seed matrix with a high number of non-zero cells. The process includes posting of ridership counts on appropriate segments and stops to capture existing demand at each park-and-ride facility. These considerations, together with the fact that existing park-and-ride facilities are adequately represented throughout the region provide a good database from which to calculate access shares. Steps used to estimate access shares are summarized below:

- Perform a select segment analysis on segments representing potential PM peak demand to park-and-ride facilities
- Aggregate the resulting demand matrix for PM peak auto-access trips and the total PM peak transit trip table at 26 districts (work ends) and 165 FAZs (home ends)

- Divide the aggregated trip tables to provide existing auto-access shares at a 26-district-to-165-FAZ aggregation level.

2.4.4 Discussion of staged build-up analysis application

For future year forecasts, the ST incremental ridership forecasting modeling procedures are applied in three distinct stages as highlighted in Figure 2-4. This application method explicitly recognizes a build-up approach to the ridership forecasts and encourages the analysis of intermediate results in the process as well as the checking of intermediate results for reasonableness. Specific contributions to changes in ridership at each stage are calculated and analyzed separately as they build on each other. The three stages are:

- Overall growth in travel related to population and employment growth
- Changes in ridership related to changes in highway congestion and costs
- Changes in ridership related to transit service changes, including transit fare changes, if any

By applying forecasting analysis in stages, the method also ensures that only those changes that are important to the study transit alternatives will be considered. For example, it is common in ridership forecasting (and preferred by the FTA) that only the changes in transit service be considered in the future year comparisons of transit ridership. Therefore, all demographics, such as land use, trip distributions, and gas and parking prices, are effectively held constant when comparing ridership on transit alternatives.

FTA now considers transit benefits measures related to economic development effects and to land use entirely separately from the ridership estimating process. Furthermore, by requiring current year ridership estimates, with future years optional, FTA is de-emphasizing future year forecasts in favor of simple network-based comparisons. As the FTA Policy Guidance points out, “Use of current year data increases the reliability of the projected future performance of the proposed project by avoiding reliance on future population, employment, and transit service levels that are themselves forecasts.”¹⁹

Staging the forecasts in an incremental model explicitly isolates sources of error, makes consistencies in the non-transit assumptions transparent, and reduces superfluous calculations. When only variations in the transit service are under consideration, Stage 3 of the incremental model is the only step needed to evaluate each proposed variation in transit service. This method does not preclude varying inputs other than the transit service (i.e., for sensitivity testing) but allows such variation to be addressed simply and specifically, rather than as a hidden piece of a very large and complex model.

2.5 Base-trip table development

The essential basis for incremental mode choice modeling analysis is the reliance on actual transit travel patterns. Capturing existing travel patterns is achieved in the ST model by using available, pertinent data that provide a complementary balance between origin-destination (O-D) data and detailed route-level transit ridership information by direction and time-of-day for the base year. Chapter 3 includes a detailed discussion of the process used to develop base year (2016) peak and off-peak transit-trip tables.

¹⁹ Final Interim Policy Guidance—FTA Capital Investment Grant Program (June 2016).

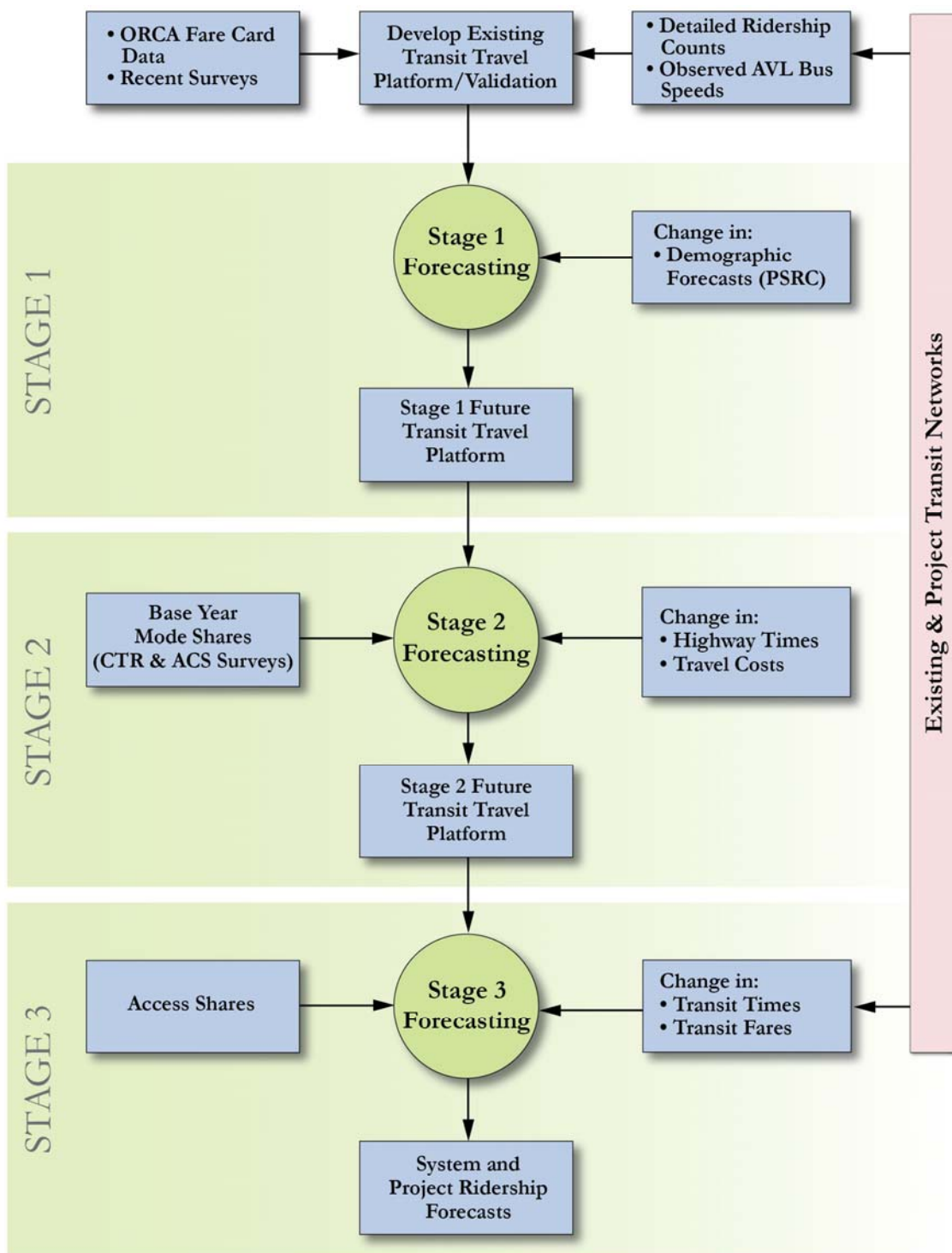


Figure 2-4. Staged ridership forecasting process

FTA now considers transit benefits measures related to economic development effects and to land use entirely separately from the ridership estimating process. Furthermore, by requiring current year ridership estimates, with future years optional, FTA is de-emphasizing future year forecasts in favor of simple network-based comparisons. As the FTA Policy Guidance points out, “Use of current year data increases the reliability of the projected future performance of the proposed project by avoiding reliance on future population, employment, and transit service levels that are themselves forecasts.”²⁰

Staging the forecasts in an incremental model explicitly isolates sources of error, makes consistencies in the non-transit assumptions transparent, and reduces superfluous calculations. When only variations in the transit service are under consideration, Stage 3 of the incremental model is the only step needed to evaluate each proposed variation in transit service. This method does not preclude varying inputs other than the transit service (i.e., for sensitivity testing) but allows such variation to be addressed simply and specifically, rather than as a hidden piece of a very large and complex model.

2.6 Stage 1—Changes in demographics

2.6.1 Formulation of Stage 1 forecasting analysis

The ST ridership forecasting analysis depends on PSRC model databases for the overall growth in travel demand when performing future year forecasts. Growth estimates could either be derived from PSRC model trip distribution results or directly based on forecasts of demographics. Travel growth factors for the ST model are derived from published PSRC forecasts of households and employment growth.

Growth in total households and employment between 2016 and a future year is calculated at a FAZ level and applied to the base year (2016) transit-trip tables using a two-dimensional matrix balancing method (i.e., similar to a Fratar calculation). The results of the Stage 1 analysis are the estimated transit trips for a future year. The secondary impacts of growth on transit demand (e.g., increased highway congestion or costs) are not yet accounted for at the end of Stage 1.

A combination of households and employment is used in establishing the zonal growth factors applied at the origin and destination end of the base year (2016) trip tables.

- For the PM peak period, a combination of 20 percent households and 80 percent of employment is used to calculate the growth in PM peak transit origins and the reverse is used to calculate growth in PM peak transit destinations.
- For the off-peak period, a combination of 50 percent households and 50 percent employment is used to calculate growth for both origins and destinations.
- These factors are derived from ST on-board surveys conducted over the years 2011 through 2016.

²⁰ Final Interim Policy Guidance—FTA Capital Investment Grant Program (June 2016).

Because of earlier concerns about a supposed tendency of two-dimensional balancing to artificially increase trip lengths, an examination is performed to determine any alteration in average trip length for every application of the Stage 1 process. As highlighted in Figure 2-5, the balancing method has only slightly changed the underlying average trip length frequency distribution exhibited in the base year (2016) transit trip table. In fact, the average trip length and the standard deviation of the trip lengths increase slightly upon application of the two-dimensional balancing. While this check on trip lengths is performed for each new application of the Stage 1 balancing, the results of the checks have consistently shown the process to be neutral for trip lengths.

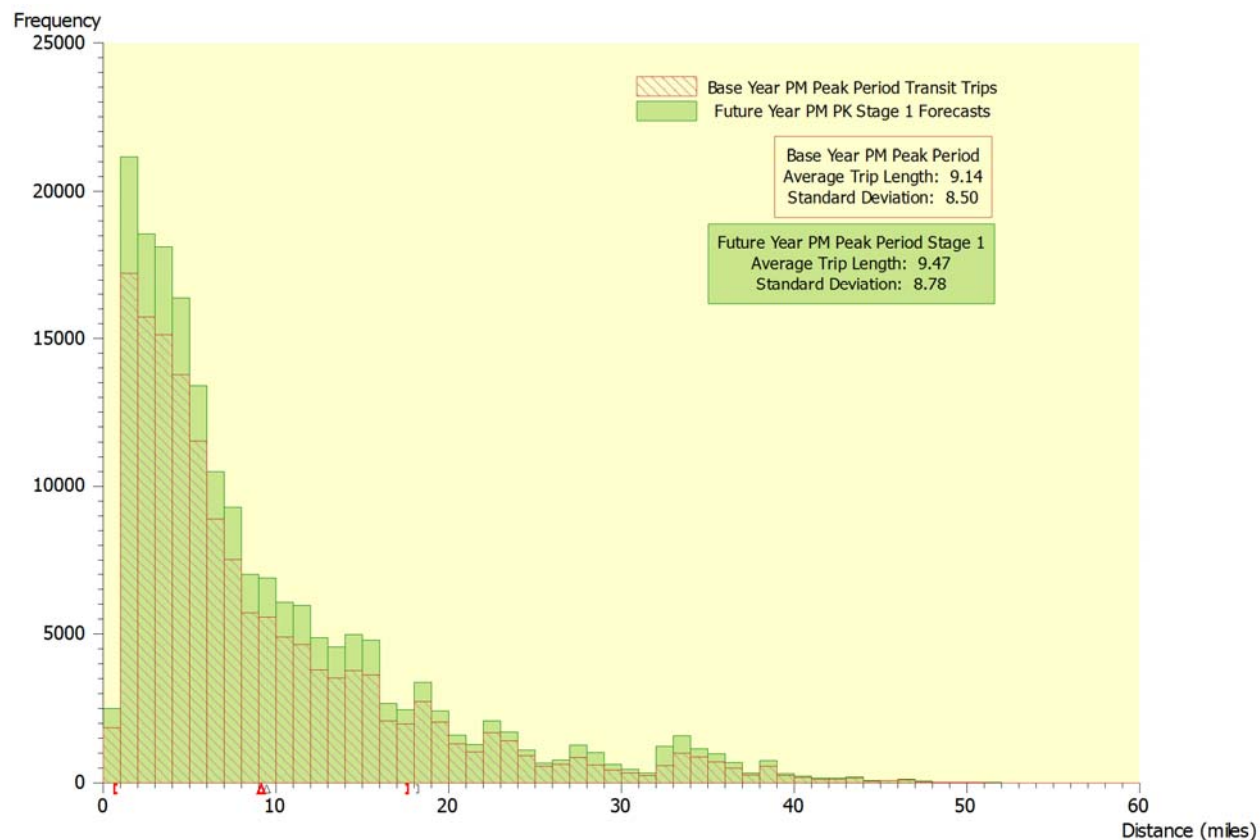


Figure 2-5. Average trip length frequency distribution comparison

2.7 Stage 2—Changes in highway congestion and cost

2.7.1 Formulation of Stage 2 forecasting analysis

Stage 2 considers how changes in highway congestion and auto costs (including parking, operating, and insurance) will influence mode choice.

The ST ridership forecasts use the PSRC model version, as adopted by WSDOT for travel forecasting in support of major highway projects, to estimate highway travel times. This highway model has been refined and validated in recent years for use on the SR 99 Alaskan Way Viaduct & Seawall Replacement project, the I-90 tolling analysis, Puget Sound Gateway project, the Lynnwood Link and Federal Way Link Extensions (see Appendix C). Base year (2016) zone-to-zone highway travel times are obtained directly from Google travel time data (see Appendix B). Rate of change in highway travel times is obtained using the PSRC model and applied to actual base year highway travel times to establish future year zone-to-zone highway travel times. This incremental process is executed on the FAZ-to-FAZ highway travel times.

When a transit alternative significantly affects the highway system (e.g., taking freeway lanes for transit facilities), additional analysis of future highway networks and congestion using the PSRC highway model is required. Likewise, when a Build alternative has significantly higher ridership in a corridor than the No Build alternative, an additional highway model application may be necessary to account for slightly higher highway volumes in a No Build alternative.

In the Puget Sound region, transit fares and auto costs (except parking costs) are usually assumed to increase only at the rate of overall inflation; therefore, they are usually immaterial to the ST model. The ST model, however, includes these variables for use in sensitivity tests that are not directly part of project planning ridership forecasts.

Stage 2 transit trip forecasts are calculated using the following incremental logit equation:

$$(8) \quad \text{Stg2Trn} = \frac{\text{Stg1Trn}}{S_t + (1 - S_t) \times [\exp(K \times \text{DIFF LogSum}_h)]}$$

where

Stg2Trn	=	Stage 2 transit trip forecasts
Stg1Trn	=	Stage 1 transit trip forecasts
S_t	=	the base year observed transit shares
K	=	nesting coefficient on the auto nest
DIFF LogSum _h	=	Difference in the LogSum values due to changes in highway congestion and auto costs (future vs. base year). Data from the ACS and CTR surveys (for the baseline share), highway skims, and auto costs are used in Equation 8 to estimate the DIFF LogSum _h on the auto side.

Stage 2 transit-share forecasts (Stg2Shr) are also calculated as follows:

$$(9) \quad \text{Stg2Shr} = \frac{\text{Stg2Trn} \times S_t}{\text{Stg1Trn}}$$

Resulting from the Stage 2 forecasting analysis are the transit trips for a future year, having accounted for factors external to the transit service itself. These results then serve as a platform for analysis of ridership on alternative transit networks. Note that bus speed degradations are used in the Stage 3 forecasting analysis. They are, however, based on changes in the level of highway congestion estimated using the Stage 2 PSRC model runs.

Note also that the final distance skim matrices from Stage 2 are saved for subsequent calculation of vehicle-miles traveled when estimating the environmental effects of various transit alternatives. This simple multiplication of a vehicle miles' matrix by a New Riders matrix is now incorporated in the FTA's Final Policy Guidance for estimating the environmental effects for New and Small Starts evaluations.²¹

In most project planning ridership forecasting, Stages 1 and 2 need not be calculated as often as Stage 3. It is only when a transit alternative is presumed to have a strong effect on external factors, such as the regional highway network, that the entire process would have to be cycled through. However, for the New Starts project rating purposes, FTA discourages forecasts that are based on different externalities for different alternatives.²²

2.7.2 Estimation of parking costs

For the purpose of representing daily and hourly parking costs more accurately, a survey of parking costs scattered around the parts of the region that have paid parking was conducted in 2017. Based on the findings from this survey, base year daily parking costs were updated. This update compared target daily values with observed hourly parking rates, showing that the ratio of hourly-to-daily parking averaged around 25 to 30 percent, with a range from 10 percent in South Lake Union to 42 percent in downtown Seattle and around Seattle Center.

According to the limited historic information available, real parking costs have averaged an annual growth of approximately 1.5 percent since 1960. This is primarily attributable to changes in employment density, which has averaged similar growth over the last five decades. Forecast increases in employment density at the FAZ-level are used to estimate future year changes in real parking costs. This results in parking cost increases around the region varying between 0.5 and 2.0 percent per year between 2016 and 2040. The average for all zones for which there are parking cost increases is around 1.0 percent annually, with the weighted average being considerably lower.

2.7.3 Estimation of other costs and median income

Because auto operating costs in the Puget Sound region are usually assumed to increase only at the rate of overall inflation, they are less significant to ST models. Base-year (2016) and future auto operating costs are estimated at about \$0.19 per mile (in 2016 dollars). Auto operating costs also include any relevant tolls or driving fees. The ST model assumes a conservative 0.5-percent annual (real) growth in income.

²¹ Final Interim Policy Guidance—FTA Capital Investment Grant Program (June 2016).

²² Final Interim Policy Guidance—FTA Capital Investment Grant Program (June 2016).

2.8 Stage 3—Changes in transit service

2.8.1 Formulation of Stage 3 forecasting analysis

In the third and final stage of the forecasting analysis, the incremental changes in the transit level of service, including transit fares, are considered. This change (as indicated in Section 2.4.1) is reflected in the resulting relative values of the LogSum_t variable using the base-year and future transit networks.

The Stage 3 transit shares and ridership forecasts are calculated as follows:

$$(10) \quad P'_{ac} = \frac{P_{ac} \times \text{LOS}_{ac}}{P_{ac} \times \text{LOS}_{ac} + (1 - P_{ac}) \times \text{LOS}_{wlk}}$$

and

$$(11) \quad \text{Stg3Trn} = \frac{\text{Stg2Trn} \times [\exp(K \times \text{DIFF LogSum}_t)]}{\text{Stg2Shr} \times [\exp(K \times \text{DIFF LogSum}_t)] + [1 - \text{Stg2Shr}]}$$

where

LOS_{ac} = Difference in (future vs. base year) utility of the park-and-ride access submode

LOS_{wlk} = Difference in (future vs. base year) utility of the walk-access submode

ac = Forecasted Stage 3 shares for the auto-access mode

P_{ac} = Base-year observed shares for the auto-access mode, derived from the base year trip table development process reflecting actual counts on park-and-ride facilities.

K = Nesting coefficient

DIFF LogSum_t = Difference in the LogSum values due to changes in transit level-of service (future vs. base year)

Transit service that is taken into consideration in the ST model Stage 3 forecasting analysis is represented by means of a coded network. Details on transit network preparation are included in Appendix D. Treatment of bus speeds in the ST model includes the degradation of bus speeds due to roadway congestion, estimated by the PSRC model in a manner developed in consultation with the FTA.²³ Bus speed degradation is considered in Stage 3 forecasting analysis and held constant among alternatives. It is applied only to bus run time in mixed traffic (excluding high-occupancy vehicle lanes) and not to dwell and lay-over time components.

2.8.2 Transit fares

Any changes in transit fares are considered in Stage 3 of the ST model, along with changes in transit service. However, fares are always held constant among alternatives. Transit fare matrices were developed for the ST model and were assumed to be:

- The zone-to-zone averages in effect in 2016 (for the base year)
- The zone-to-zone averages in effect at the start of a project (for all future years)

²³ Billen, D., Sound Transit, "Updated Treatment of Bus Speeds in the Sound Transit Model," Memorandum to Eric Pihl of FTA, dated August 1, 2002. A copy of this memorandum is included in Appendix D.

- Independent of transit path choices

Independence from path choice is a reasonable approach to fares with the RTA District. The path-independent approach to transit fares also aligns with FTA's guidance to keep any fare-related utility differences between alternatives to a minimum. Upon the introduction of the ORCA smart card as the primary fare medium for all transit operators in the District, zonal fares are more appropriate than path-based fares. For most trips within the District, the fare implications of path choice and transfers have become less critical for forecasting. This is due to the very high market penetration of the regional employer pass programs, to the wide use of ORCA smart cards and to the refined agreements among the transit operators for assigning cash value to trips involving more than one transit vehicle or more than one transit agency.

3 Base Year Transit Trip Table Development and Validation

Before a model can be used for transit travel analysis, it must be validated. The process of validation involves comparing the performance of the model to the most recent observed data sources available to confirm that the model is accurately replicating current transit travel patterns.

An incremental approach, which is used in the ST model, generally reduces the need for validation because it relies not on travel behavior theory, but on current data. However, it is still useful to check the overall performance of the model against current known conditions.

This model version represents a departure from previous versions, primarily because of a significant increase in the amount of data available in the Puget Sound Region for describing current transit travel. The most significant of these is the availability of ORCA fare card transaction data, which removes the need for an ad hoc assembly of disparate seed matrix sources.

The availability of detailed and accurate system-wide peak and off-peak transit speed data from AVL systems enables a complete revision to previous methods for posting transit speeds. Of further significance, has been the increased detail and improved sample rates for the APC data, including stop-to-stop volumes and boarding and alighting details by stop.

This chapter is organized into three sections. Section 3.1 describes the data preparation, including network data, ridership count data, and seed matrix data. Section 3.2 describes the base year matrix estimation process. Section 3.3 describes the base year (2016) validation results and the final transit demand matrices.

3.1 Data preparation

3.1.1 Transit network

To facilitate translation of speeds and other geographic data to and from the model networks, all model networks are now converted to the XY coordinate base used in most local GIS and transportation applications (i.e., *Washington State Plane North* coordinates). Documentation of this shift of the coordinate system is provided in Appendix D.

Transit operating speeds are no longer estimated from posted schedules and spot data from terminus-to-terminus reliability reports, but directly from AVL systems managed by the transit operators. Thus, average speeds for every stop-to-stop segment within the RTA district boundaries are posted from the measured average speeds directly to the ST Model transit network. Documentation of this direct translation of operating data to model speeds is also provided in Appendix D.

Regional transit agencies currently implement two service changes each year, in late September and late March.

- This model version is constructed on a transit network base covering the winter 2016-2017 service levels (late September 2016 to late March 2017). We refer to this network as the 2016 Base Year network even though it spans six months over portions of two calendar years.

- The Base Year transit network thus includes the two recently opened Link light rail extensions—north to the University of Washington in March 2016 and south to Angle Lake in September 2016.
- The Base Year transit network also includes associated King County Metro (KCM) bus service changes implemented in response to those Link extensions.
- The Base Year transit network reflects all bus service as operated by all operators throughout the ST District for this winter 2016-2017 Base Year service period.
- Bus and rail headways are still obtained from agency posted schedules.
- Headway management data is now available stop-by-stop only for rail lines but are not available for bus lines. Such data may be useful in the future for adjusting model headways to data-driven perceived headways.
- All fixed-route fixed-schedule public transit services within the ST District are included, except for lines with fewer than six scheduled trips per weekday.
- Demand-response services, dial-a-ride services, employer provided services, and ferry services are omitted from the transit network.

3.1.2 Passenger counts data

Current passenger counting techniques have improved greatly, both in their accuracy and their level of available detail. This may be especially true here in the Puget Sound Region, although the technologies used are now widely available. The sampling rate for counts in this region is now over 25 percent on local bus lines, 30 percent on Link light rail, 50 percent on bus rapid transit lines, and 100 percent on commuter rail lines. Likewise, the detail available includes all stops, all segments, and all times of day by direction and vehicle trip.

The resulting data, averaged over a half year or over a quarter, should be considered perfectly reliable as a precise snapshot of current transit travel. Use of this level of existing detail resolves a significant portion of potential Base Year error. Detailed ridership counts were obtained from all transit operators within the RTA district boundaries. For the winter 2016-2017 service period described above, these operators are

- King County Metro
- Pierce Transit
- Community Transit
- Everett Transit
- Sound Transit

All the above operators supply complete ridership data from on-board APC systems. This data includes boardings and alightings by stop or station, by line, by direction, by trip, and by time of day. For use in the ST Model, the counts data is consolidated into segment volumes by line and by direction for peak and daily volumes and peak and daily boardings and alightings by stop or station. Off-peak counts are calculated from daily counts so that the daily counts remain control totals for all APC data. The

consolidated counts data is processed directly into various stages of the matrix estimation process as described in Section 3.2.

- The PM peak period is defined as 3:00 p.m. to 6:30 p.m. for the partitioning and consolidation of the counts. This time-period allows specification of the peak-only services and peak-specific train and bus frequencies.
- For the ST model, an AM peak period is not defined or used directly in the model.
- Daily counts are consolidated into 24-hour totals for an average weekday within the six-month period described above.
- The daily counts always represent control totals for the boarding, alighting, and segment volume counts.
- Off-peak counts for use in the off-peak matrix estimation process are calculated as daily counts minus the PM peak counts minus the inverse of the PM counts, then balanced by direction.
- Detailed boarding and alighting counts by stop or station, line, direction, and time-period are retained for use in Matrix Estimation Quality Control (QC) exercises.
- QC methods include both machine error trapping and direct inspection of results on the model network.
- Further QC efforts are undertaken during the matrix estimation process as issues and inconsistencies arise in transit demand assignments produced over many iterations of matrix estimation.

The number of counts posted and the precise locations of the postings changes somewhat during the iterative matrix estimation process in response to issues arising in the QC process. Therefore, the number and types of posted counts are described in Section 3.2.

3.1.3 Data for seed matrices

Because of the difficulties inherent in attempting to accurately estimate or synthesize the shape of travel demand O-D matrices, the ST Model now uses primarily ORCA fare card data to construct the shape of the Base Year transit trip tables. This source substantially replaces the sparse and outdated rider O-D data from on-board surveys used in previous model versions.

- The widespread use of regional fare cards provides a very large sample of transit travel patterns (over 60 percent regionally and over 75 percent on ST rail and bus services). Not all of this ORCA data is directly usable for the seed matrices for a variety of reasons related to fare collection anomalies. However, the usable data sample remained very large, about 50 percent.
- Additional transit rider data from recent Washington CTR peak commute surveys and recent ST on-board rider surveys are also used, to the extent that they open new cells in the seed matrices.

The ORCA data has some specific advantages compared to sources of O-D patterns used in previous model versions. These include

- The data contains all types of transit trips, regardless of trip purpose, and is not skewed toward commute trips or long trips.
- The trip sample is so large that the potential response bias is minimal, compared to the sparse surveys used by ST over many years.
- The data is very detailed regarding time-of-day.
- The data is the first reliable large-sample information on transfer rates and transfer locations, now using a consistent regional definition of transfers.
- Because of its detailed information on transfer behavior, ORCA data provide data-driven rather than model-estimated totals of observed linked-trips for peak, off-peak, and daily transit travel, now using a consistent definition of what constitutes a linked-trip.

Data analysis and trip table preparation is a cooperative effort between ST and the Washington State Transportation Center (TRAC) at the University of Washington. Details of the ORCA data processing and geocoding to the ST Model 807-zone system are provided in Appendix B.

Some relevant basic information on the ORCA data details presented in Appendix B would include

- ORCA data is obtained for all transit operators on all lines operating within the ST District.
- The data chosen covers weekdays over a 9-week period from March 26, 2016, through May 28, 2016, after the University Link extension opened but prior to the Angle Lake station opening.
- Trips included in the resulting seed matrices account for 20.4 million weekday boardings, of which 4.9 million boardings involve transfers. This translates into an average weekday transfer rate of 1.32.
- The ORCA data comprises 97 percent of all trips in the two resulting (PM peak and off-peak) seed matrices and accounts for 90 percent of the O-D open cells. Total open cells amount to 29 percent of the available cells in the two 807-by-807 seed matrices.

3.2 Matrix estimation

Matrix Estimation (ME) in the ST transit model creates Base Year transit demand matrices, which replicate measured existing average weekday transit flows.²⁴ The methodology requires well-validated networks, precise ridership counts, and seed matrices of peak and off-peak transit demand in a zone structure tailored to the transit networks. The method uses an iterative gradient-reduction approach to minimize the differences between estimated and observed ridership counts posted at designated locations on the network.

The objectives of the ME process are to achieve a close match between estimated and actual peak and daily

- Transit volumes
- Boardings and alightings at all stations and at major BRT and high ridership bus stops

²⁴ The updated ST model was implemented in the current EMME Software (version 4.3.3). The Matrix Estimation process in the current EMME Software was used to develop base year (2016) demand matrices.

- Boardings by line
- Average trip length by operating agency and mode and by line for rail lines and BRT lines

3.2.1 Stepwise matrix estimation

It is possible to run ME in a single process which considers all routes at once and to achieve reasonable R-squared, slope, and intercept results for the major transit lines at their high-volume locations. The gradient-reduction measures with this method may indicate relative closure after about 25 iterations showing an apparent equilibrium between the lines and the matrices.

This apparent equilibrium is deceptive because closer examination of results of a single-step approach reveals that low-volume and medium volume lines and some low-volume segments on high-ridership lines may show serious mismatches in the resulting volumes. In the type of detailed analysis ST requires from this model, such relatively minor errors in the Base Year validation and in forecasting situations can seriously detract from the usefulness of the model.

Therefore, the ME is performed in a sequential and cumulative manner. Performing the ME in this manner mitigates the dominance of high-volume routes and allows better alignment of the counts data within subareas and within service types. The specification of the matrix estimation process in steps is shown in Table 3-1.

Table 3-1. Specification of matrix adjustment in steps

Step No.	Count Posting Type	Routes Considered
Step 1	Segments	Include segment counts from Pierce Transit, Everett Transit, Community Transit (excluding SWIFT line), and KCM 900 routes
	Boardings/Alightings	Bus boardings/alightings on RapidRides A/C/D, ST express bus, and KCM mid-town mid-range routes
Step 2	Segments	Step 1 + KCM local routes and street car + ST routes 541/556/566/596
	Boardings/Alightings	Same as Step 1
Step 3	Segments	Step 2 + KCM mid-town, mid-range routes
	Boardings/Alightings	Same as Step 1
Step 4	Segments	Step 3 + CT SWIFT + all ST and KCM routes excluding C/D/E/545/550/Sounder/Light Rail
	Boardings/Alightings	Same as Step 1
Step 5	Segments	Step 4 + RapidRides C/D/E + ST routes 545/550
	Boardings/Alightings	Step 4 + boardings/alightings for Sounder
Step 6	Segments	Same as step 5
	Boardings/Alightings	Step 5 + boardings/alightings for Light Rail

The segment counts are first grouped based on the markets and the service type. Then, the matrix adjustment is performed on each group by cumulatively including the segment loads from all the previous groups and using the previous result matrix as a new seed matrix. Such a step-wise matrix estimation process allows adjusting the transit-trip table for low volume segments before including the next level of higher volume segments. This allows the ME adjustment method an opportunity to adjust

segments or stops with low volumes as well as segments with high volumes. The adjustments to low-volume segments or stops are not greatly modified as the higher-volume segments are brought in, so low-volume information is retained.

3.2.2 Calibration of path parameters

The approach to ME outlined above is complemented by an extensive and rigorous path analysis effort. This effort involves comparisons over many runs of ME against all available data, including agency data on line boarding and alighting locations, average trip lengths, route segment volumes, and other data available for the Base Year.

The parameters used in path-building are of critical importance in estimating path changes between an existing network and a proposed network, whether the proposed network postulates minor or major changes. These parameters include walking speeds, “escalator” link lengths, auto-access parking lot walk link lengths, boarding penalties, and weights or perception factors applied to the various components of out-of-vehicle time.

Previous ST model versions used a variety of weakly-calibrated assumptions, often postulated from external sources. The wealth of detail available for this model calibration enabled the first serious check of those postulated parameters. Since the parameters should be held constant through Matrix Estimation, Base Year assignments, mode choice skims, and final assignments, they are calibrated during the ME process.

The calibration involves many iterations through ME and final assignments. This requires constant checks against aggregate data, such as actual transfer rates, and detailed data, such as route-level and bus-stop-level boardings and alightings. An extensive analysis of outlier routes using scatterplots of estimated vs. actual boardings/route and average trip lengths is particularly productive in parameter calibration. These checks also provide as a byproduct, extensive QC checks on minor errors in the counts data and minor network coding errors. Table 3-2 shows the more important resulting path-building parameters.

The iterative check of assignment result details also includes review of important transfer locations, with emphasis on locations of existing rail transfers, and bus transfer activity at likely future rail transfer locations. Virtually all likely future rail transfer locations are on existing BRT or ST Express Bus lines.

Finally, the iterative ME calibration process allows adjustment of the count data posting locations, including moving or adding segment count locations to capture minor variations in the market profile along individual routes. For this model version, it allows posting boarding and alighting data at all rail stations and the major BRT and ST Express Bus stops. The final PM peak ME relied on posted actual ridership values at 1140 line segments and 180 stations or stops. The off-peak ME used about 80 percent of these, reduced by the presence of some having no off-peak service, e.g., Sounder Commuter Rail.

Table 3-2. Boarding penalty, wait time factor, and escalator link parameters

Description	Value
Regular Bus Stops	
Boarding penalty	4.0 minutes
Wait time factor	0.60
Escalator link	NA
Transit Centers¹	
Boarding penalty	3.0 minutes
Wait time factor	0.50
Escalator link	NA
Downtown Bus Tunnel	
Boarding penalty	3.0 minutes
Wait time factor	0.50
Escalator link	1.4 minutes
Rail Stations (surface)	
Boarding penalty	1.5 minutes
Wait time factor	0.50
Escalator link	1.2 minutes
Rail Stations (tunnel or elevated, excluding Downtown Seattle Transit Tunnel stations under joint operations)	
Boarding penalty	1.5 minutes
Wait time factor	0.50
Escalator link	1.4–2.4 minutes

¹ List of Major Transit Centers (TC):

- | | |
|-------------------------|-------------------------------------|
| 1) Bellevue TC | 13) Lakewood TC |
| 2) Federal Way TC | 14) Everett Station |
| 3) Northgate | 15) Tacoma Community College |
| 4) Burien TC | 16) Tacoma Commerce St |
| 5) Kent Station TC | 17) Tukwila International Boulevard |
| 6) Auburn Station TC | 18) Tukwila Station |
| 7) Kirkland v | 19) Lakewood Station |
| 8) Overlake TC | 20) Sumner Station |
| 9) Aurora Village TC | 21) Puyallup Station |
| 10) Renton TC | 22) Issaquah TC |
| 11) Lynnwood TC | 23) West Seattle |
| 12) Tacoma Dome Station | 24) Ballard |

Related Assumptions:

- Walk speed = 2.5 mph
- Weight factor on out-of-vehicle travel times = 1.5
- Weight factor on the auxiliary walk times on 1st, 2nd, 3rd and 4th Avenues in downtown Seattle leading to King Street Station = 1.0

3.2.3 Sensitivity test using ST3 build network

Understanding the performance of this model version compared to the previous version, i.e., the 2014 Base Year version used for the ST3 planning work, suggests applying a Current Year sensitivity test using the ST3 Build network. This requires a Current Year forecast using the new model version for comparison with the previous Current Year forecast for ST3 performed using the 2014 model version. Not only does this provide additional QC opportunities, especially on the network specifications, but it enables several checks on the model application to future networks, which include significant expansion of the rail system and realignment of the bus systems.

This is particularly important for understanding the relevance of unassigned trips. These trips are short trips which are in the seed matrix and therefore known to have occurred on transit, but which are assigned as walk-only paths. The trips therefore never appear as transit boardings or segment volumes.

The change in the transit path times between the Base Year network and a future network, such as the ST3 Plan network, results in some of these short trips having efficient paths using rail segments in the future network, even though they were erroneously assigned as walk-only trips in the Base Year network. Identification and analysis of unassigned trips is necessary to minimize discrepancies between the trip tables and the resulting transit network values.

3.2.4 Identification and removal of unassigned trips

Unassigned trips are analyzed by network analysis of the assignment results, especially network analysis of those trips assigned by themselves. Because EMME transit assignments are multi-path, unassigned trips in the ST model tend to be unassigned portions of trip values within certain O-D pairs, in particular closely adjacent zones.

Careful examination of the transit paths and fine-tuning of network elements in areas of dense transit demand and dense network structure enables the reduction of the total unassigned trips from 14,000 to 6,700, when correcting path elements on the Base Year network. In the application of the sensitivity test described above as a Current Year forecast on the ST3 Build network, the unassigned trips are reduced to 3,800. This includes the removal of 2,000 ferry trips double-counted upon the introduction of ORCA data as the primary source for transit travel patterns.

The final effect of the matrix estimation on the travel patterns in the initial seed matrix is summarized in the trip length frequency distribution comparison shown in Figure 3-1. This comparison is between the seed matrices at the start of ME and the resulting final Base Year demand matrices. Trip lengths in this figure are for entire zone-to-zone linked-trips. For consistency, the transit trip lengths for this comparison are based on a common neutral highway distance between zones.

As shown, the ME process has not impacted original shape exhibited in the seed matrix. It has only reduced the number of transit trips longer than 6 miles and increased the number of trips shorter than 6 miles. It has correspondingly reduced average transit trip length to 8.36 miles from almost 10 miles in earlier model versions.

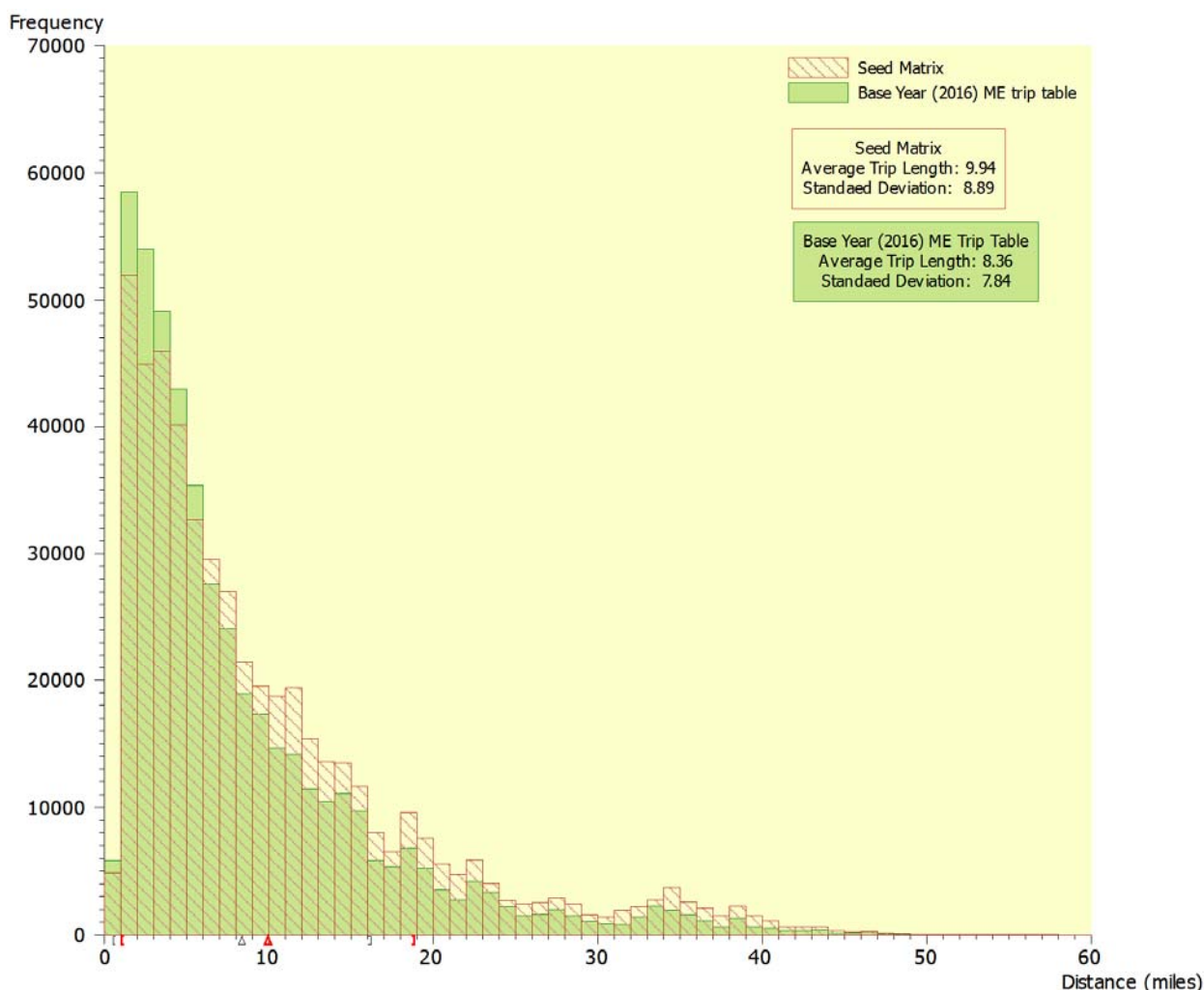


Figure 3-1. Average weekday (2016) trip length frequency distribution comparison: Seed matrix vs. matrix-estimated trip table

The validation analysis results for Base Year (2016) transit-trip table development are discussed below.

3.3 Base Year (2016) validation results

The validation analysis focuses on evaluating both the transit trip tables from the matrix estimation process and the accuracy of the assignment results. These are reflected in

- System-wide linked and unlinked trips and the system-wide transfer rate
- Transit boardings comparison by agency and mode
- Rail station boardings comparison for all existing stations
- Transit ridership volumes in locations relevant to major ST3 projects
- Average transit trip length comparison by operator
- Peak and daily boardings by transit line

Table 3-3 presents system-wide linked transit trips and unlinked transit trips by operator and mode. The estimated trips closely match the actual trips in all cases, reflecting the breadth and quality of the network inputs, the counts, and the seed matrix travel patterns from ORCA data.

Table 3-3. Systemwide 2016 linked and unlinked transit trips comparison: PM peak period and average weekday

	PM Peak Period (3:00–6:30 PM)			Average Weekday		
	Actual ¹	Estimated	Est/Act	Actual ¹	Estimated	Est/Act
Linked transit trips	145,500	151,900	1.04	467,000	466,900	1.00
Total Boardings by Operator						
KC Metro	119,500	122,200	1.02	397,000	384,200	0.97
Sound Transit	51,300	52,500	1.02	151,600	151,600	1.00
Pierce Transit	6,700	7,200	1.07	27,000	28,800	1.07
Community Transit	11,100	11,600	1.05	34,000	32,600	0.96
Everett Transit	2,000	1,900	0.95	7,000	7,000	1.00
Three-county total boardings	190,600	195,400	1.03	616,600	604,200	0.98
Systemwide transfer rate ²	1.31	1.31	1.00	1.32	1.32	1.00
Rail and Regional Bus Boardings						
Central Link Light Rail	22,100	21,800	0.99	68,400	67,700	0.99
Tacoma Link Light Rail	900	900	1.00	3,600	3,100	0.86
Commuter Rail	8,500	8,400	0.99	16,600	16,900	1.02
ST Express Bus	19,800	21,500	1.09	63,000	63,900	1.01

¹ Actual boardings are the actual counts for the winter 2016/2017 obtained from transit agencies.

² Transfer rates are calculated by excluding unassigned trips.

The total estimated PM peak linked transit trips are 151,900, which is 32.5 percent of the total weekday 467,000 linked transit trips.

In this model version, the actual transfer rates of 1.32 for average weekday and 1.31 for PM peak are known for the first time, due to the availability of ORCA fare card data, as described above in Section 3.1.3. These observed transfer rates are also the basis of the 467,000 (for average weekday) and 145,500 (for PM peak) actual linked trips shown in the first row of Table 3-3 for the transit system. The definition of what exactly constitutes a linked trip is now closely tied to the regional agreement on fares and transfer policies, managed by Sound Transit and agreed upon with the other transit operators. The primary purpose of the regional agreement is revenue sharing among the operators, for which transfer information is an important input.

The close match between estimated and actual boardings by agency and mode is evident in Table 3-3. Both estimated and actual boardings reflect the same model Base Year period and bus service period, late September 2016 through late March 2017.

Table 3-4 and Table 3-5 show station-by-station comparisons of estimated versus actual station boardings for the same period. The closeness of the estimates to the counts at this level of detail is explained by the introduction of boarding and alighting counts, augmenting the segment line volume counts in the ME process.

Table 3-4. Average weekday (2016) light rail station boardings comparison

Station Name	Actual	Estimated	Est/Actual
UW	9,400	9,400	1.00
Capitol Hill	8,000	8,000	1.00
Westlake	10,200	9,900	0.97
University Street	5,300	5,200	0.98
Pioneer Square	4,100	3,900	0.95
International District	5,600	5,500	0.98
Stadium	1,300	1,400	1.08
SODO	1,900	2,000	1.05
Beacon Hill	2,900	2,900	1.00
Mount Baker	2,300	2,200	0.96
Columbia City	2,400	2,500	1.04
Othello	2,400	2,500	1.04
Rainier Beach	1,900	1,900	1.00
Tukwila International Blvd	2,900	2,800	0.97
Sea-Tac Airport	5,000	4,900	0.98
Angle Lake	2,900	2,700	0.93
Total Station Boardings	68,500	67,700	0.99

Table 3-5. Average weekday (2016) commuter rail station boardings comparison

Station Name	Actual	Estimated	Est/Actual
Everett	300	300	1.00
Mukilteo	200	200	1.00
Edmonds	400	400	1.00
King Street	6,800	7,000	1.03
Tukwila	1,000	1,000	1.00
Kent	1,900	2,000	1.05
Auburn	1,500	1,600	1.07
Sumner	1,200	1,200	1.00
Puyallup	1,500	1,500	1.00
Tacoma Dome	1,200	1,200	1.00
South Tacoma	200	200	1.00
Lakewood	400	300	0.75
Total Station Boardings	16,600	16,900	1.02

Table 3-6 compares estimated and actual bus ridership volumes at eight locations in major transit corridors. These locations are chosen for their relevance to major rail and BRT projects in the ST3 System Plan. The comparison illustrates that the existing base year volumes are closely approximated by the Base Year model in corridors which will be of interest over the term of this model version.

Table 3-6. Comparison of 2016 estimated and actual average weekday volumes—locations relevant to major ST3 Projects

Everett Extension: Routes 510/512/513/532 & Sounder, north of Ashway	4,700	4,400
Tacoma Extension: Routes 574/586/590/592/594/595 & Sounder, at county line	14,600	14,600
Ballard: RapidRide D at Magnolia Bridge	6,700	7,100
West Seattle: RapidRide C at West Seattle Bridge	7,000	7,100
I-405 BRT: Routes 532/535, at county line	2,500	2,500
I-405 BRT: Routes 560/566/567, at Coal Creek	2,300	2,200
I-405 BRT: Route 560 at Tukwila	900	800
SR 522 BRT: Route 522 at Kenmore	2,400	2,400

Table 3-7 and Table 3-8 contain summaries of the Base Year PM peak and daily trip tables at 10 x 10 districts. A map of the 10 districts is shown in Figure 3-2. Note that the totals for each of these matrices are the same as the totals presented in Table 3-3. These tables are the result of the matrix estimation process, representing a snapshot of the Base Year transit demand within the 3-county ST district. The matrices are the platform for subsequent work using the staged incremental transit demand model as described in Chapter 2.

Estimated and actual base year average in-vehicle trip lengths are compared in Table 3-9. Actual trip lengths shown are for the length of travel in each transit vehicle, derived from agency-reported total passenger-miles and boardings by mode. Thus, these trip lengths are not directly related to the overall zone-to-zone linked-trip lengths shown in Figure 3-1. The shorter average trip lengths on ST Express bus lines (8 percent low) are indicative of matrix estimation process estimating greater than actual rider turnover on some of the longer of these lines. The directional volumes on segments along these lines match the volume counts very closely.

Table 3-7. 10-district base year (2016) PM peak period transit trip table

ORIGIN	DESTINATION	Everett	SW Snohomish	Shoreline	North Seattle	Seattle CBD	South Seattle	East King	South King	Tacoma	Pierce	Origin totals	Origin shares
		1	2	3	4	5	6	7	8	9	10		
Everett	1	1,700	300	100	100	–	–	100	100	–	–	2,400	1.6%
SW Snohomish	2	500	1,500	100	200	100	100	100	–	–	–	2,600	1.7%
Shoreline	3	100	200	200	400	100	100	100	–	–	–	1,200	0.8%
North Seattle	4	200	1,500	1,200	11,700	2,200	4,600	1,600	900	300	200	24,400	16.1%
Seattle CBD	5	900	4,000	1,200	10,200	2,100	17,900	7,100	7,000	1,200	1,300	52,900	34.8%
South Seattle	6	400	1,600	600	6,400	5,300	13,800	2,300	5,200	600	1,200	37,400	24.6%
East King	7	300	1,000	100	1,100	1,000	1,500	7,200	900	–	100	13,200	8.7%
South King	8	–	100	–	300	900	1,800	200	7,400	400	900	12,000	7.9%
Tacoma	9	–	–	–	–	–	100	–	200	2,600	1,100	4,000	2.6%
Pierce	10	–	–	–	–	–	–	–	100	800	900	1,800	1.2%
Destination totals		4,100	10,200	3,500	30,400	11,700	39,900	18,700	21,800	5,900	5,700	151,900	100.0%
Destination shares		2.7%	6.7%	2.3%	20.0%	7.7%	26.3%	12.3%	14.4%	3.9%	3.8%	100.0%	

Table 3-8. 10-district base year (2016) average weekday transit trip table

ORIGIN \ DESTINATION		Everett	SW Snohomish	Shoreline	North Seattle	Seattle CBD	South Seattle	East King	South King	Tacoma	Pierce	Origin totals	Origin shares
		1	2	3	4	5	6	7	8	9	10		
Everett	1	6,200	1,600	200	400	1,100	600	400	100	–	–	10,600	2.3%
SW Snohomish	2	1,600	6,100	700	2,100	4,600	1,800	1,300	100	–	–	18,300	3.9%
Shoreline	3	200	700	1,000	2,700	1,800	1,000	300	100	–	–	7,800	1.7%
North Seattle	4	400	2,100	2,700	38,500	17,900	16,200	4,300	1,900	400	200	84,600	18.1%
Seattle CBD	5	1,100	4,600	1,800	18,000	6,600	37,000	10,300	11,500	1,500	1,600	94,000	20.1%
South Seattle	6	600	1,800	1,000	16,200	37,000	46,100	5,400	11,000	900	1,400	121,400	26.0%
East King	7	400	1,300	300	4,300	10,300	5,400	22,400	1,700	–	100	46,200	9.9%
South King	8	100	100	100	1,900	11,500	11,000	1,700	25,900	1,100	1,300	54,700	11.7%
Tacoma	9	–	–	–	400	1,500	900	–	1,100	10,000	3,700	17,600	3.8%
Pierce	10	–	–	–	200	1,600	1,400	100	1,300	3,700	3,400	11,700	2.5%
Destination totals		10,600	18,300	7,800	84,700	93,900	121,400	46,200	54,700	17,600	11,700	466,900	100.0%
Destination shares		2.3%	3.9%	1.7%	18.1%	20.1%	26.0%	9.9%	11.7%	3.8%	2.5%	100.0%	

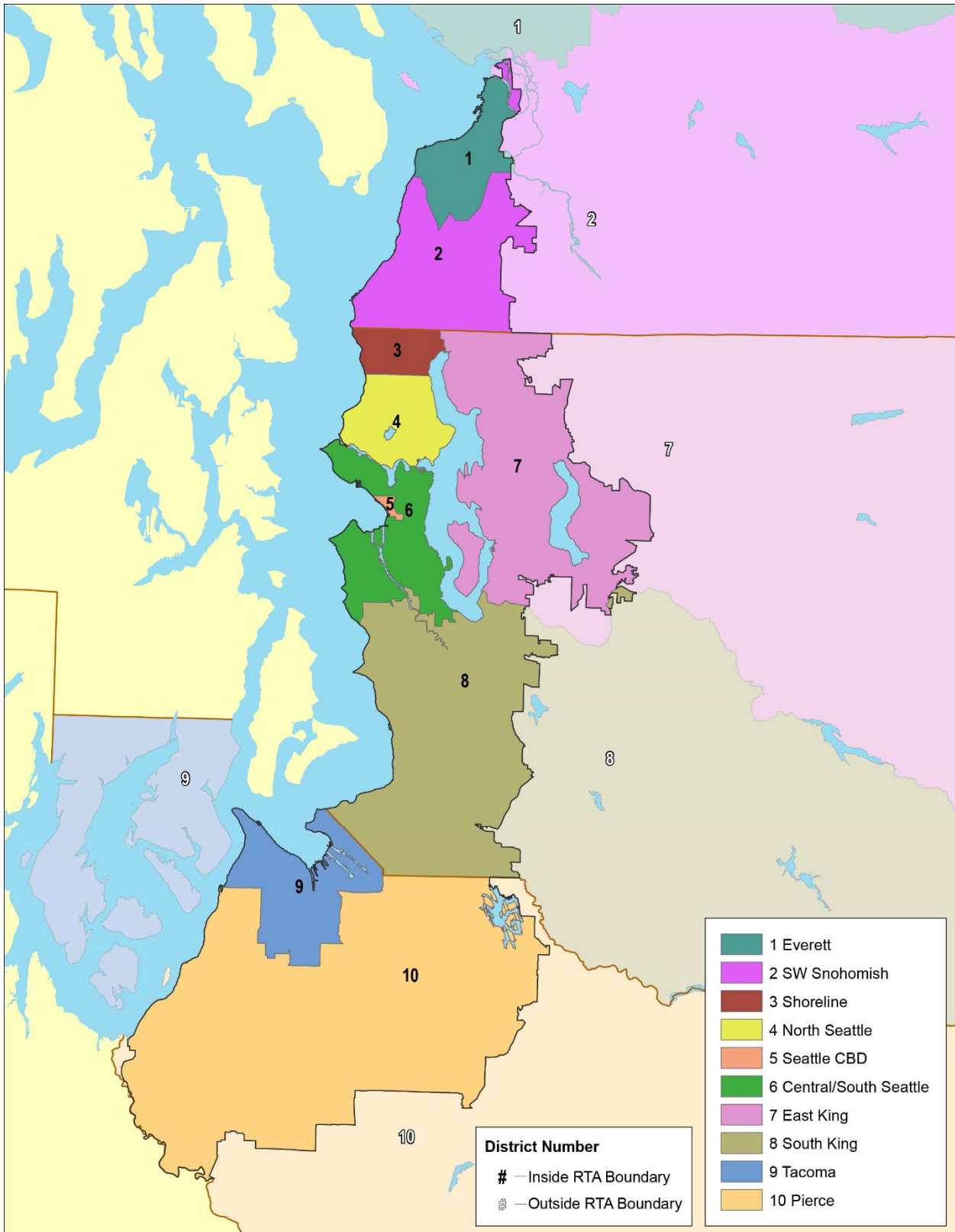


Figure 3-2. 10-district map

Table 3-9. Estimated and actual base year (2016) average weekday in-vehicle trip length comparison

Transit Operator	Actual ¹	Estimated	Est/Actual
King County Metro	4.3	4.1	0.95
Sound Transit Link	6.1	6.1	0.99
Sound Transit Sounder	24.8	24.0	0.97
Sound Transit Express Bus	14.3	13.1	0.92
Pierce Transit	4.1	4.0	0.98
Community Transit	9.3	8.5	0.91
Everett Transit	3.8	4.1	1.08
Systemwide	6.2	6.0	0.97

¹ Bus values are from 2016 National Transit Database; Rail values are from ST winter 2016/2017 counts

Figure 3-3a, Figure 3-3b, Figure 3-4a, Figure 3-4b and Figure 3-5 summarize comparisons of estimated to actual line boardings for every transit line in the region. These are more rigorous validation tests than a comparison of posted line segment volumes, since the matrix estimation process aims at precisely these segment matches. The process consistently returns R-squared values between 0.98 and 1.00. The comparisons of line boardings validates in greater detail the ability of the model estimates to replicate base year ridership profiles on a line-by-line basis.

Note that this attention to line detail is particularly important when a network-based model is to be used to estimate line volumes and station boardings for future rail line extensions. Validations against transit screenline counts do not provide sufficient confidence for forecasts of ridership on specific lines or line segments.

This line-by-line validation test assists the supplemental analysis of outlier bus lines, especially some mid-range ridership lines. The outlier analysis, including stop-level review of actual line profiles, provides strong additional QC on the networks and the counts.

Figure 3-3a and Figure 3-3b illustrates the PM peak line boardings comparisons, including and excluding the rail lines, with R-squared values of 1.00 and 0.98, respectively. Figure 3-4a and Figure 3-4b illustrates the average weekday line boardings comparisons, including and excluding the rail lines, with R-squared values of 1.00 and 0.99, respectively. The comparisons excluding the rail are necessary because of the dominance of Link ridership when it is included.

Finally, Figure 3-5 illustrates the average weekday boardings comparison for ST Express bus lines only, with an R-squared value of 0.98 and a slope of 0.99.

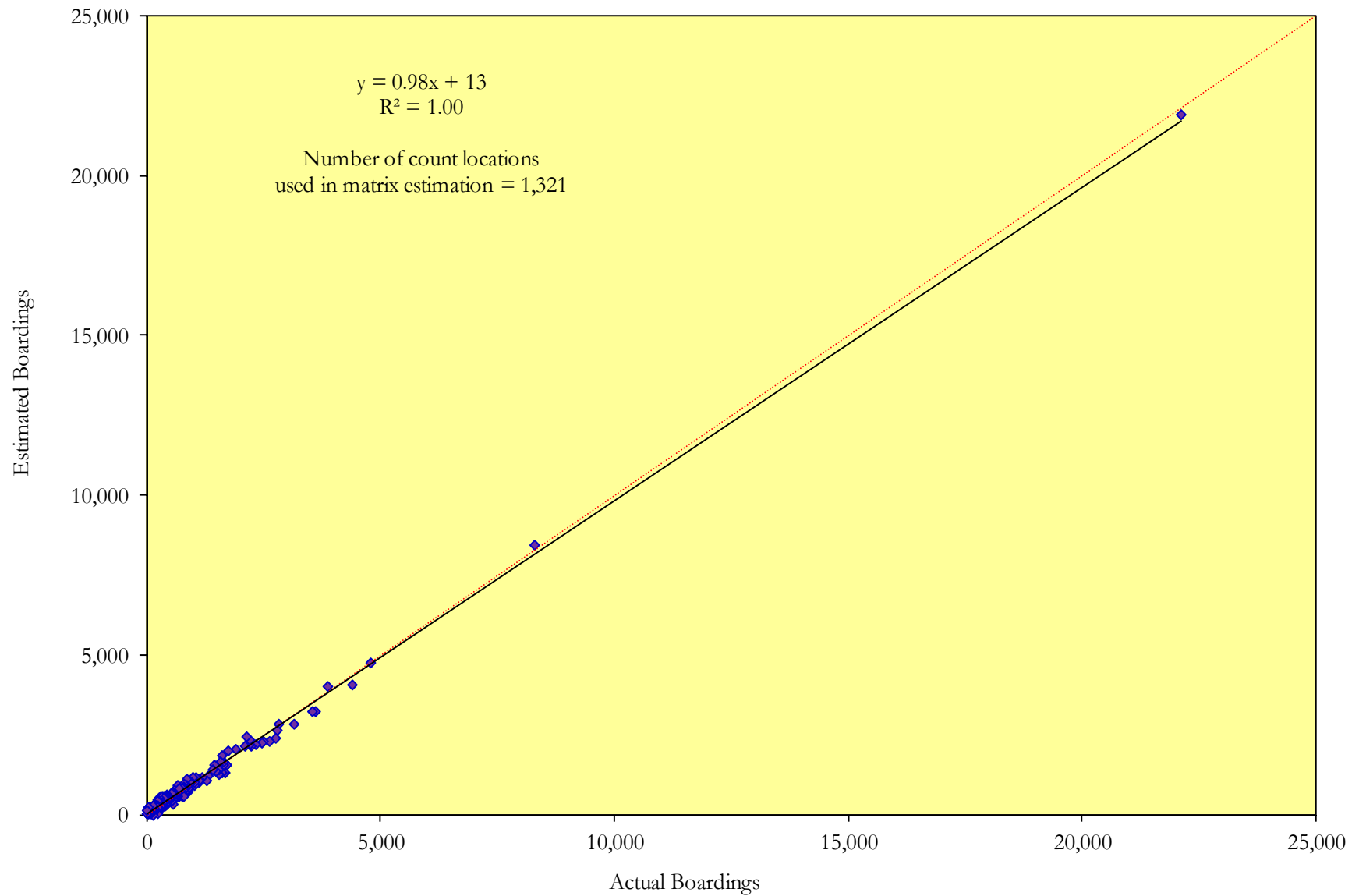


Figure 3-3a. Comparison of base year (2016) PM peak period transit line boardings (all agencies)

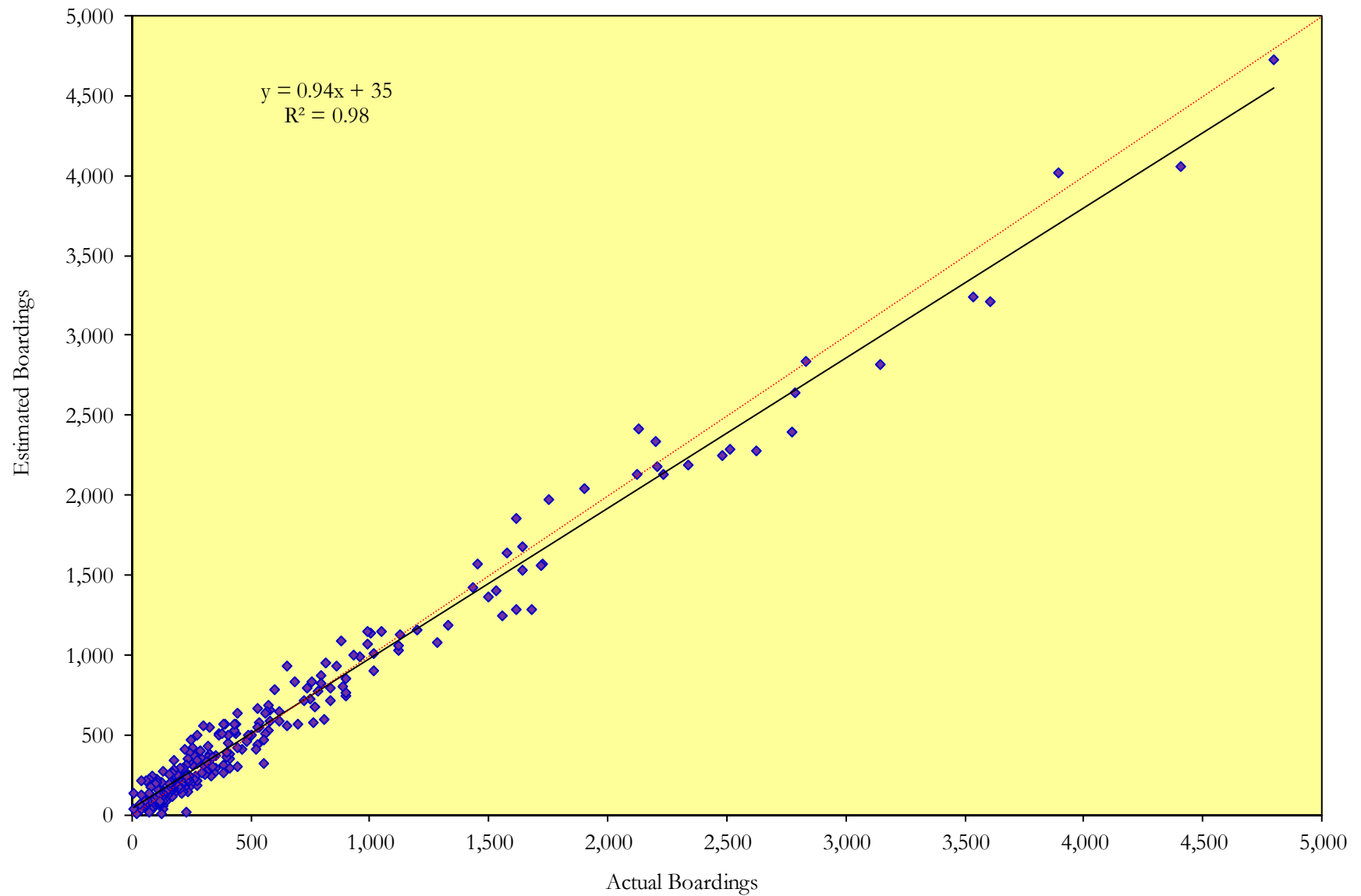


Figure 3-3b. Comparison of base year (2016) PM peak period transit line boardings (all agencies, but excluding light rail and commuter rail)

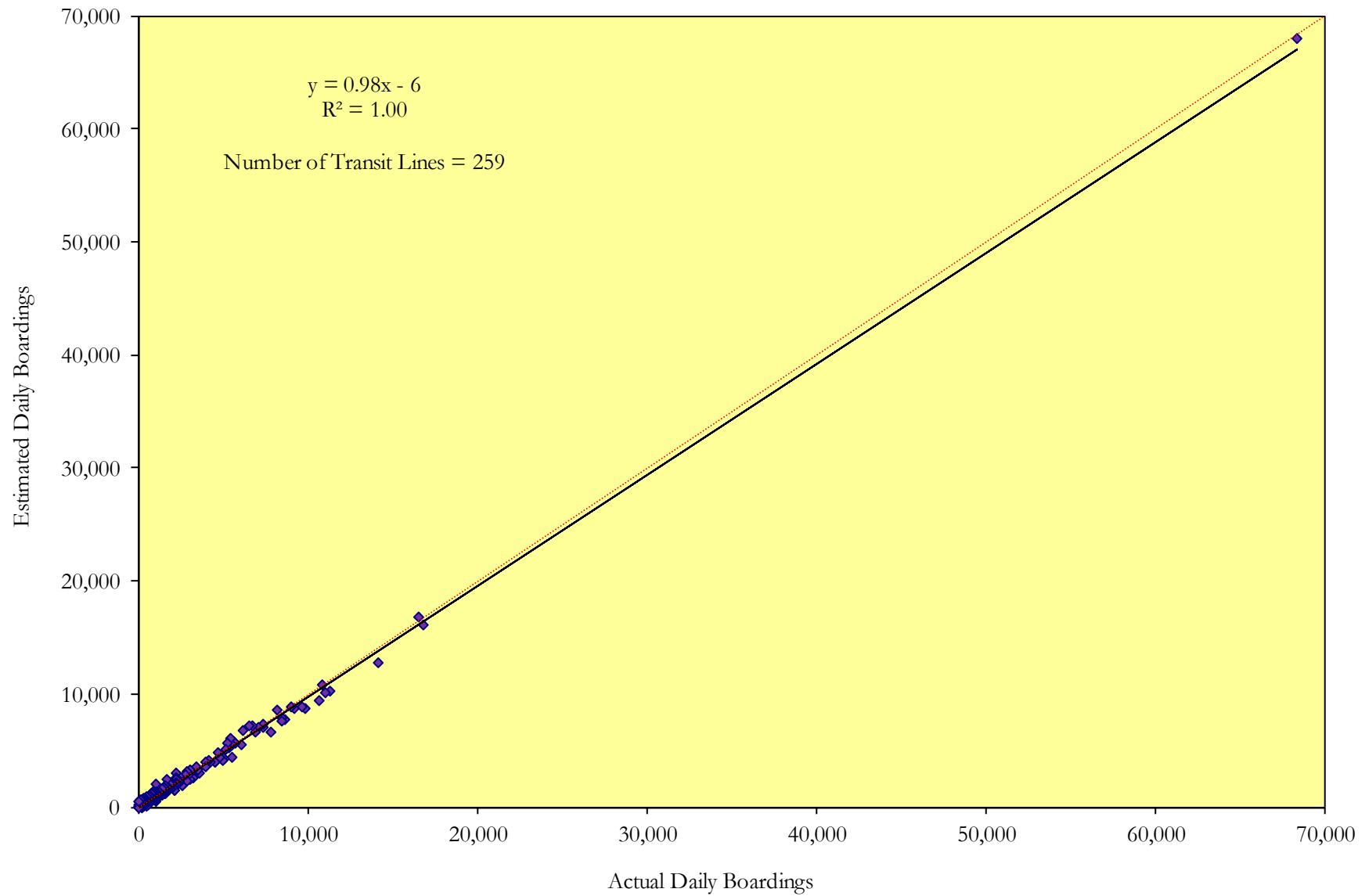


Figure 3-4a. Comparison of base year (2016) average weekday transit line boardings (all agencies)

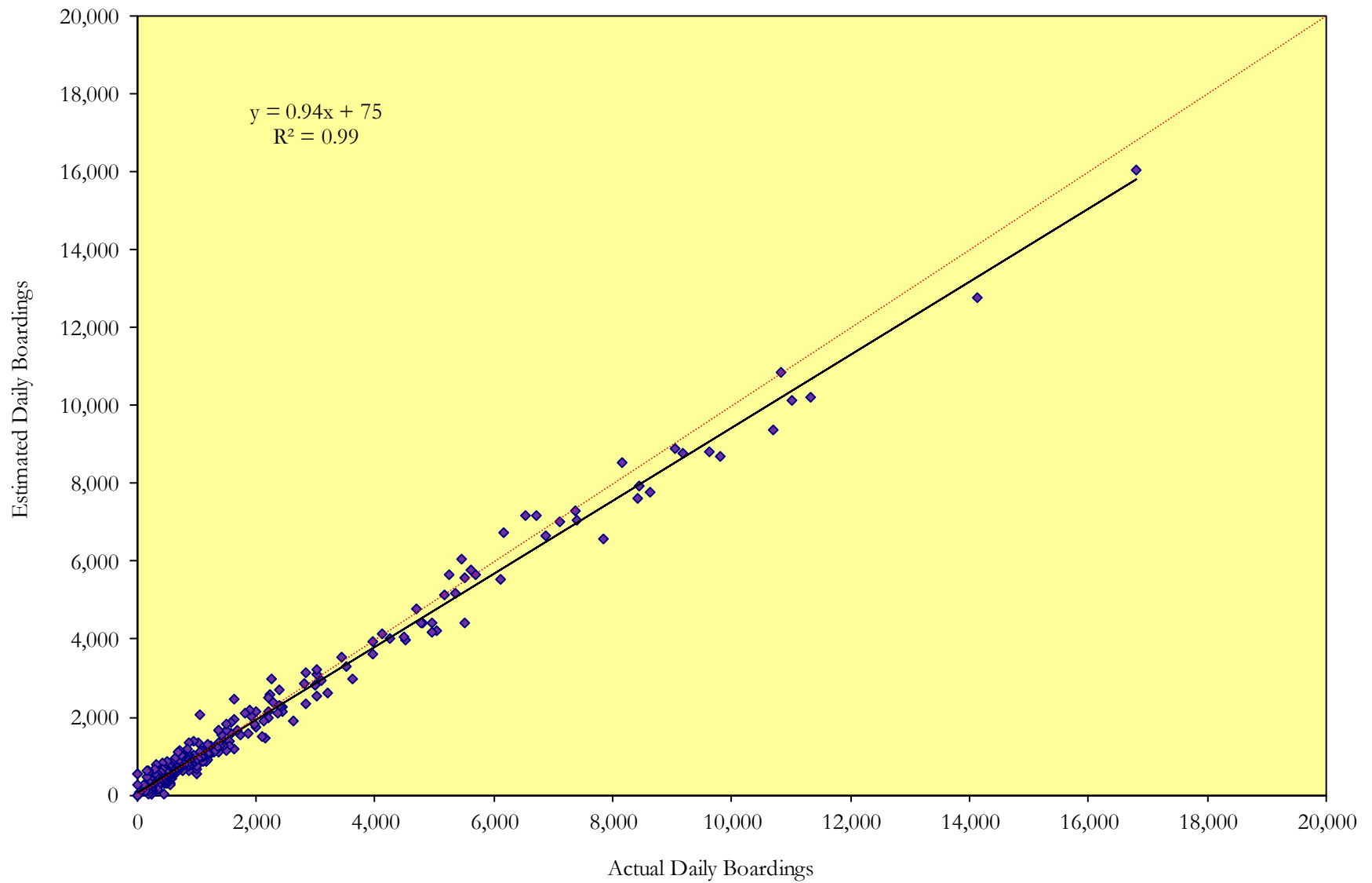


Figure 3-4b. Comparison of base year (2016) average weekday transit line boardings (all agencies, but excluding light rail and commuter rail)

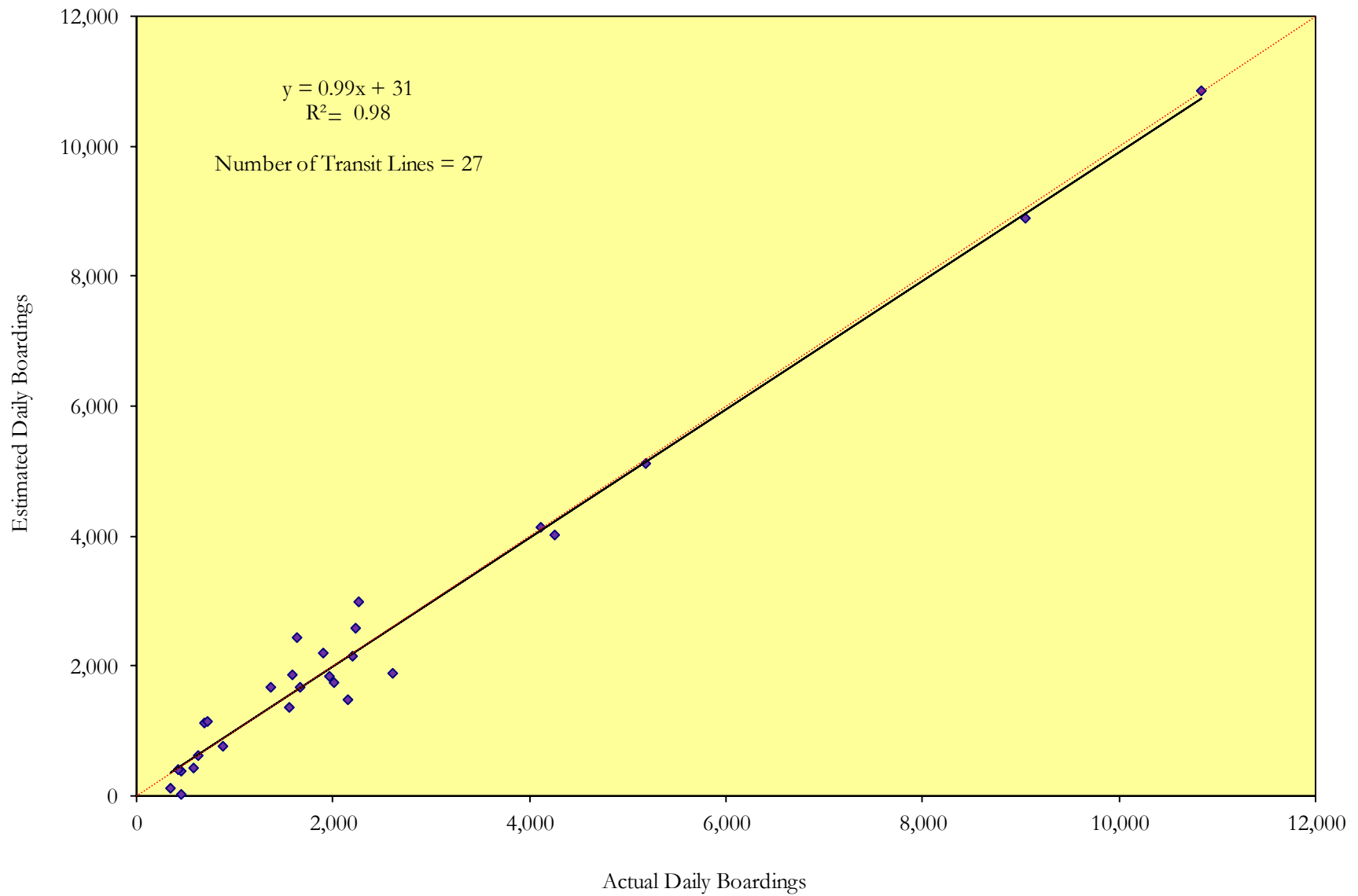


Figure 3-5. Comparison of base year (2016) average weekday transit line boardings (ST express bus only)

Appendix A: Maps

- *Forecasting Analysis Zones (FAZ)*
- *Alternative Analysis Zones (AAZ)*
- *10 and 26 Districts*



Figure A-1. PSRC FAZ Map—Snohomish County



Figure A-2. PSRC FAZ Map—King County



Figure A-3. PSRC FAZ Map—Pierce County

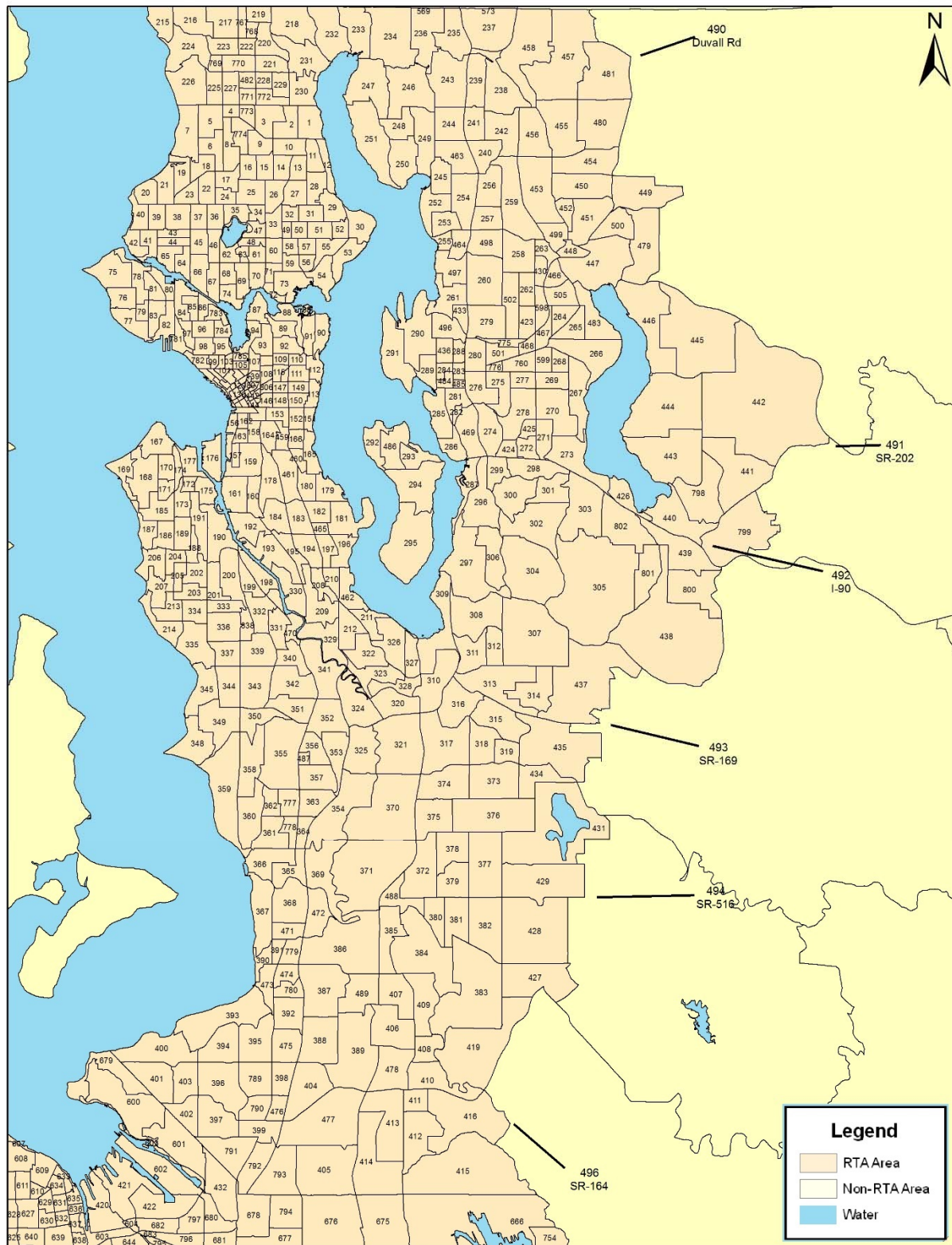


Figure A-4. 807 AAZ Map—King County

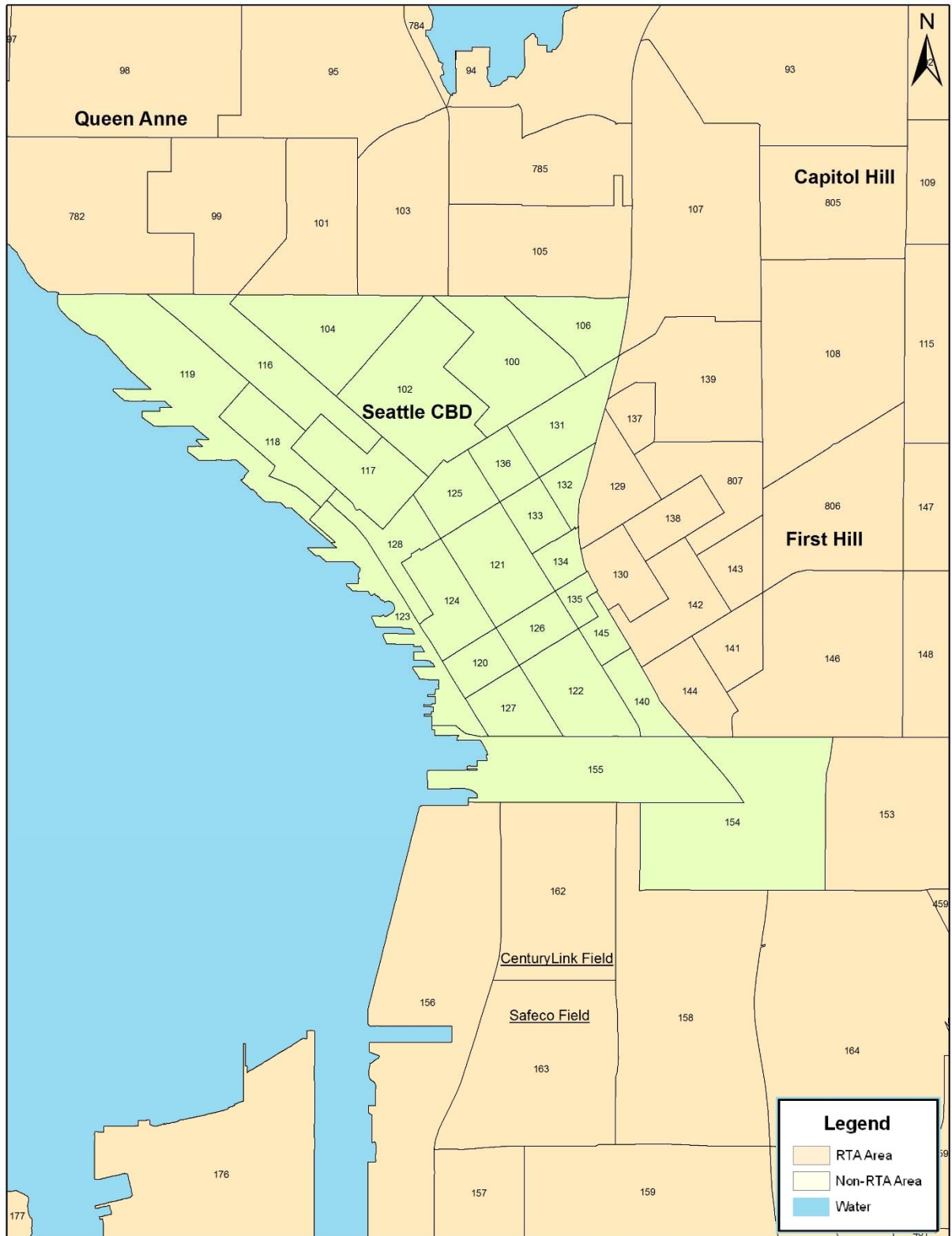


Figure A-4a. 807 AAZ Map—Central Seattle



Figure A-4b. 807 AAZ Map—Capitol Hill, First Hill, Ballard & Queen Anne

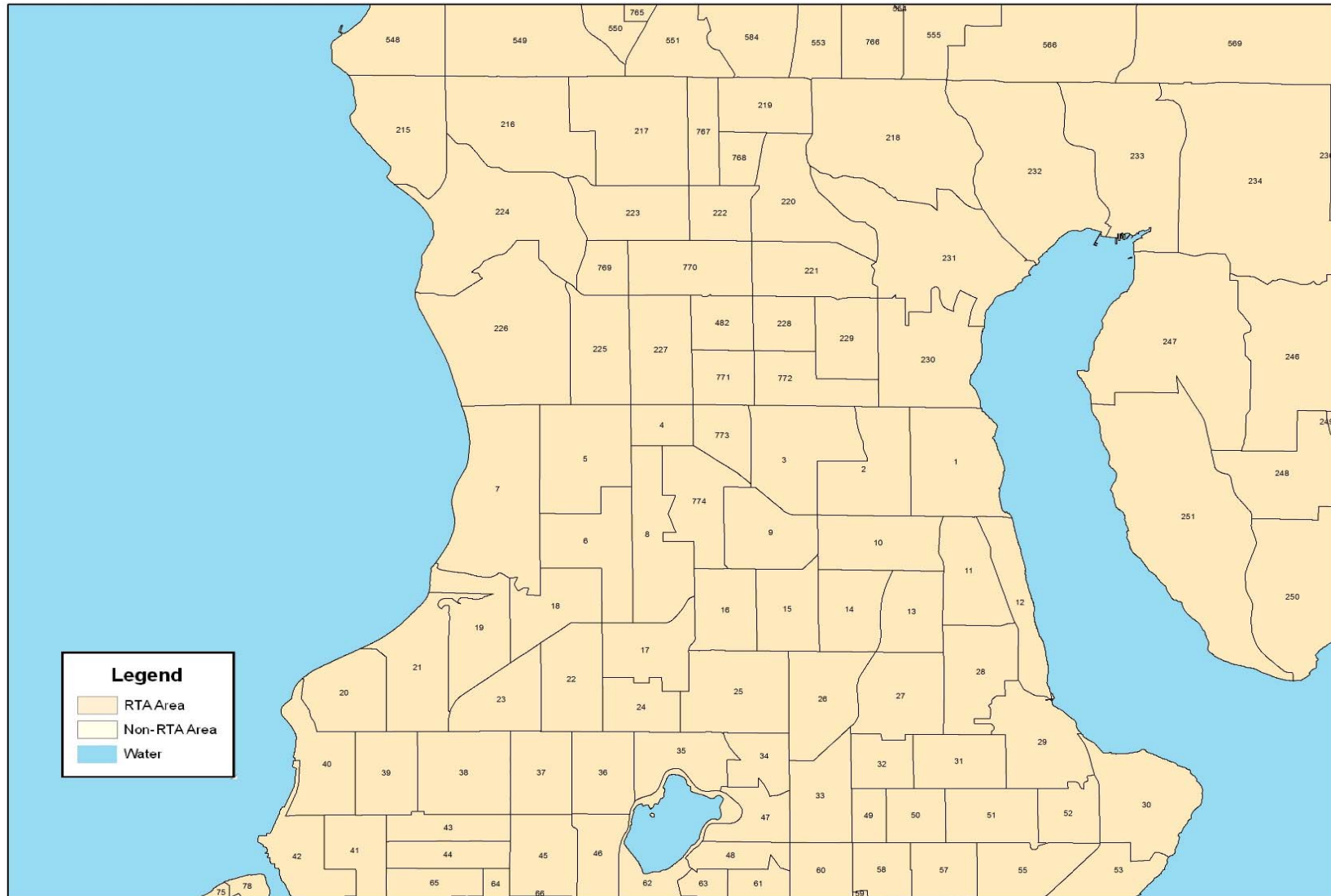


Figure A-4c. 807 AAZ Map—North Seattle

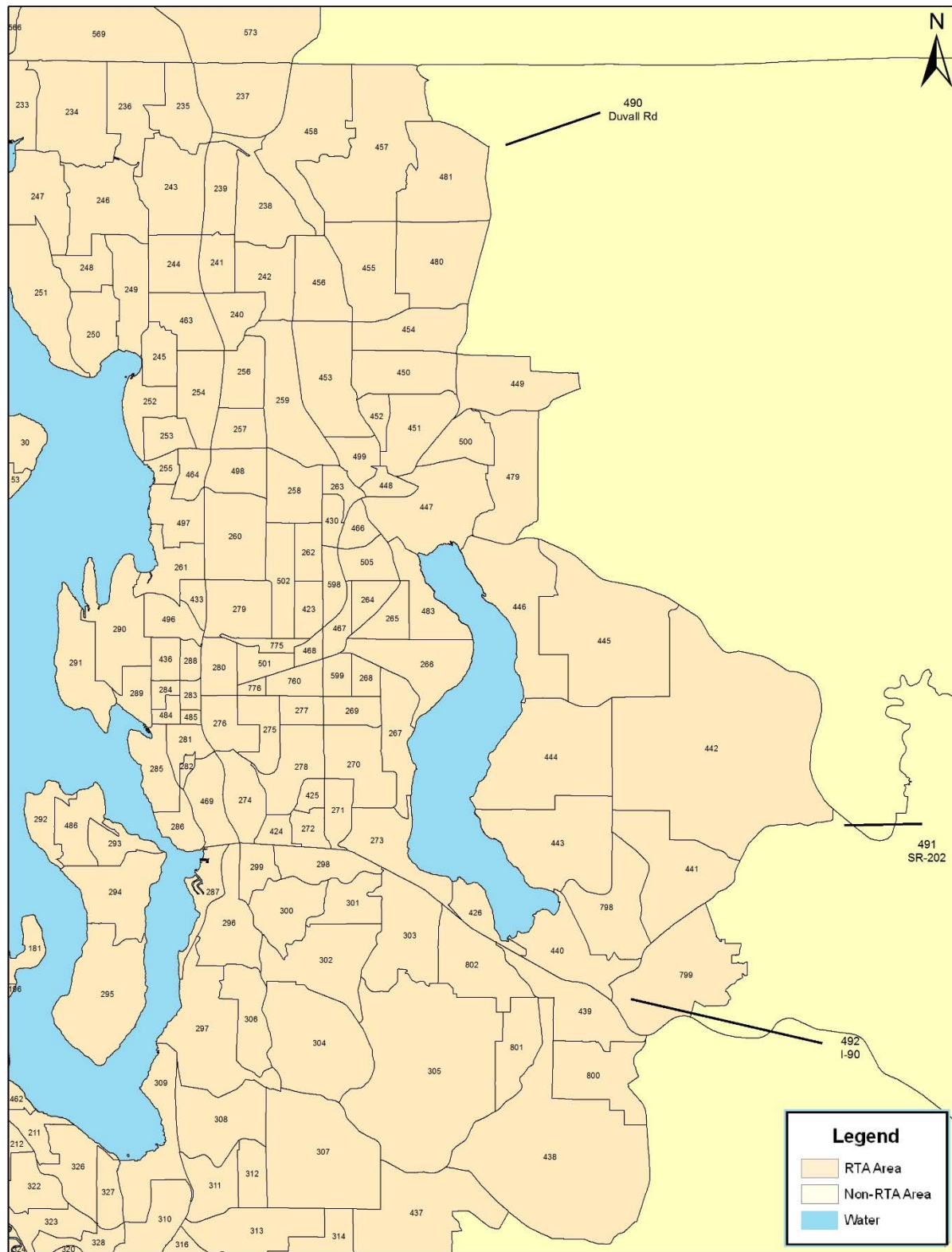


Figure A-4d. 807 AAZ Map—East King County



Figure A-4e. 807 AAZ Map—Southeast/West Seattle

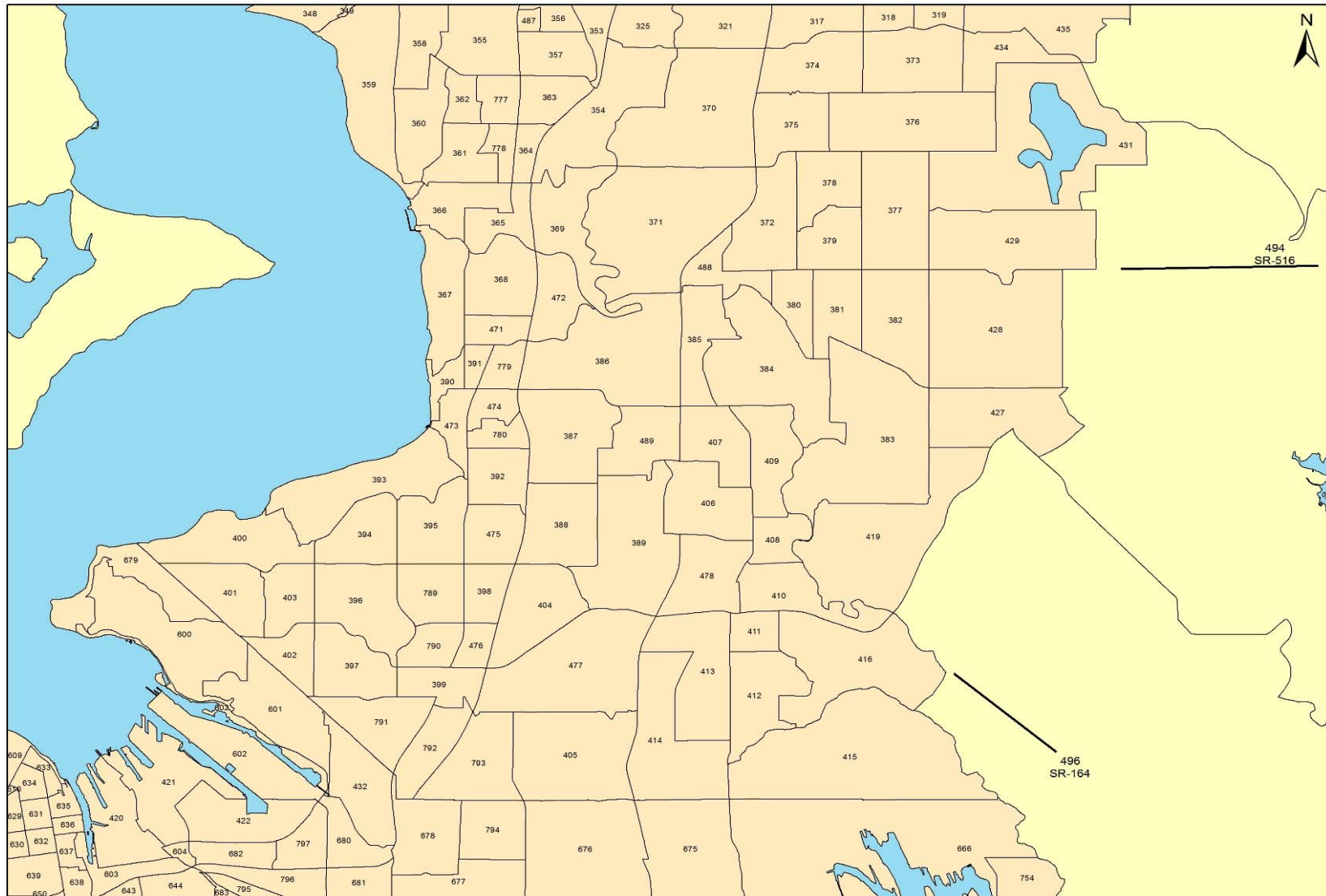


Figure A-4f. 807 AAZ Map—South King County

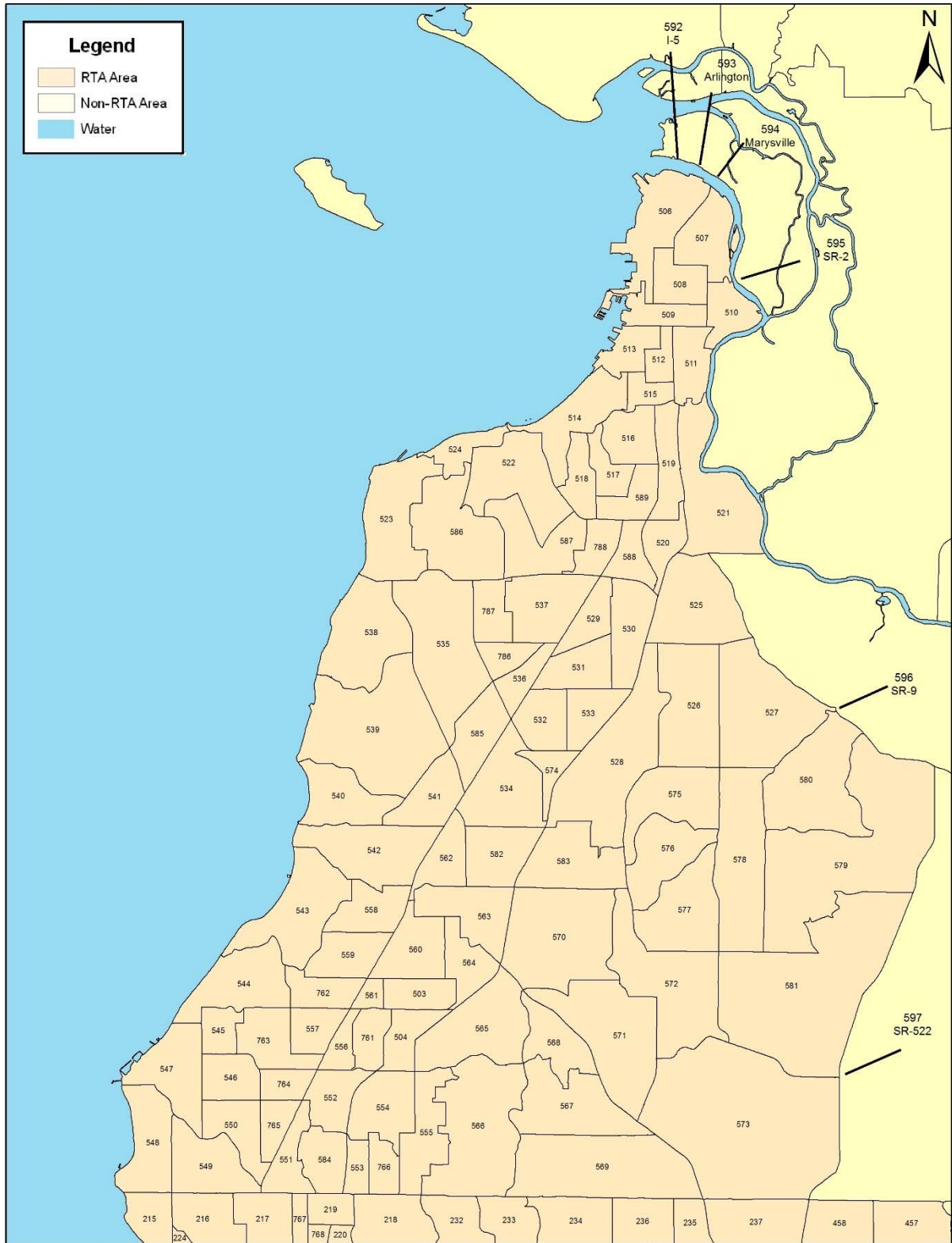


Figure A-5. 807 AAZ Map—Snohomish County

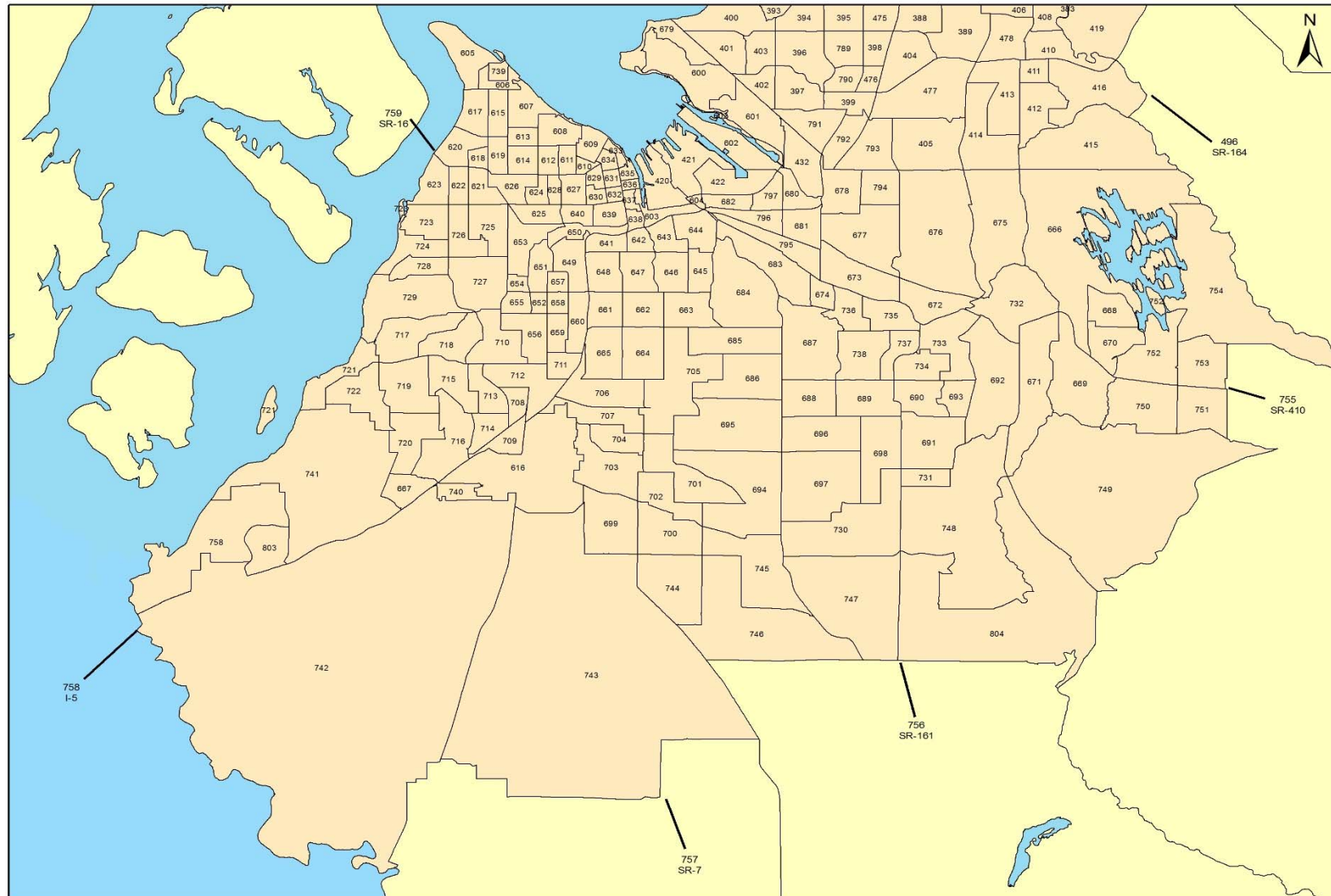


Figure A-6. 807 AAZ Map—Pierce County

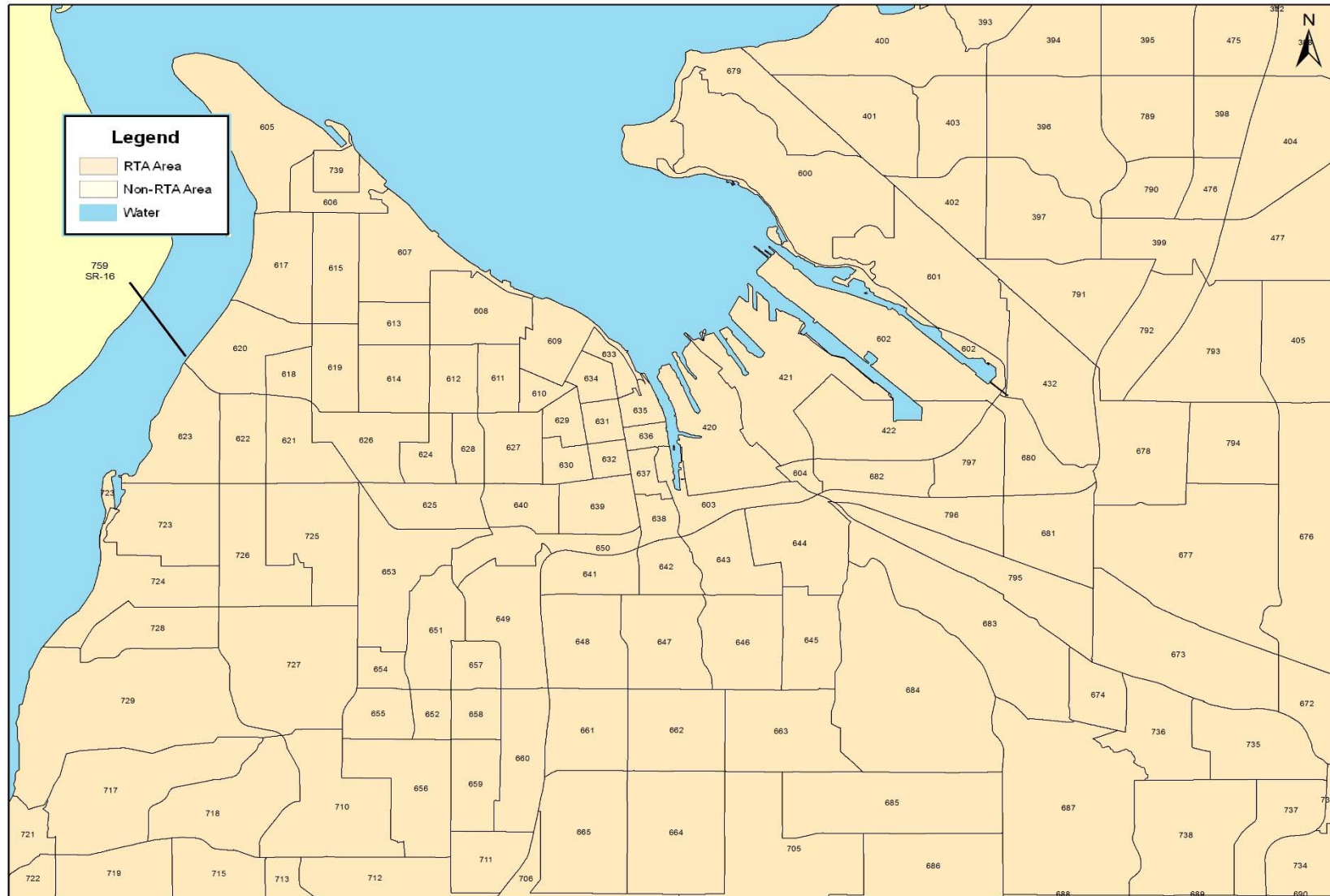


Figure A-6a. 807 AAZ Map—Tacoma

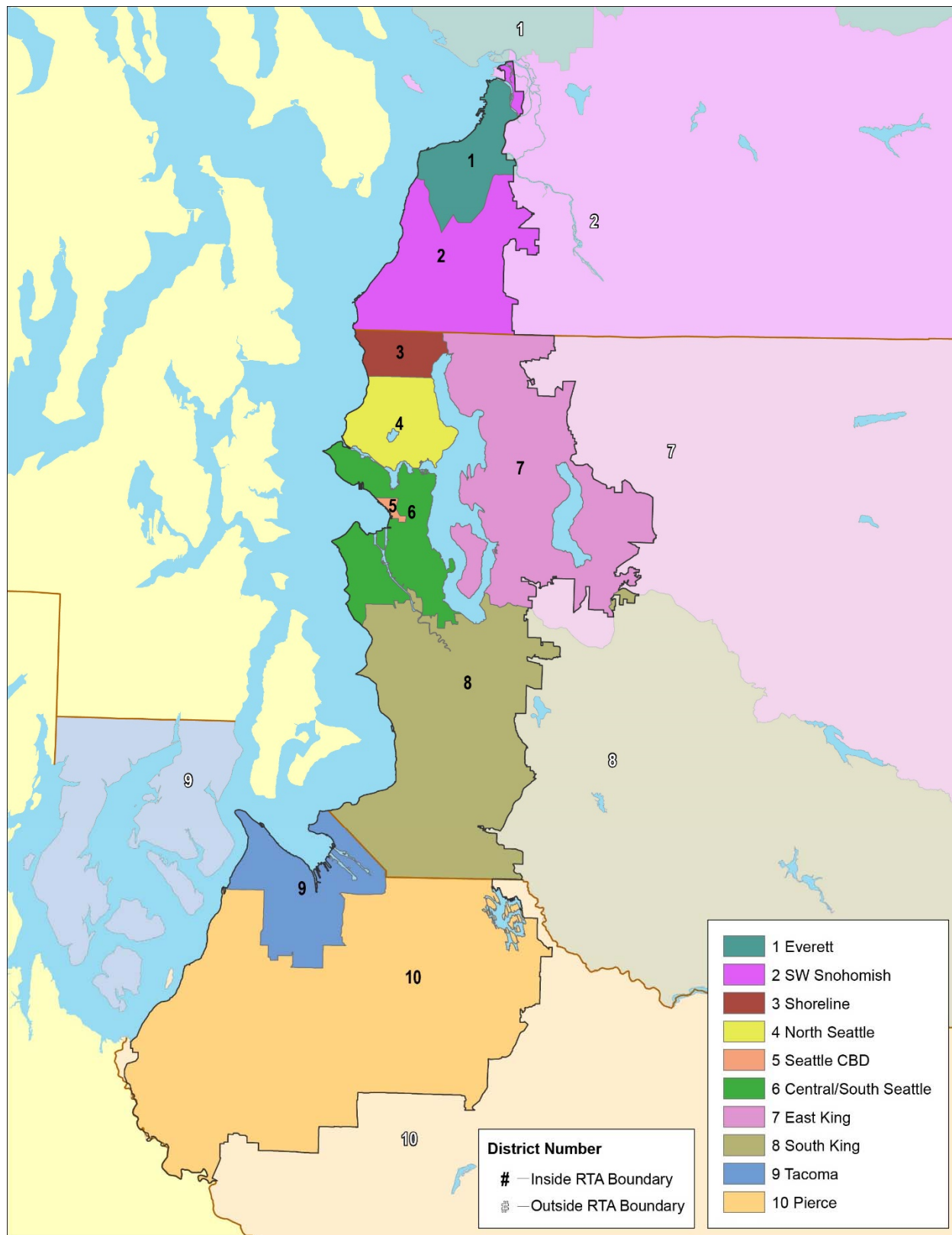


Figure A-7. 10-district map

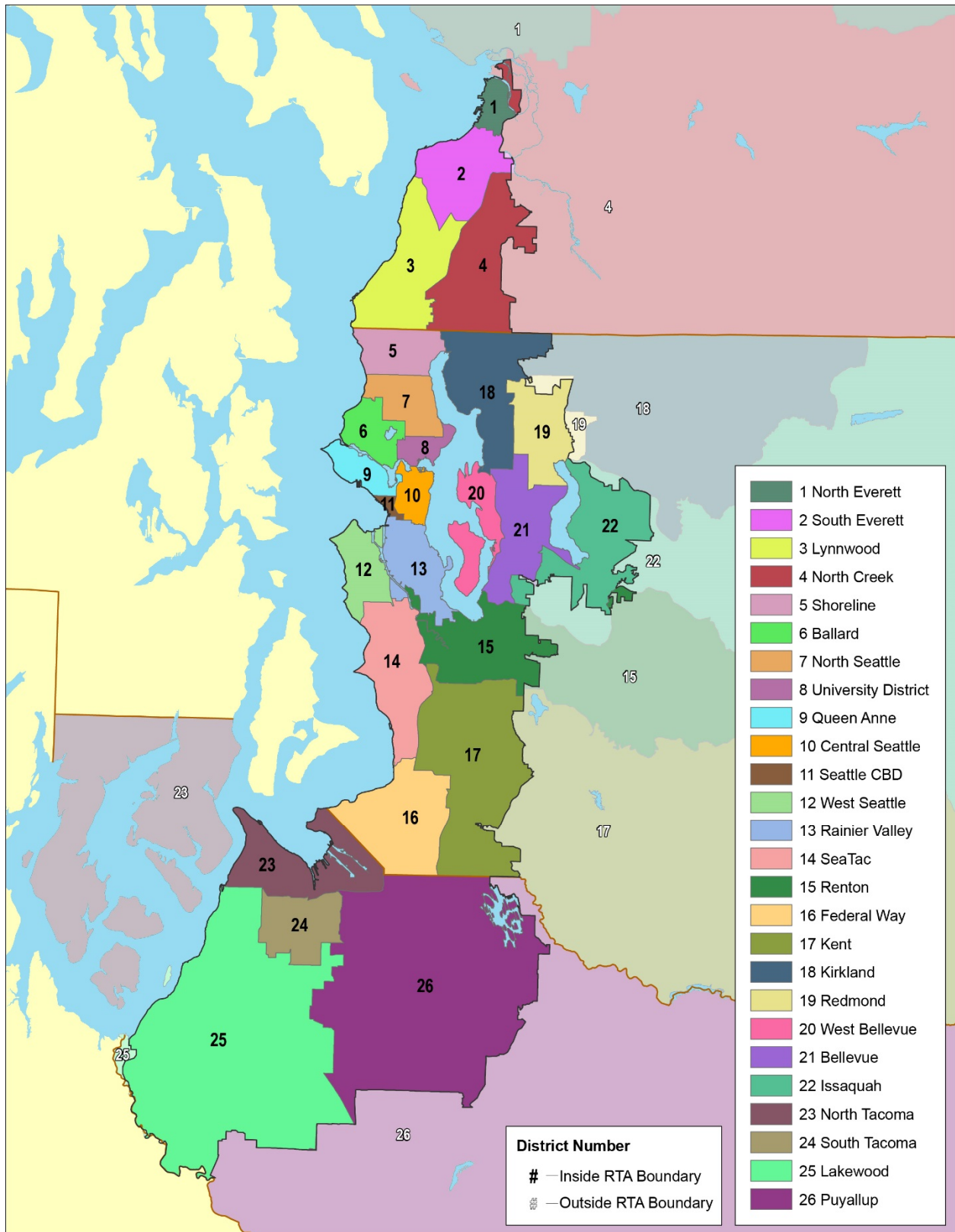


Figure A-8. 26-district map

Appendix B: ORCA, Surveys and Google Travel Time Data

Appendix B: ORCA and Surveys Data

This appendix includes a summary of the recent ORCA and surveys data used to update the 2017 version of the Sound Transit (ST) Ridership Model. This model version represents a departure from previous versions, primarily because of a significant increase in the amount of data available in the Puget Sound Region for describing current transit travel. The most significant of these is the availability of ORCA fare card transaction data used to create peak and off-peak seed matrices and provide a realistic estimate of transfer rates. ORCA data is now the primary source of shaping transit travel patterns. It constitutes opening 26 percent of (zone-to-zone) cells in the seed matrices with non-zero values. Commute trip reduction (CTR) and ST surveys open, respectively, an additional 3.0 and 0.3 percent of the cells.

B.1 ORCA Data

The ORCA card is a smart card technology to allow transit users to easily pay fares by tapping the card against an electronic card reader. The card enables seamless transfers between transit systems thanks to revenue-sharing agreements between transit agencies in the region. Transit users are incentivized to use the card instead of cash since they receive free or discounted transfers between agencies only if they use an ORCA card. The ORCA card allows for enhanced data collection as well, since the particular route, time of boarding, and transfers are logged; additionally, for rail, both the boarding and alighting locations are logged.

The ORCA data used to update the ST model is an outcome of previous work performed by the Washington State Transportation Center (TRAC) office at the University of Washington, designed to demonstrate the value of using ORCA transaction data for planning and operational purposes. The project is funded jointly by TRAC and Sound Transit, with staff support from the Puget Sound Regional Council.

The origin-destination data provided to Sound Transit and their consultants are developed from nine weeks of ORCA transaction data from March 26, 2016, to May 28, 2016, containing about 23 million boardings. On an average weekday during this period, 453,000 boardings were paid with ORCA cards. The number of true transfers, excluding round trips paid as transfers, was 109,600, yielding about 353,000 average weekday linked trips. This results in a transfer rate of 1.32. For the PM peak period, 148,200 boardings were paid for with ORCA cards. The number of true transfers, excluding round trips paid as transfers, was 35,400, yielding about 112,800 PM peak period linked trips. This results in a PM peak transfer rate of 1.31.

Trips on Kitsap Transit, Everett Transit, and Washington State Ferries were not geocoded and thus were not used in the estimation of the transfer rate.

Note that origins and destinations are assigned to specific transit stops and do not indicate the actual geographic origin (land use parcel or alternative analysis zone) or destination of that trip. An additional analysis used to allocate trips to zones for the matrix estimation seed matrix is described below.

B.1.1 ORCA data processing

The ORCA system supplies ORCA fare transaction records in two basic forms: on-board bus transactions (which include the date and time, bus number, route, and operating agency) and off-board transactions

from rail and BRT services (which include the date and time, location of the card reader and, in some cases, where the rider exited the rail system).

The initial pre-processing step of the origin-destination process links the automatic vehicle location (AVL) records of each agency to the on-board ORCA fare transaction records. This allows the analysis process to geolocate a very high percentage of the ORCA transit boarding records. Next, a look-up table is used to identify the location of each off-board rail and BRT payment location. This allows the geolocation of the BRT and rail trips. For BRT trips, the vehicle location files are then used to identify which bus the rider boarded based on routes serving the indicated stationary card reader. Sometimes multiple tap records occur to account for fare reloads or covering additional required fare; therefore, these taps are removed from the dataset, as they are not records of boardings or alightings. The product of these basic pre-processing steps is the geolocated ORCA transactions file indicating when, where (bus stop or rail station), and which vehicle each rider boards.

B.1.2 Origin-destination processing

The input to the origin-destination estimation process is the geolocated transactions file described above. This file is sorted by hashed ORCA card number and then by date and time. Data processing then occurs for one hashed card ID at a time. (That is, all ORCA cards with a hashed card ID of “abc123” are processed together, and that processing occurs in date/time order, with the “oldest” record processed first.) While the process described below aims to determine origins and destinations, it focuses on destinations for transit trips that do not involve transfers; transfer processing is discussed in a later section.

Destination Estimation

Starting with the first record (Record J), the geolocated boarding location (Stop J) is assigned as the origin of the trip (Trip J). The next record (Record K) for that ORCA card ID is then examined. If Record K is a transfer,¹ then transfer processing (see the next major section) is performed. If Record K does not describe a transfer boarding, then the location of boarding for Record K is used as a potential indicator of the destination of Trip J.

A 1/3-mile circle is drawn around the boarding location described for Record K. If the transit route boarded for Record J (Route J) has a bus stop that falls within the 1/3-mile circle around the boarding location for Record K, then the stop closest to the boarding location shown for Record K (Stop K) that is served by Route J (Exitstop J) is assumed to be the destination for the trip with a defined origin at the boarding location for record J. The process then produces a record indicating the origin (Stop J) and destination (Exitstop J). An illustration of this process is shown in Figure B-1. If Route J does not pass within 1/3-mile of Stop K, then no destination can be assigned for Trip J and the trip is discarded for O-D purposes, as illustrated in Figure B-2. For rail trips where the person did “tap off,” this tap-off location is used as the destination, unless there is a transfer, in which case the process in the section below applies.

¹ ORCA records contain an indicator variable which indicates if the current boarding has occurred within 2 hours of a non-transfer boarding. If this boarding occurs within 2 hours of a non-transfer boarding, it is considered a transfer by ORCA.

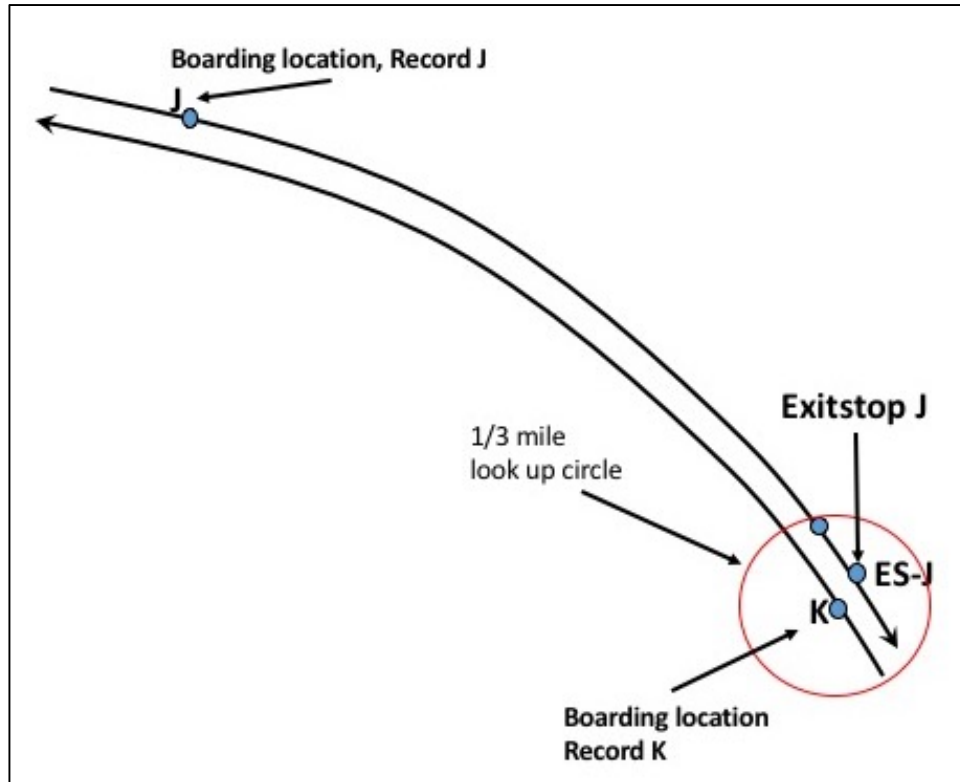


Figure B-1. The destination identification process

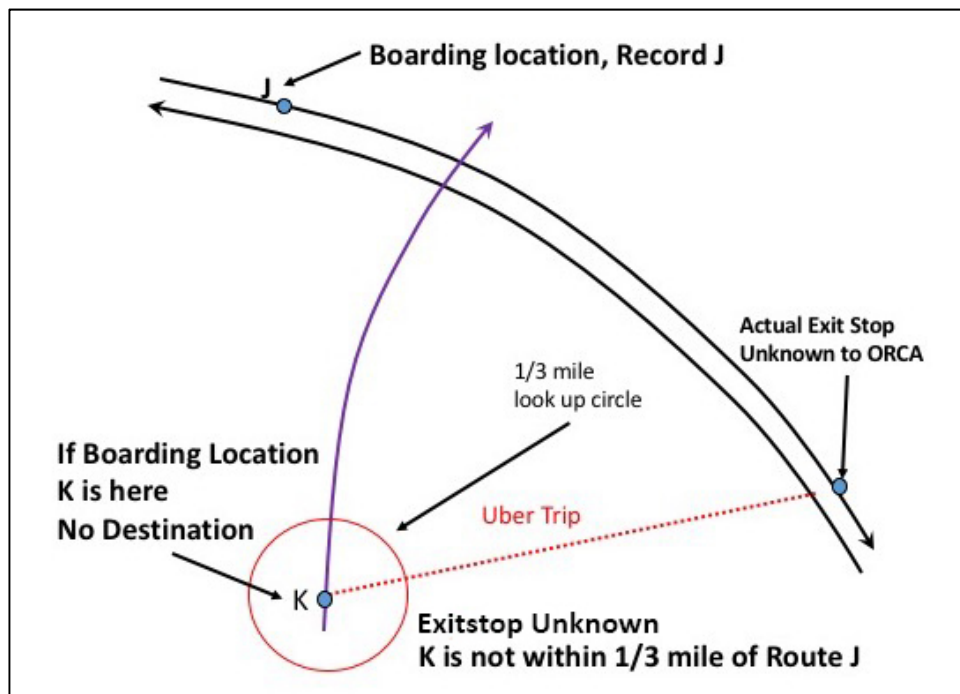


Figure B-2. The destination identification process, with no destination found

Transfer Handling

When a transfer is indicated by an ORCA record, the following steps are taken in place of the destination discovery steps described above. First, if the Route being boarded (i.e., the Route in Record K) is the same as the route being transferred from (Route J), then an activity is assumed to be taking place between the first boarding and the second boarding because no one gets off a bus to simply get right back on that bus. Consequently, if Route K = Route J, boarding stop K is the identifier of the logical destination for Trip J. Therefore, a 1/3-mile look-up is performed. Note that it is allowed to have boarding stop K as the destination for Trip J. This would be what is termed a “pit stop”: the rider gets off at a bus stop, does an activity, and then re-boards that same route, going in the same direction, at the same stop. Alternatively, the rider may be involved in an “end point” transfer: where exit stop, J is essentially across the street from boarding stop K, and s/he is likely returning to the origin for Trip J, having completed an activity near exit stop J and boarding stop K.

If Route J is not equal to Route K, then the 1/3-mile check is created around the new boarding location (Stop K). If that look-up fails (the two routes are not close to each other), then it is assumed that some trip occurred between the first and second transit trips and, therefore, no destination can be found for Trip J and the trip is discarded for O-D purposes.

If the 1/3-mile look-up finds a stop, then the transfer is assumed to be valid. Route K is then used as the route for which a destination must be found. The next record (Record L) for this ORCA card number is then examined. If it is also a transfer, then the transfer process is repeated. If Record L is not a transfer, then the destination search process described above seeks a destination for Route K.

Rail Transfers

If Trip J occurs on a rail vehicle (Sounder or Link), an exit tap is made and a transfer occurs, then the validity of the transfer boarding is verified by checking the location of the transfer boarding (Stop K) against the exit station for the rail portion of the trip. If the new boarding is not within 1/3 mile of the exit rail station, then it is assumed that some trip occurred between the first and second transit trip, and the trip destination is assumed to be the rail station exit point. If the rider does not “tap off,” then the 1/3-mile computation takes into consideration the entire rail line in order both to determine the validity of the transfer and to identify the rail station that served as the exit point from the rail portion of the trip.

B.1.3 Apportioning ORCA flows to ST model zones

This data needs to be aggregated to the zonal level for use in the Sound Transit model. A naïve approach could be used where trips to or from a given stop are assigned entirely to the zone where the bus stop is located. However, this results in a number of issues:

- Stops along streets that are zone boundaries will have significant imbalances in daily flows
- Zones which have no stops will show no activity even if there are nearby stops

This document describes the process used to allocate flows from stop-to-stop to zone-to-zone.

Method for apportionment

Since the processed ORCA origin-destination flows represent linked trips (including transfers), the primary modes of access or egress from each stop are walking and biking, with auto access (drop off and

parking) at park-and-ride locations. For walk/bike access, spreading trips over a reasonable access area was deemed appropriate. Historically, a 0.25-mile walk distance for bus and 0.5-mile for rail was considered typical. However, recent research, including the Sound Transit Before/After study for Initial Segment/Airport Link, indicated a willingness to walk longer distances, but extending the distance too far can result in unreasonably long access distances, given the large size of some zones. Table B-1 shows the distances used. For short trips, smaller distances were used to spread the flows since it makes sense that people will not walk as far for a short trip. For longer trips, 50 percent of trips were assigned to the area within half the walk access distance and the remaining 50 percent assigned to the outer ring of the distance as shown in Figure B-3. Whether for short trips or longer trips, the number of trips allocated to each zone is proportional to the area of the circle over each zone. Note that these distances were not used for the Downtown Seattle Transit Tunnel stations; for those stations, unique travelsheds were manually developed, reflecting station access, topography, zonal coverage, and likely use of each of the stations.

Table B-1. Walk access distances by stop type

Stop Type	Total Trip Length > 2 miles	Total Trip Length <= 2 miles
Link, Bus, & Streetcar	0.4 miles	0.2 miles
Sounder	0.6 miles	0.3 miles
Sounder at King Street Station	0.8 miles	N/A

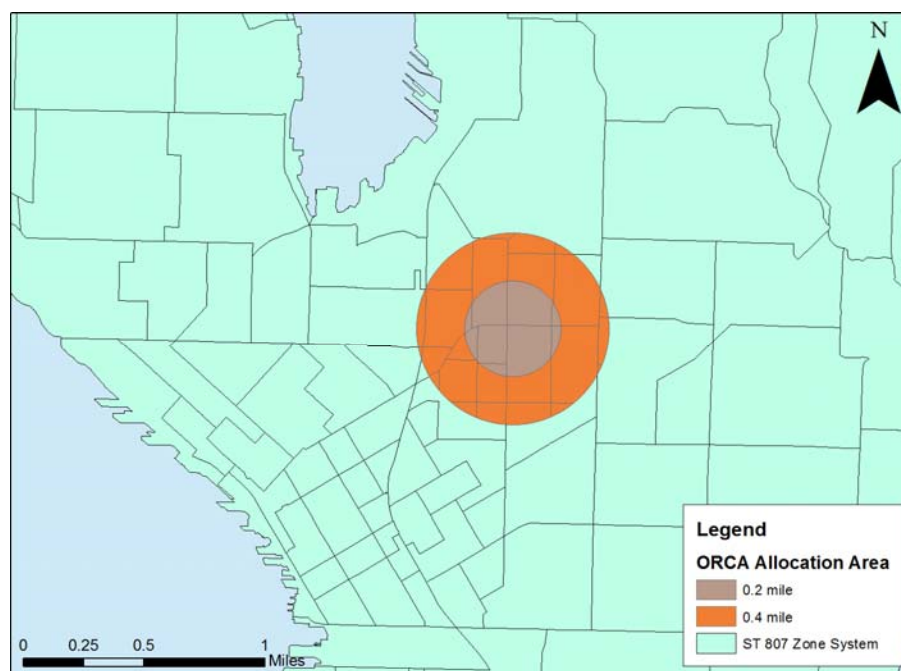


Figure B-3. Allocation area for walk/bike access at Capitol Hill Station

For stops at park-and-rides, the method above was used for walk access trips. However, for auto access, patterns of access tend to originate farther away from the destination (e.g., nobody drives from Mercer

Island to Bellevue to take a bus to Seattle). To apportion auto-access trips, park-and-ride-specific networks for automobiles to and from zones were used to apportion flows from an AM origin or PM destination stop (that serves commuter routes) over the zones this network connects to. These park-and-ride networks are reflective of the likely primary travelshed of auto access to each park-and-ride. The relative proportion of households was used to allocate between zones (e.g., zones with more households received a larger share of the flows from a stop). Finally, each stop was characterized as high (75 percent), medium (50 percent), or low (25 percent) auto access, representing the percent of trips that arrive/depart as auto access rather than walk or bike. This categorization of high, medium, and low recognizes that certain park-and-ride locations have much better walk accessibility for transit trip origins and destinations (e.g., Northgate). This results in smaller percentage of total boardings at that location to be allocated to auto-access than for other park-and-ride locations (e.g., Lakewood Station).

B.2 Surveys

In addition to ORCA data, relevant information from a number of recent surveys was also used in the ST model update. This included ST transit on-board surveys (2011-2016), CTR surveys (2011-2016), and American Community Survey. The ST and CTR surveys were used to open additional cells in the seed matrices. The American Community Survey was used to scale Base Year transit share matrix produced from the CTR survey. This was to neutralize the large-employer sample bias in the CTR data.

B.3 Google Travel Time Data

The Google Distance Matrix API (<https://developers.google.com/maps/documentation/distance-matrix/>) was used to establish Base Year non-transit travel times between each zone pair. The Distance Matrix API provides the network-based travel distance associated with the fastest travel time between two given points at a specified start time. Using a future date results in travel time estimates that represent typical travel times for that day of the week, including any recurring congestion, but without any delay from specific incidents that would result from using historical data. Representative points for each zone were selected by starting with the zone centroid, then adjusting the representative point as needed to reflect the center of travel activity for that zone. Representative points for some external ferry zones were chosen at the ferry terminal, meaning these travel times do not include ferry wait or travel times.

Travel times between points representing every zone pair (except intra-zonal pairs) for the following trip start times:

- Wednesday, June 7, 2017, at 12:15 p.m.
- Wednesday, June 7, 2017, at 5:15 p.m.

Collecting travel times between all zones for two start times resulted in over 1.3 million requests. The Google API limits the total number of requests to 100,000 per day per API key, the process was run the last week of May and first week of June, using the June 7 date for all travel time requests. The 12:15 p.m. time represents an off-peak hour, while 5:15 p.m. reflects the PM peak hour. Change in travel times from the ST highway model will be applied to the Google-based Base Year non-transit travel times to produce corresponding future year travel time inputs required in the ST model Stage 2 forecasting step.

Appendix C: Highway Model

- *Overview*
- *Network Refinements*
 - *Base Year*
 - *Future Baseline*
- *Model Results*

Appendix C: Highway Model

The Puget Sound Regional Council's (PSRC) 4K trip-based regional travel forecasting model¹ provides key inputs into the ST incremental transit ridership model. These include estimates of changes in (a) demographic growth, (b) non-transit travel times, and (c) bus speed degradation estimates. For the purpose of level-of-service and traffic design/mitigation analyses, it also provides estimates of changes in (a) performance measures (such as vehicle miles traveled) and (b) vehicular traffic as highlighted in Figure C-1. This figure shows the relationship between the ST incremental transit ridership model and the PSRC regional travel forecasting model, along with other related processes.

As illustrated in Figure C-1, the PSRC regional model is not meant to provide facility-specific traffic estimates at a level of detail adequate for use in analysis of impacts. It can only provide an overall estimate of generic growth factors when needed. Other locally detailed subarea traffic models, mesoscopic models, or micro-simulation models should be used for level-of-service and traffic design/mitigation analyses.

This appendix discusses the background of this highway model and highlights efforts to improve the results from the model to best reflect observed conditions and provide quality inputs into the ST model. This includes presentation of some Base Year model results.

C.1 Overview

The PSRC regional model used to support the ST incremental ridership model has benefited from the culmination of over two decades of experience from the application of PSRC regional model to major WSDOT projects, such as the SR 520, I-5 to Medina: Bridge Replacement and HOV Project, Alaskan Way Viaduct and Seawall Replacement Program, and Puget Sound Gateway Program. The observations and data regarding the operation of facilities in the ST area have provided insight to guide enhancements to the ST highway model.

As part of the analysis for the SR 99 tunnel toll traffic and revenue analysis, a Dynamic Traffic Assignment (DTA) model was created to analyze traffic and revenue that would be affected by tolling of the new tunnel. The mesoscopic DTA model provides a level of detail between a demand model and operational models, while still using the zonal system from the City of Seattle model. Likewise, a DTA model has been used to support evaluation of conceptual design scenarios for the Gateway project. For the purpose of preserving all the previous network changes and refinements, the original 1K zone system was adopted in conjunction with the current PSRC 4K model procedures.

Using the above model background information, the PSRC regional model incorporated network attributes and model procedures that would provide the best representation of travel conditions within the ST area. In addition to knowledge provided from these models, additional review of network attributes and existing roadway conditions was performed to provide additional updates that might not necessarily have been included in the focus of other recent modeling efforts.

¹ Puget Sound Regional Council, 4K Travel Model Documentation, June 2015.

Base Year and Future Year travel times from the PSRC regional model are not used in the ST transit model. Peak and off-peak non-transit travel times are taken directly from measured Google highway times, as described above in Appendix B, Section B.3. The PSRC regional model is used to estimate incremental changes in the measured non-transit times for use in Future Year transit ridership forecasts only.

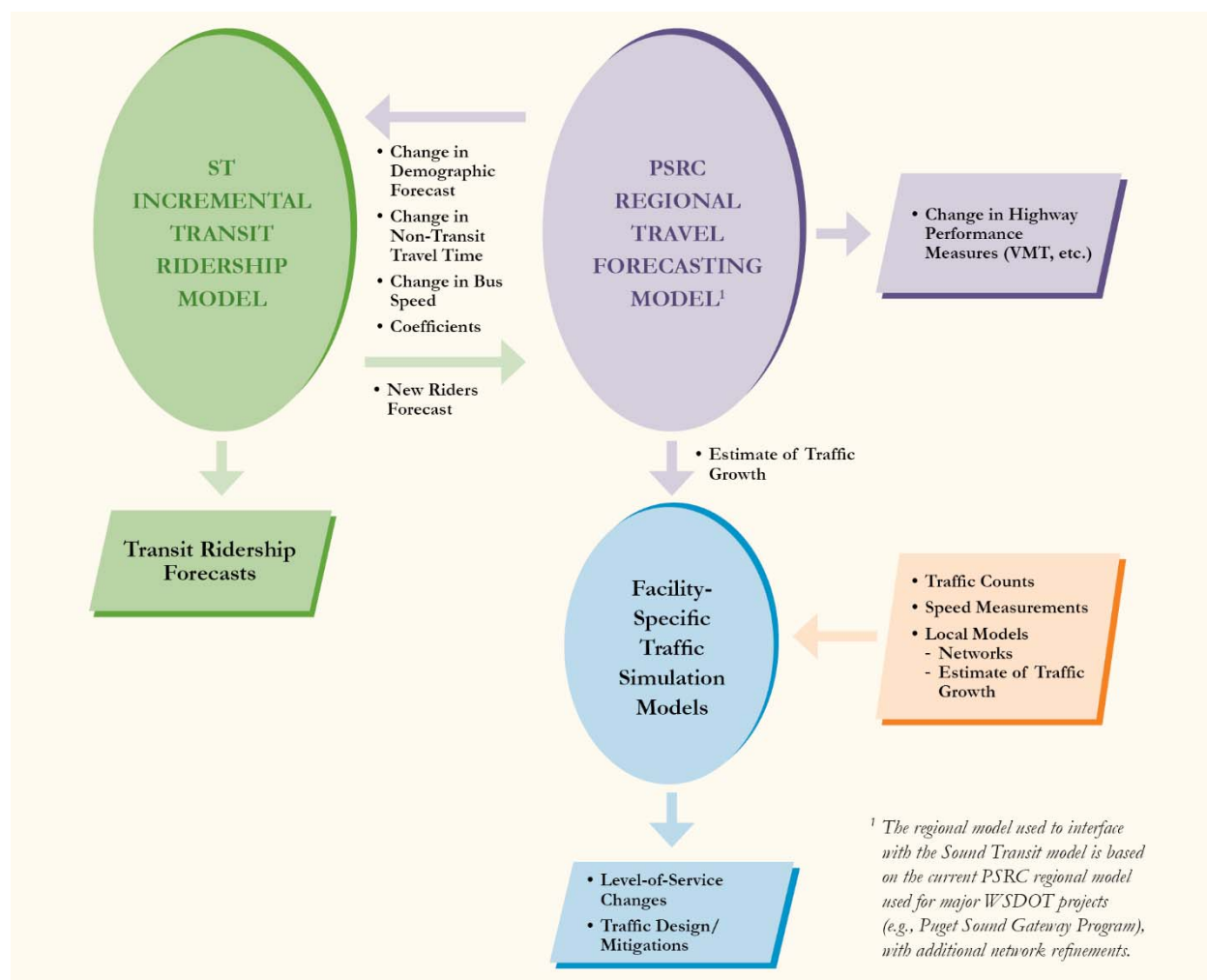


Figure C-1. ST incremental transit ridership and PSRC regional models relationship

Likewise, output from this model is not used to estimate Current Year or Future Year project-related changes in vehicle miles travelled. For vehicle-miles-travelled changes related to transit projects, the FTA preferred method, as described in recent FTA guidelines for the New Starts Capital Investment Grant Program, is used. This method requires only the transit new riders' estimates for Current Year and Future Year plus a generic highway distance matrix for the region.

C.2 Networks

C.2.1 Base Year

The Base Year (2016) highway network reflects existing conditions. To better reflect existing roadway configurations, the model link attributes were compared to actual conditions. Appropriate adjustments

to speed, capacities, and congestion factors were made accordingly. The Base Year transit network in the ST ridership model was used as a guide to update the base transit network in the PSRC regional model. The path-builder parameters are similar to those used in the current ST incremental model.

C.2.2 Future baseline

Highway projects

The future baseline for the highway model includes several major and minor highway projects that were defined in PSRC's *Transportation 2040 Preferred Alternative (Constrained)* network. This network, therefore, includes some projects that are planned but not funded. A single baseline network is used for the transit no-build and build alternatives since none of the build alternatives significantly affect the design of any roadways.

Transit projects

Transit changes significant enough to affect regional highway demand levels are also included in the 2040 PSRC regional model. The 2040 PSRC regional model assumes that the ST Link light rail network extends from Federal Way south to Lynnwood in the north and to Downtown Redmond in the east. Background transit assumptions for the PSRC model always include only transit projects with a Record of Decision and full funding. Bus routes and frequencies are adjusted to reflect updated connections to light rail service as well as King County's RapidRide arterial BRT service and Community Transit's Swift arterial BRT service.

Demographic forecasts

The PSRC regional model uses the Land Use Vision (LUV.2).

C.3 Bus speeds

Historically, the ST transit ridership model has used estimates of long-term speed degradation from the PSRC regional model in order to slightly reduce future bus speeds. This degradation typically has been in the 7- to 9-percent range per decade, depending on the location and type of highway segment used by the bus route. The historical justification for this approach included review of actual bus operating speeds over the four decades from about 1960 to 2016; long-term degradation of about 9 percent per decade was observed.

There is no reason to change this procedure in current applications of the ST transit model. After a period of very modest bus speed degradation from 2008 to 2013, there has been a steep decline in bus speeds from 2014 to 2017. The average decline over the past decade (i.e., combined for 2008-2017) has, in fact, been about 10 percent.

BRT routes, where freeway or arterial route segments are barrier-separated or grade-separated, are treated identically to rail lines in the ST transit model. That is, the speeds are entered directly on the links, with the addition of reasonable times for deceleration/dwell/acceleration at proposed stops. However, bus speed degradation is applied to routes that operate in congested high-occupancy vehicle lanes and which often require interaction with adjacent lanes, since recent history of measured bus speeds in these lanes exhibits continuing bus speed degradation in all major corridors.

A wide variety of existing BRT-type stop-spacing situations are available within the existing regional bus network for inference of new BRT travel times. While there is always a risk of over-optimism in the modeling of BRT operations for ridership estimation, careful reference to existing situational experience with actual bus speeds and station-to-station times reduces this risk.

C.4 PSRC regional model results

Although the primary purpose of this model is to provide estimates of future changes in non-transit travel times, a comparison of estimated and observed vehicle volumes at key screenlines provides a reasonableness check on model performance. Model-estimated vehicle volumes are compared to recent observed traffic counts on arterials and highways across a number of screenlines. The screenlines used are shown on the map in Figure C-2. As seen in Table C-1 through Table C-3 the estimated screenline total volumes are mostly within 10 percent of observed volumes during the peak hours and over the entire day.

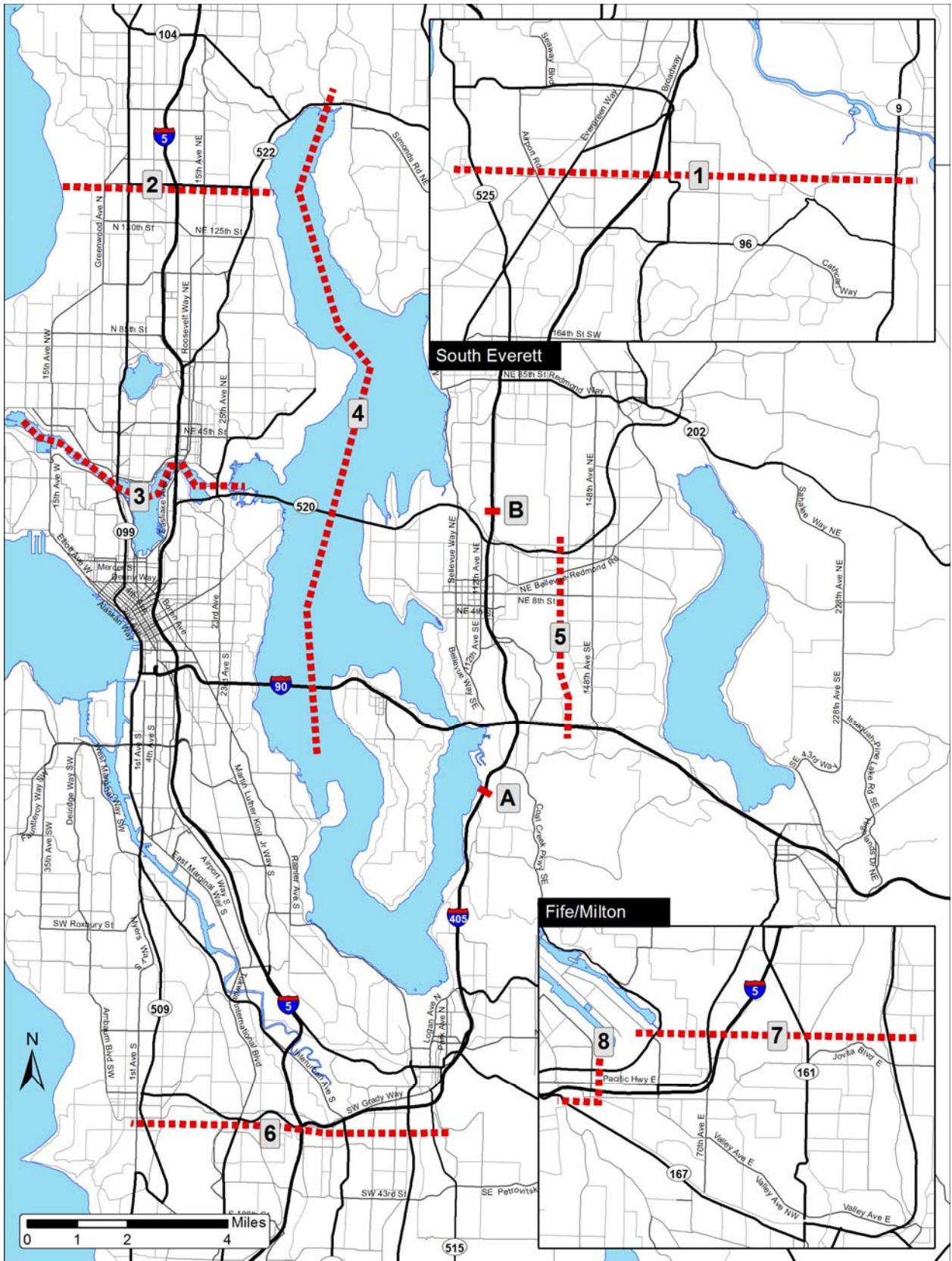


Figure C-2. Highway screenlines map

Table C-1. Base Year (2016) screenline total vehicle volume comparison (AM peak hour)

	Actual Volumes			Estimated Volumes			
	NB/EB	SB/WB	Total	NB/EB	SB/WB	Total	Est/Obs
Screenline 1 - North of 112th St SW							
Freeways	5,600	6,870	12,470	3,800	6,630	10,500	0.84
Arterials	3,840	5,040	8,880	4,230	4,510	8,800	0.99
Screenline Total	9,440	11,910	21,350	8,030	11,140	19,300	0.90
Screenline 2 - South of N 145th Street							
Freeways	5,010	8,070	13,080	4,870	7,980	12,900	0.99
Arterials	4,320	6,670	10,990	3,070	6,170	9,100	0.83
Screenline Total	9,330	14,740	24,070	7,940	14,150	22,000	0.91
Screenline 3 - Ship Canal							
Freeways	5,910	11,770	17,680	6,340	11,220	17,600	1.00
Arterials	3,880	5,670	9,550	3,670	4,920	8,700	0.91
Screenline Total	9,790	17,440	27,230	10,010	16,140	26,300	0.97
Screenline 4 - Midlake							
Freeways	8,720	10,700	19,420	8,010	8,170	16,300	0.84
Screenline Total	8,720	10,700	19,420	8,010	8,170	16,300	0.84
Screenline 5 - West of 140th Ave E							
Freeways	9,640	11,090	20,730	8,290	9,000	17,290	0.83
Screenline Total	9,640	11,090	20,730	8,290	9,000	17,290	0.83
Screenline 6 - South of SR 518/I-405							
Freeways	15,070	10,270	25,340	12,990	6,960	19,950	0.79
Arterials	3,610	4,800	8,410	3,390	3,590	7,000	0.83
Screenline Total	18,680	15,070	33,750	16,380	10,550	26,990	0.80
Screenline 7 - King/Pierce County Line							
Freeways	7,410	6,860	14,270	9,120	5,610	14,730	1.03
Arterials	5,100	3,250	8,350	5,480	3,250	8,700	1.04
Screenline Total	12,510	10,110	22,620	14,600	8,860	23,350	1.03
Screenline 8 - East of Port of Tacoma Rd							
Freeways	7,980	7,040	15,020	8,880	6,420	15,300	1.02
Arterials	2,230	3,360	5,590	1,760	2,010	3,700	0.66
Screenline Total	10,210	10,400	20,610	10,640	8,430	19,050	0.92
Point Locations - A & B							
I-405, South of Coal Creek Pkwy -- A	6,040	4,250	10,290	5,750	3,510	9,260	0.90
I-405, North of SR 520 -- B	4,980	7,960	12,940	4,680	7,430	12,110	0.94

Table C-2: Base Year (2016) screenline total vehicle volume comparison (PM peak hour)

	Actual Volumes			Estimated Volumes			
	NB/EB	SB/WB	Total	NB/EB	SB/WB	Total	Est/Obs
Screenline 1 - North of 112th St SW							
Freeways	7,240	6,290	13,530	7,800	4,400	12,200	0.90
Arterials	5,890	6,100	11,990	6,000	5,000	11,000	0.92
Screenline Total	13,130	12,390	25,520	13,800	9,400	23,200	0.91
Screenline 2 - South of N 145th Street							
Freeways	7,440	5,070	12,510	8,500	5,000	13,500	1.08
Arterials	7,990	7,190	15,180	9,200	5,600	14,800	0.97
Screenline Total	15,430	12,260	27,690	17,700	10,600	28,300	1.02
Screenline 3 - Ship Canal							
Freeways	10,560	4,660	15,220	11,900	6,900	18,800	1.24
Arterials	6,260	5,080	11,340	6,700	6,200	12,900	1.14
Screenline Total	16,820	9,740	26,560	18,600	13,100	31,700	1.19
Screenline 4 - Midlake							
Freeways	10,310	8,720	19,030	10,700	9,300	20,000	1.05
Screenline Total	10,310	8,720	19,030	10,700	9,300	20,000	1.05
Screenline 5 - West of 140th Ave E							
Freeways	11,140	8,580	19,720	11,500	9,400	20,900	1.06
Screenline Total	11,140	8,580	19,720	11,500	9,400	20,900	1.06
Screenline 6 - South of SR 518/I-405							
Freeways	12,590	15,080	27,670	9,500	16,300	25,800	0.93
Arterials	4,470	4,780	9,250	4,100	5,500	9,600	1.04
Screenline Total	17,060	19,860	36,920	13,600	21,800	35,400	0.96
Screenline 7 - King/Pierce County Line							
Freeways	7,090	8,200	15,290	6,800	12,000	18,800	1.23
Arterials	4,020	5,130	9,150	4,100	7,100	11,200	1.22
Screenline Total	11,110	13,330	24,440	10,900	19,100	30,000	1.23
Screenline 8 - East of Port of Tacoma Rd							
Freeways	8,010	8,580	16,590	7,200	10,100	17,300	1.04
Arterials	3,620	3,430	7,050	2,600	4,300	6,900	0.98
Screenline Total	11,630	12,010	23,640	9,800	14,400	24,200	1.02
Point Locations - A & B							
I-405, South of Coal Creek Pkwy -- A	4,970	4,820	9,790	4,300	6,200	10,500	1.07
I-405, North of SR 520 -- B	7,940	5,910	13,850	8,600	6,000	14,600	1.05

Table C-3: Base Year (2016) screenline total vehicle volume comparison (average weekday)

	Actual Volumes			Estimated Volumes			
	NB/EB	SB/WB	Total	NB/EB	SB/WB	Total	Est/Obs
Screenline 1 - North of 112th St SW							
Freeways	104,100	105,200	209,300	85,400	82,300	167,700	0.80
Arterials	69,100	76,900	173,300	88,900	86,600	175,500	1.01
Screenline Total	173,200	182,100	382,600	174,300	168,900	343,200	0.90
Screenline 2 - South of N 145th Street							
Freeways	101,300	102,300	203,600	110,400	107,300	217,700	1.07
Arterials	76,000	72,300	148,300	85,500	84,300	169,800	1.14
Screenline Total	177,300	174,600	351,900	195,900	191,600	387,500	1.10
Screenline 3 - Ship Canal							
Freeways	133,900	122,000	255,900	146,700	138,500	285,200	1.11
Arterials	62,100	63,500	269,300	155,400	159,800	315,200	1.17
Screenline Total	196,000	185,500	525,200	302,100	298,300	600,400	1.14
Screenline 4 - Midlake							
Freeways	120,400	120,000	240,400	135,600	126,400	262,000	1.09
Arterials	29,600	29,600	59,100	26,400	25,800	52,200	0.88
Screenline Total	150,000	149,600	299,500	162,000	152,200	314,200	1.05
Screenline 5 - West of 140th Ave E							
Freeways	136,600	132,700	269,300	147,800	136,000	283,800	1.05
Arterials	51,700	51,700	103,300	49,600	52,000	101,600	0.98
Screenline Total	188,300	184,400	372,600	197,400	188,000	385,400	1.03
Screenline 6 - South of SR 518/I-405							
Freeways	220,400	204,000	424,400	182,600	180,400	363,000	0.86
Arterials	76,100	81,300	157,400	61,300	70,900	132,200	0.84
Screenline Total	296,500	285,300	581,800	243,900	251,300	495,200	0.85
Screenline 7 - King/Pierce County Line							
Freeways	155,300	145,300	300,600	152,100	150,600	302,700	1.01
Arterials	41,800	45,200	87,000	52,000	55,300	107,300	1.23
Screenline Total	197,100	190,500	387,600	204,100	205,900	410,000	1.06
Screenline 8 - East of Port of Tacoma Rd							
Freeways	122,900	120,000	242,900	128,400	124,500	252,900	1.04
Arterials	41,600	47,200	88,800	34,300	40,300	74,600	0.84
Screenline Total	164,500	167,200	331,700	162,700	164,800	327,500	0.99
Point Locations - A & B							
I-405, South of Coal Creek Pkwy -- A	85,300	79,400	164,700	81,600	74,800	156,400	0.95
I-405, North of SR 520 -- B	105,200	99,600	204,800	100,400	99,800	200,200	0.98

Appendix D: Procedures for Transit Network Preparation

- *Development of the Base Network*
 - *Coordinate System*
 - *Bus Speed from AVL Data*
 - *Bus Speed Degradation Procedures*
-

Appendix D: Procedures for Transit Network Preparation

Actual transit service is represented in a transit ridership forecasting model by means of a coded network. This service representation actually consists of two elements:

- A highway network, or “base network,” is coded to create a computerized representation of existing and planned roads, busways, and tracks in the study region.
- Transit service assumptions are overlaid on this base highway network.

Significantly, for Sound Transit (ST) studies, the base network does not vary among alternatives. A single base network is used for all alternatives—meaning that for each alternative, elements of the base network may exist on which no transit service is coded. For example, rail rights-of-way are coded in every network although rail service may not yet exist on many of these rights-of-way.

ST decided to construct a single base network for several reasons. One advantage of keeping the base network constant is that it eliminates spurious errors caused by roads or walkways which could accidentally be coded differently in different alternatives. A second reason for maintaining a single base network is that it minimizes differences in results due to accidental differences in access coding. Because a major aim of any forecasting effort is to capture differences among various alternatives, it is important that these differences are attributable to actual differences among the alternatives, rather than to coding inconsistencies.

In contrast to the base network, the transit service that operates on this network does vary, both by forecast year and by alternative. The transit service network created for each alternative is represented by a set of bus and rail transit routes operated by local transit agencies.

D.1 Development of the base network

The base network is coded within the ST boundary and consists of links and nodes that represent the road system on which transit and automobiles travel. As mentioned, exclusive rights-of-way for transit (e.g., busways and rail tracks) are also coded, although they may not be used in every alternative. Park-and-ride lots are also coded, although some of these may not be served by transit in every alternative.

Each of the links coded in the base network has a set of attributes consisting of the length, type, modes allowed, lanes, and speed. More detail on link attributes is presented below.

The network outside the study area is not coded, although the major roads leaving the study area are coded by means of external links. These links serve as a method of accounting for travel into the study area from areas beyond the study area boundaries.

D.1.1 Transit mode types

The following seven modes are specified on links within the base network:

Symbol	Mode represented
b	Bus
t	Trolley Bus
r	Rail (including streetcar)
a	Auto access/egress (directional link)
w	Walk access/egress (directional link)
p	General pedestrian link
x	Park-and-ride lot connection (directional link)

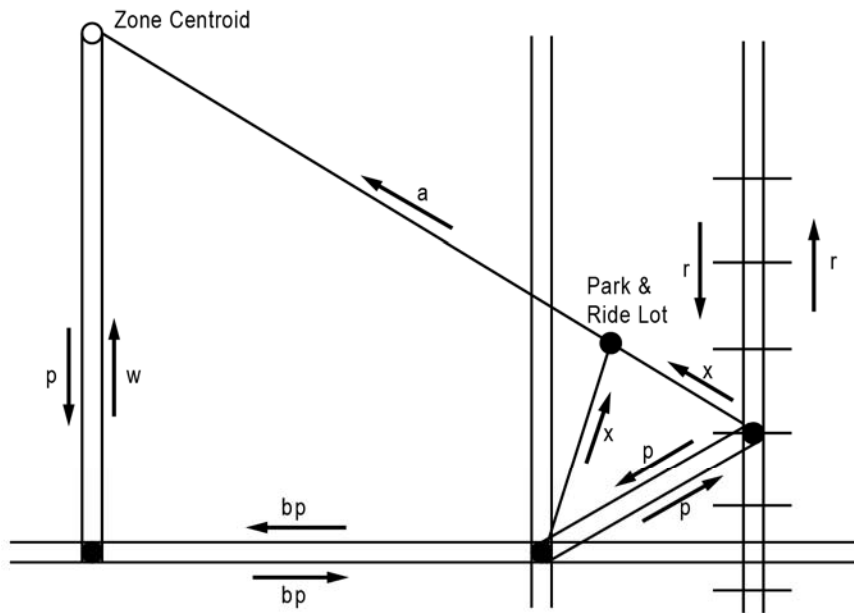
The access modes (i.e., modes “a,” “w,” “p,” and “x”) are an important aspect of the base network. Note that in a PM peak transit network, the conventional terms “auto access” and “walk access” would be more properly described as “auto egress” and “walk egress”. There is a minor variation in the way these access modes are used in the PM-peak and off-peak networks. In the peak networks, both auto access and walk access modes are allowed at the destination end of the transit trip, while in the off-peak, only walk access is allowed. At the origin end of the trip, the “p” mode enables all trips access to the network from an origin zone.

Walk-access links are coded with a speed of 2.5 miles per hour (mph). The “w” mode allows walking from the base network to a destination zone centroid. The specification of a “w” mode enables the analysis of auto-access-only paths by disallowing this mode for peak auto-access assignments. The “p” mode accommodates all other walking, including zonal walk access, sidewalks and pedestrian paths, and station escalators, elevators, and transfer paths.

The other two access modes (modes “a” and “x”) are associated with the use of park-and-ride lots to access transit. Mode “a” allows auto trips between park-and-ride lots and zone centroids, and mode “x” represents walking between platform and car.

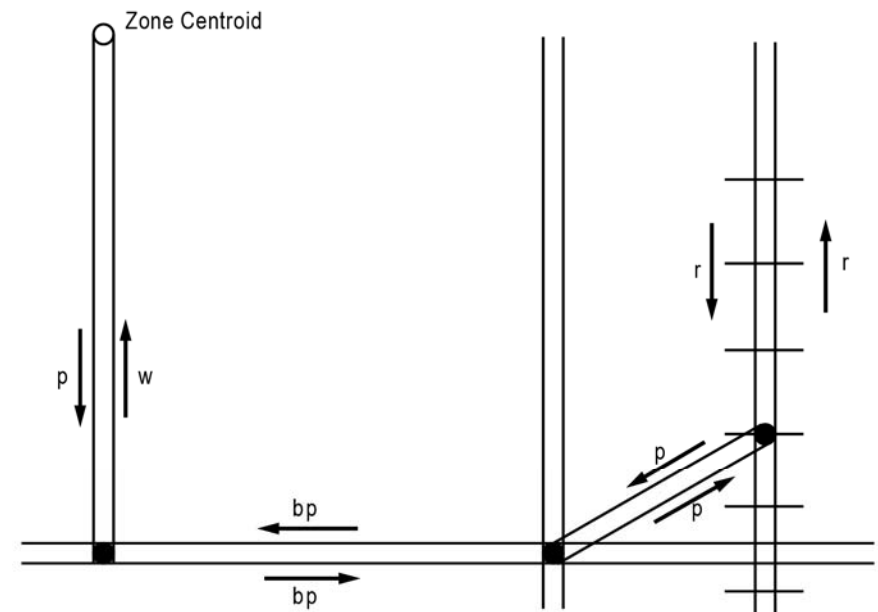
Figures D-1a and D-1b illustrate this coding convention. For ease of understanding, only modes used in the path building at the destination end are shown. The network as used for the PM-peak path-building and calculations is shown in Figure D-1a. The network as used for the off-peak path-building and calculations is shown in Figure D-1b.

There are several reasons for including the x-links to represent park-and-ride access to transit. First, using such links allows for counting the number of trips that use park-and-ride locations to access transit. Second, the use of such links will allow for modeling the effect of charging fees at park-and-ride lots should this be desired. Third, there is a certain disutility associated with having to walk some distance between a bus or train platform and a parked car. Using x-links allows for the inclusion and variation of this disutility in the model.

**LEGEND**

Symbol	Mode Represented
a	Auto Access (Directional Link)
b	Bus
p	General Pedestrian Link
r	Rail
w	Walk Access (Directional Link)
x	Park and Ride Lot Connection Link

Figure D-1a. Sample mode coding on base network links (PM peak)

**LEGEND**

Symbol	Mode Represented
b	Bus
p	General Pedestrian Link
r	Rail
w	Walk Access (Directional Link)

Figure D-1b. Sample mode coding on base network links (off-peak)

Finally, the use of x-links allows for a more even-handed comparison of park-and-ride access to transit between rail and non-rail alternatives. The use of x-links allows one to connect a single park-and-ride lot to both a bus stop and a rail station. This allows use of exactly the same park-and-ride location and auto-access by adjacent bus and rail stops.

All auxiliary transit modes have identical speeds in the peak network and the off-peak network. However, speeds on links used by bus and rail lines may vary between the peak and off-peak networks. Sources of bus and rail speeds are described below.

D.1.2 Development of the future transit service networks

Transit service networks are created to represent the transit service planned for each alternative and forecast year, as well as the service operated in the base years used to validate the model. Each service network is characterized by a unique set of routes, which includes rail lines, bus rapid transit (BRT) lines, express bus lines, and local bus lines. Each route is described by the nodes and links over which it travels, the travel time on each link, the locations where it stops, and its peak and off-peak headways. The characteristics are described in detail below.

Route patterns

Each route can be described by its route alignment, or the set of nodes and links over which it travels. The places where passengers are picked up and dropped off are coded by placing a dwell time on the nodes that represent bus stops for each particular route. All Sound Transit, King County Metro, Community Transit, Everett Transit, and Pierce Transit routes within the forecast study area are coded for each alternative and forecast year, with the exception of dial-a-ride services and routes that have less than six trips per day.

Route headways

Bus and rail headways are specified for each route in each transit service network, peak and off-peak. The headways in the PM peak network reflect the number of trips between 3:00 and 6:30 p.m., and the headways in the off-peak network reflect the base headways from 9:00 a.m. to 3:00 p.m. and 6:30 p.m. to 10:00 p.m. For the Base-Year network, headways are determined directly from the published operating schedules.

Future networks are developed according to the specific definition of alternatives as defined in appropriate Definition of Alternatives reports for Draft EIS, Final EIS, and PE projects as well as New Starts applications.

Rail speeds and bus speeds

For bus lines, peak and off-peak link speeds are obtained directly from AVL data as described below. For existing rail lines, all link speeds are obtained directly from ST operating data.

For future rail lines, link speeds are developed from operating plans supported by simulations. Future bus speeds are degraded according to the change in general roadway congestion level estimated by the PSRC model for arterial and freeway facilities and by geographic area. This procedure was developed and documented by ST staff in a memorandum to the FTA. A copy of this memorandum follows this section. Speeds of buses on busways, protected lanes are not affected and remain constant into the future.

D.2 Coordinate system

The ST model was previously projected in a variant of the WGS 1984 UTM Zone 10N coordinate system. This caused some network distortions that affected accurate plotting of the links and link distances. These issues were more pronounced farther from Seattle, such as in Everett and Tacoma. The coordinate system in the 2017 version of the ST model was updated to NAD 1983 HARN State Plane Washington North FIPS 4601. This update significantly reduced those distortions.

The following method was applied to update the coordinate system:

- Convert the existing nodes to State Plane North.
- Manually move nodes to more accurate locations.

This method preserves existing link and node numbers, allowing for preservation of the existing ST model transit network. The method is performed in a relatively short timeframe, and it limits possible unintended issues within the ST model.

The model nodes, with their existing identifiers and other values, are projected into State Plane North coordinates within ArcGIS. Then in ArcGIS, the nodes are manually moved to locations that best reflect the intersections that they represent in the model. This is an extensive process that spans the entire network coverage area (i.e., the RTA district boundaries).

To expedite the process and increase quality of node relocation, the nodes are typically snapped to a non-model GIS roadway network. An example of a completed area with nodes adjusted is shown in Figure D-2a. Additionally, the distortions in the network are greatly reduced, as exemplified by the change in scale and link locations in Everett shown in Figure D-2b.

D.3 Bus speed from AVL data

In previous model updates, bus speeds were hand-adjusted for major facilities and subareas of interest. This worked effectively in the past, partly because the changes to the seed matrices were modest. As the origin-destination seed matrices for this model version are now based on ORCA data instead of historical surveys, the actual speeds from Automatic Vehicle Locator (AVL) data should reflect the travel conditions that correspond directly to this origin-destination data.

King County Metro (KCM), Pierce Transit (PT), and Community Transit (CT) now have AVL equipment on their entire fleets and keep records of the AVL data. Sound Transit buses operated by these three agencies also have AVL equipment and associated data. As this data is more complete and readily available than for previous model updates, it is now used in the current 2017 ST model version.

The AVL data used in the ST model is received from the Washington State Transportation Center (TRAC) at the University of Washington and covers the same 9-week period in 2016 as the ORCA data. Each agency's data is in a distinct format. KCM and CT provide stop-to-stop travel times, including dwell times if applicable. PT only provides stop-to-stop times where the bus door opened, which reduces the number of observed data points.

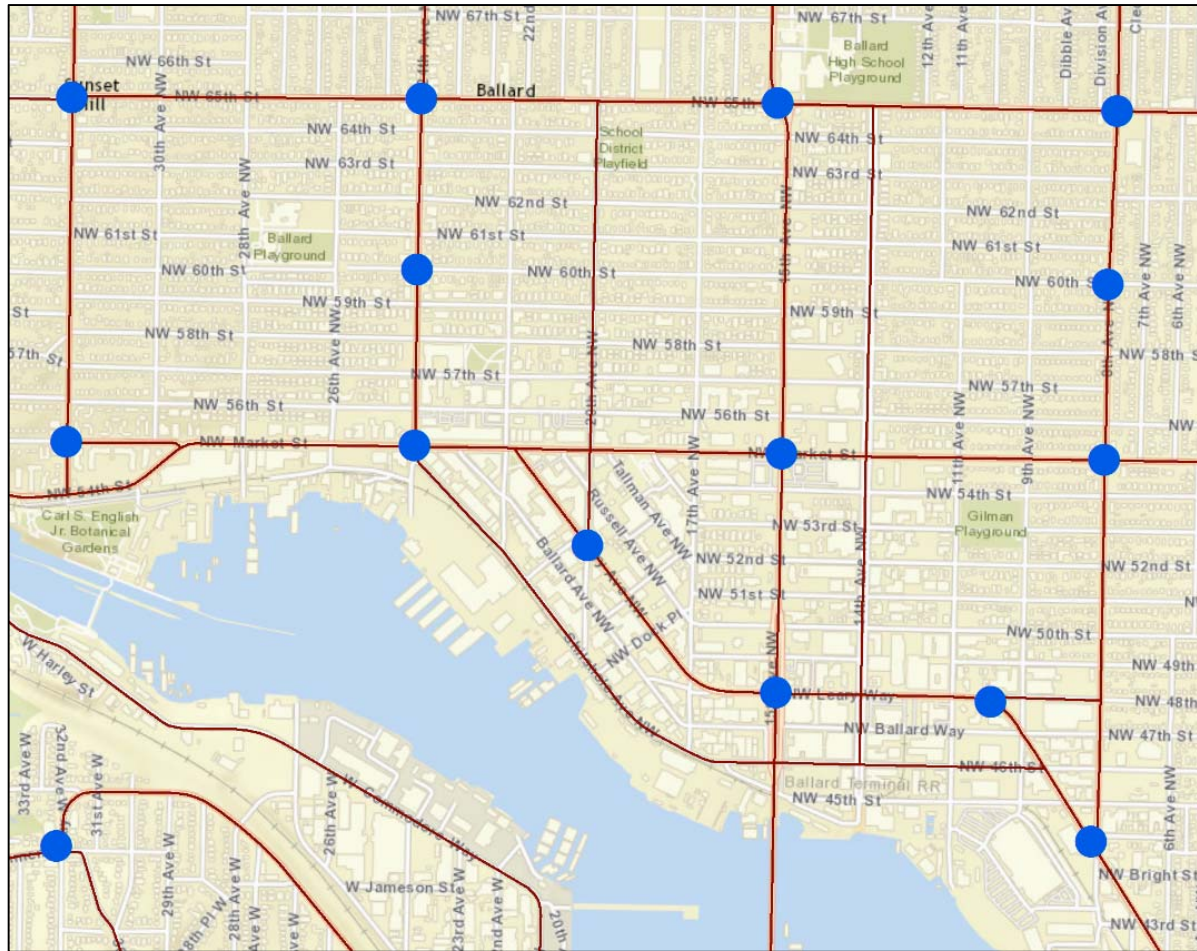


Figure D-2a. Updated nodes viewed in ArcGIS

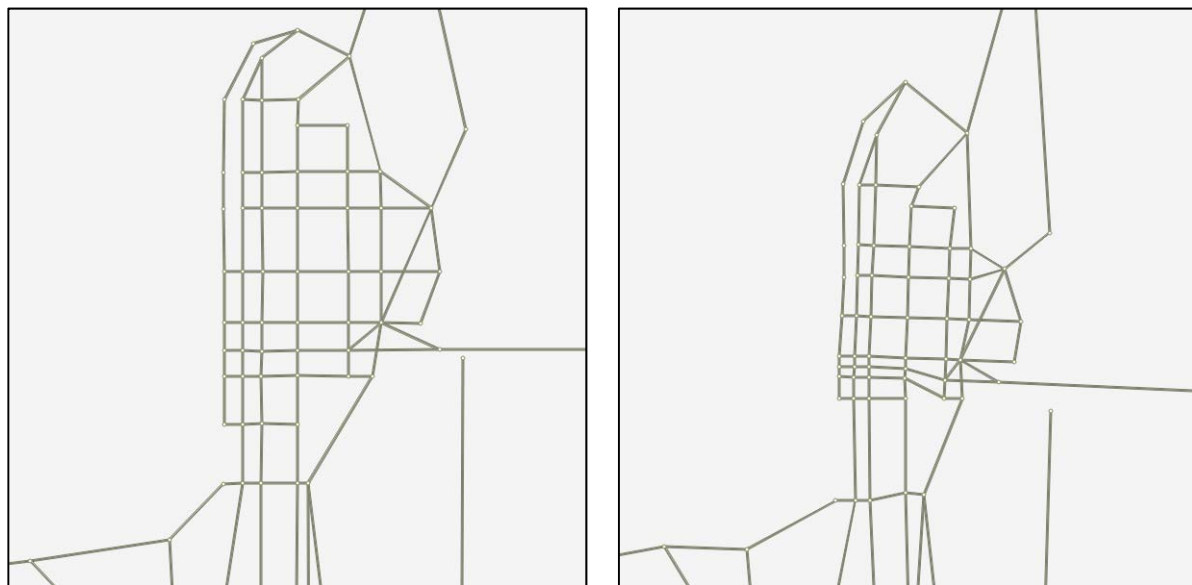


Figure D-2b. Model network before (left) and after (right) the update

AVL data processing

The process for attaching observed bus speeds to ST model links is described in this section.

In ArcGIS, each stop-to-stop travel time observation is imported as a line so that an average speed may be calculated. Both the hour-of-day and the bus route number associated with the line are saved as an attribute. The 11:00 a.m. and 5:00 p.m. hours are used to calculate off-peak and peak speeds, respectively. Over 3 million speed observations were used to prepare average link-level speed values.

A midpoint of each modeled bus link is selected and a buffer created around it. Buffers are used to account for any geometry mismatch between the observed stop-to-stop line and the model links, such as precise bus route turn locations or roadway curvature that is not in the model.

Then for each bus route, the speeds along each observed line are averaged to the midpoint buffers of model links that the route uses. Average speeds of each route are weighted by frequencies of those routes. Freeway and arterial speeds are calculated separately to account for multiple observed stop-to-stop line overlaps attributable to the typically long distances between stops along freeway routes.

After speeds are calculated for each agency and facility type, a summary table of average speeds on each link is created. In the few cases where a link is traversed by more than one transit agency, the KCM speed is given twice the weight of CT or PT speeds during the averaging process. Figure D-3 illustrates schematically the consolidation of average speeds from a mix of bus routes using a common link in the network, often with differing stopping patterns. A few examples of how AVL speeds would be attached to the links in Figure D-3 for a given time period are provided below:

- The buffer for the midpoint of model link 1 has both observed stop-to-stop travel times for routes A and B. At that location, the speed assigned to the link is the weighted averages of the speeds of the two routes at that point, even though one route is a local and the other is an express.
- For model link 2, the same calculation as link 1 applies, and the freeway route is ignored, even though the observed stop-to-stop line passes through it.
- The buffer for the midpoint of model link 3 has only route C passing through it, so the average stop-to-stop speed for that route at that location is attached to the link.

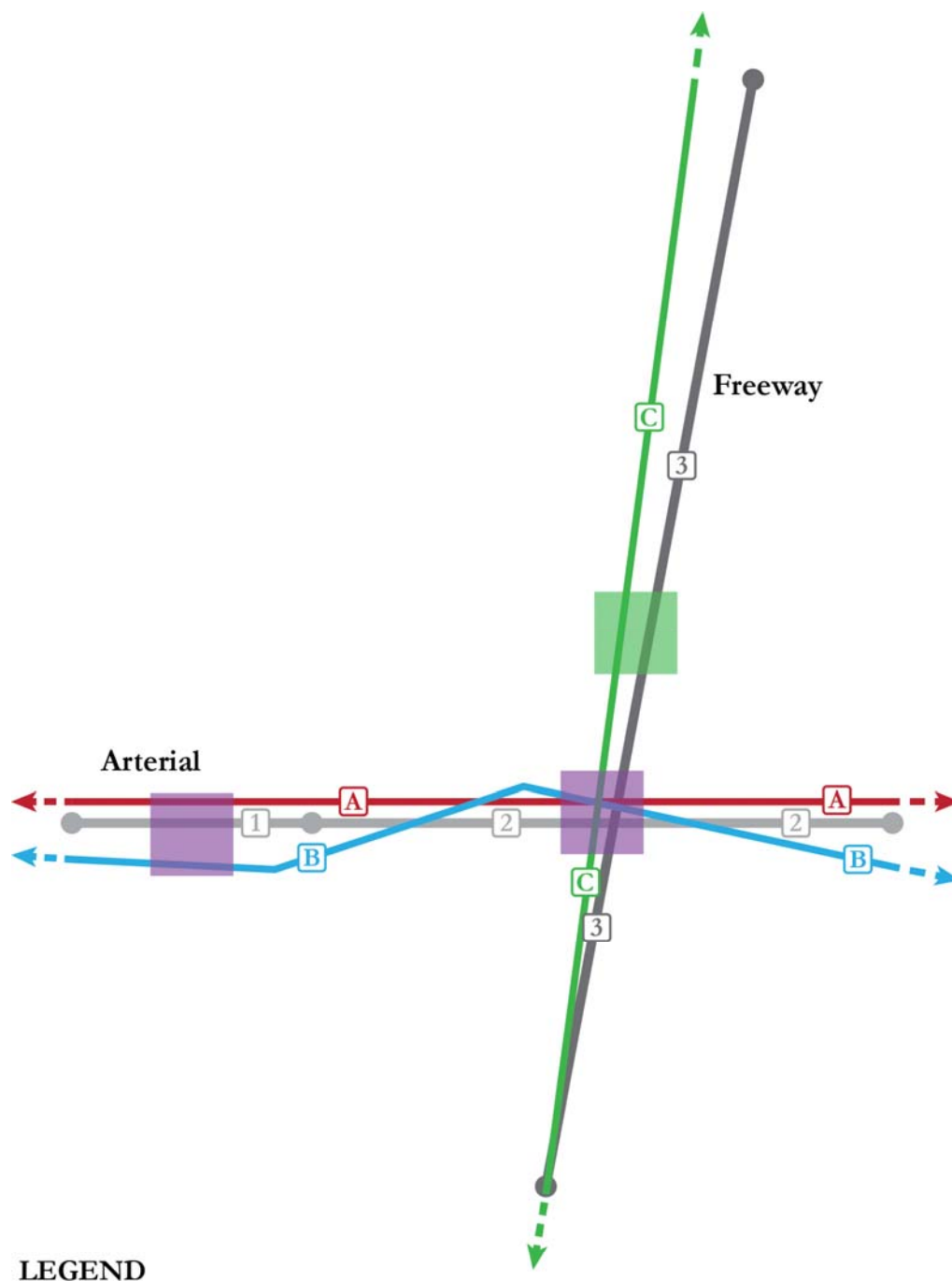


Figure D-3. Schematic representation of average speeds consolidation using AVL bus speeds and model link midpoint buffers

August 1, 2002

TO: Eric Pihl

FROM: Don Billen

SUBJECT: Updated Treatment of Bus Speeds in the Sound Transit Model

This memorandum describes the updated procedures for treating bus speeds in Sound Transit's incremental ridership forecasting process. This is in response to your request that Sound Transit rely on output from the PSRC multi-modal model to estimate changes in bus speeds over time.

Sound Transit Incremental Ridership Model

Sound Transit uses an incremental model to forecast transit ridership consisting of three stages:

- Stage 1: Changes in demographics
- Stage 2: External changes in highway travel time (congestion) and costs (including parking costs), transit fares, and household income are taken into consideration.
- Stage 3: Incremental changes in the transit level-of-service (i.e. access, wait, and ride travel times) are taken into consideration.

The third stage of the forecasting process is where the effects of changes in bus speeds are captured. Base year link speeds in combination with transit travel time functions are used so that they result in network bus travel times equal to observed bus travel times. Individual transit routes are coded with transit travel time functions that account for acceleration/deceleration time, with bus speeds equal to the base year link speed for express portions of a route. Dwell time is similarly coded for individual transit routes, with zero dwell time for express portions of a route.

Future year link bus speeds are degraded relative to base year link speeds and according to the procedures described below. The transit travel time functions which account for acceleration/deceleration time are the same in the base year and future year. Dwell time similarly remains the same in the base and future year.

Since the model's development in the early 1990s by the Regional Transit Project, future year link speeds have been estimated using a constant degradation rate of seven to nine percent per decade. This degradation rate is consistent with historic trends in bus speeds. However, FTA staff have expressed concern about extrapolating historical trends into the future and suggested relating future bus speeds to road speeds in the PSRC multi-modal model.

Updated Procedure for Estimating Future Bus Speeds

Sound Transit and its ridership consultant have investigated several methods for relating road speeds in the PSRC model to bus speeds in the Sound Transit model. After reviewing these methods with Puget Sound Regional Council and City of Seattle modeling staff, we have arrived at the following procedure.

For arterial bus speeds, weighted average auto travel time within the PSRC model is calculated at an intra-26-district level for the base year and forecast year in the PM peak and off-peak. The ratio between the base year and forecast year intra-district times is calculated. This change in intra-district auto travel times is used to estimate the change in bus speeds and is applied to the base year link speed values in the ST model for each geographic district. Table 1 shows the resulting PM peak bus degradation rates for each of the 26 districts for the period of 1998–2020.

Table 1. PM Peak Arterial Degradation Rates

Comparative Analysis of 1998 to 2020 Weighted Average Intra-District Travel Times					
District		1998	2020	2020/1998 Ratio	Change Per Decade
North Everett	1	6.13	6.80	1.11	4.8%
South Everett	2	8.24	9.28	1.13	5.6%
Lynnwood	3	8.04	9.95	1.24	10.2%
North Creek	4	10.13	11.17	1.10	4.5%
Shoreline	5	6.47	6.79	1.05	2.2%
Ballard	6	6.32	6.79	1.07	3.3%
North Seattle	7	6.64	7.29	1.10	4.3%
University District	8	4.55	5.52	1.21	9.2%
Queen Anne	9	6.44	6.94	1.08	3.5%
Capitol Hill	10	4.86	5.07	1.04	1.9%
Seattle CBD	11	2.48	2.63	1.06	2.6%
W Seattle	12	7.28	8.63	1.19	8.1%
Rainier	13	9.17	9.92	1.08	3.6%
Sea-Tac	14	8.01	8.81	1.10	4.4%
Renton	15	10.00	11.58	1.16	6.9%
Federal Way	16	8.26	9.50	1.15	6.5%
Kent	17	9.99	11.16	1.12	5.2%
Kirkland	18	8.75	10.10	1.15	6.7%
Redmond	19	8.60	11.42	1.33	13.8%
West Bellevue	20	5.51	5.68	1.03	1.4%
Bellevue	21	8.85	9.69	1.10	4.3%
Issaquah	22	8.62	10.33	1.20	8.6%
North Tacoma	23	8.48	10.58	1.25	10.6%
South Tacoma	24	6.16	6.78	1.10	4.4%
Lakewood	25	8.30	9.72	1.17	7.4%
Puyallup	26	10.51	11.46	1.09	4.0%
External	27	16.97	19.70	1.16	7.0%
Destination Totals		19.33	22.34	1.16	6.8%

For freeway bus speeds, zone to zone travel times between major entry and exit points for buses along regional freeways are calculated for the base year and future year. As with arterial times, the ratio between the base year and forecast year times is calculated. This change in freeway auto travel times is used to estimate the change in bus speeds and is applied to the base year link speed in the ST model for each freeway segment. Table 2 shows the resulting bus degradation rates on two freeway segments in the light rail study area.

Table 2. PM peak freeway degradation rates

Comparative Analysis of 1998 to 2020 Freeway Travel Times				
Freeway Segment	1998	2020	2020/1998 Ratio	Change Per Decade
I-5: Seattle CBD to Northgate	15.50	18.07	1.17	7.2%
SR 520: Seattle to Overlake	22.15	25.12	1.13	5.9%

The resulting rates of degradation for both arterials and highways are somewhat lower than historic changes in bus speeds in the Central Puget Sound Region, so may underestimate actual degradation rates. However, the updated method offers the advantage of being sensitive to varying congestion rates over time and across geographic areas and to changes in these rates with alternative land use or highway network scenarios.

Alternate method investigated

Our ridership forecasting consultant originally proposed to simply average PSRC link speeds within a cross-classification of geography and facility type for a base and future year to estimate changes in bus speeds. (see Parsons Brinkerhoff memo of 12-2-01 from Youssef Dehghani to Don Billen).

Investigation of this method between 1998 and 2020 yielded results that varied greatly between geographic areas and on the aggregate showed changes in road times much lower than other analyses of PSRC model output. The average decline in speeds across all facilities was 1% per decade between 1998 and 2020 compared to previous analysis of zone-zone road skims that showed an average decline of 8% per decade (see Parsons Brinkerhoff memo of 11-19-01 from Youssef Dehghani to Don Billen). Furthermore, the change in arterial speeds in different geographic areas varied by factors as high as 16 to 23 times. For instance, major arterial speed degradation in the Eastside of King County was 17 times as high as in Snohomish County, even though both are high growth areas with very limited road expansion currently funded. (Table 3)

Upon review of these results with PSRC and City of Seattle modeling staff, we concluded that simple averaging of link speeds is inaccurate and that it would be better to rely on zone-zone skim times than link level times. The simple averaging of link speeds results in too much influence from low volume roadways and too little influence from highway volume roadways. Also, using link level rather than zone-zone travel time skims created the possibility for the results to be influenced by the density of road networks coded in a geographic area.

Table 3. Analysis of PM peak speed degradation in PSRC model by facility type and area type

(average change per decade from 1998 to 2020)									
Facility Type	Area Type								
	All	Seattle CBD	Seattle	Eastside	Rest of King County	Snohomish County	Pierce County	Kitsap County	
All	1.5%	0.9%	0.7%	5.6%	3.0%	0.8%	1.8%	0.2%	
Freeway GP Lanes	6.3%	4.48%		8.8%	3.1%	14.4%	4.0%	6.1%	
Freeway HOV Lanes	1.2%	1.95%		4.2%		5.56%			
Major Arterials	1.4%	3.4%	0.8%	6.8%	3.0%	0.4%	1.9%	0.2%	
Minor Arterials	1.8%	0.1%	0.2%	3.1%	2.7%	2.1%	0.3%	0.0%	
Notes :- The data shown above represents the percentage speed degradation over a period of 22 years from 1998 to 2020. - The percentage degradation in speed was obtained from the "slope" of the regression equation obtained from a linear regression analysis of PM peak link travel times for a particular facility type and area type. - The regression analysis showed an R^2 of greater 0.9 for all the categories. - Major arterials include all those arterials in the PSRC model that have a speed greater than 25 mph, e.g., MLK way, Rainier Avenue, NE 8th (in Bellevue etc.). Minor arterials are arterials with a speed less than 25 mph.									

These concerns led PSRC and City of Seattle modeling staff to recommend the use of weighted average auto travel times from zone-zone travel time skims and to Sound Transit's development of the procedures described at the beginning of this memo.

CC: John Witmer, FTA Region X
Larry Blaine, Puget Sound Regional Council
Eric Tweit, City of Seattle
Tracy Reed, Ron Lewis, Mike Williams, Sound Transit