Ballard Link Extension

Second Downtown Tunnel Feasibility Assessment

December 2025

Sound Transit

Revision History

Version	Title	Date	Notes
0	Board of Directors Briefing	12/10/25	Initial draft to support Board-level discussions; subject to ongoing internal quality review

Summary

Purpose

The ST3 Plan originally proposed construction of a second downtown tunnel from SODO through Chinatown-International District (CID), Midtown, Westlake, Denny, South Lake Union (SLU), and Seattle Center as part of the Ballard Link Extension (BLE). Given rising cost pressures facing the ST3 Program, Sound Transit is investigating whether technology and reliability upgrades could allow interlining all three lines through the existing Downtown Seattle Transit Tunnel (DSTT) – instead of building the portion of the new tunnel between SODO and Westlake – and whether this could be a feasible and practical alternative that could save costs while maintaining reliable service. If achievable, this may allow resources to be prioritized to bring light rail to Ballard and West Seattle.

Background

The ST3 Plan envisioned a second tunnel to provide additional transit capacity through downtown to meet forecasted ridership. To avoid operating one long rail line (or "spine") between Everett and Tacoma, with the associated service reliability issues, the new downtown tunnel was instead envisioned to accommodate service connecting Tacoma to Ballard, while the existing DSTT would accommodate service connecting West Seattle to Everett and Redmond to Mariner. This configuration has been referred to as "spine segmentation" (**Figure 1-1**). This configuration was intended to create more manageable line lengths, necessitate fewer maintenance facilities, help balance rider volumes through downtown Seattle, and provide more operational flexibility.

The existing DSTT was originally built for buses, not trains, and does not currently have the necessary infrastructure (ventilation, traction power, platform capacity, special trackwork, communications/train control, signaling system, and other features) to run all three lines through it at the headways required to accommodate forecasted ridership.

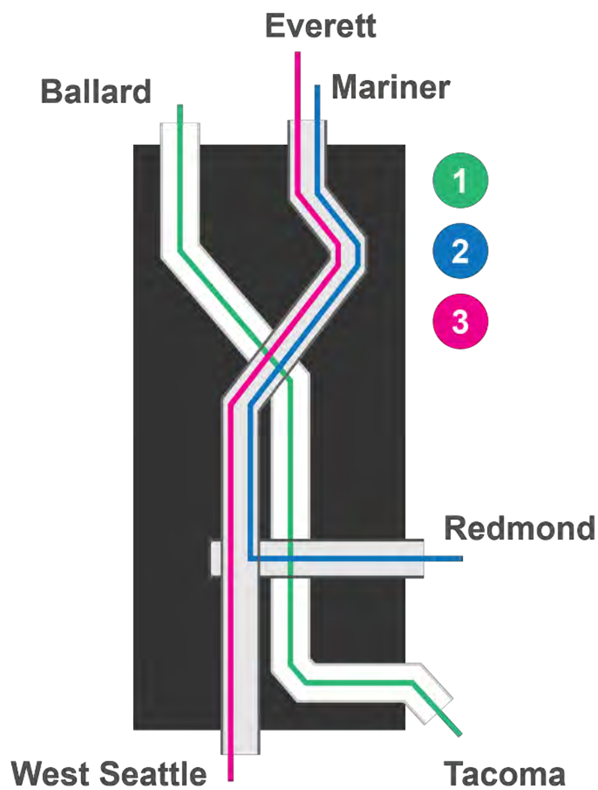

Figure 1-1 Tunneling Configuration for ST3 Plan

Approach

To determine whether technology and reliability upgrades could allow all three lines to run through the existing DSTT, Sound Transit leveraged consultant resources as well as a broad

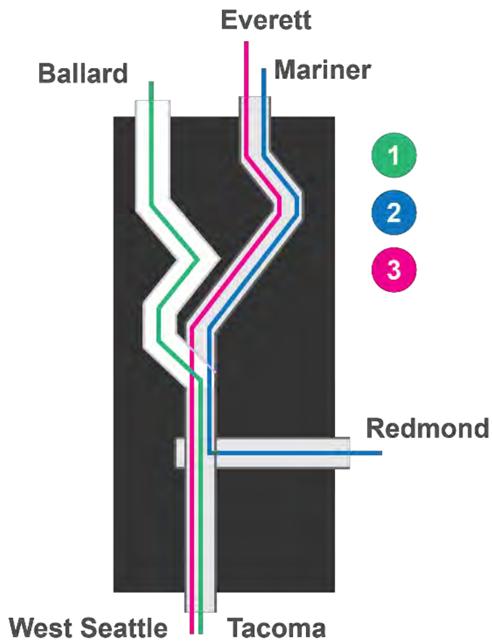

Figure 1-2 Tunneling Configuration for Interlining Alternatives

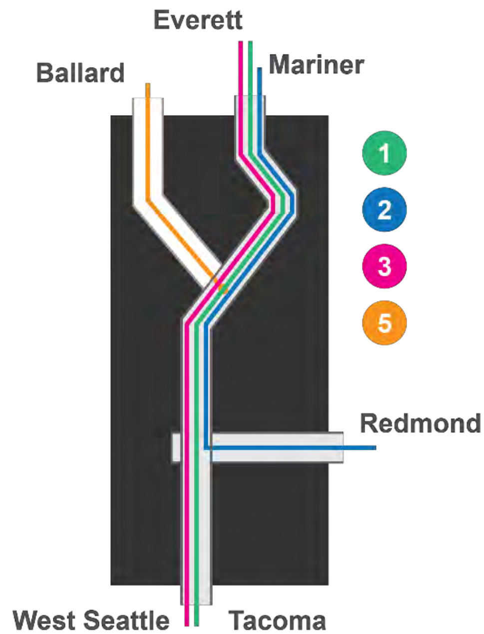

Figure 1-3 Tunneling Configuration for Stub-end Alternative

group within Sound Transit, with expertise in tunneling, track, construction, rail operations modeling, maintenance facility assessment, and cost estimating.

Several approaches were analyzed that could eliminate the need to build the portion of the new downtown tunnel between SODO and Westlake. In all cases, it was assumed that the portion of the new tunnel that extends north from Westlake, which facilitates a connection to Ballard, would still be built. To accommodate running three light rail lines through the existing DSTT, all approaches would necessitate extensive near-term infrastructure upgrades, including ventilation, traction power, platform capacity, special trackwork, communications, and train control/signaling system.

One of the approaches involves connecting ("interlining") the new tunnel from Ballard with the existing DSTT (**Figure 1-2**). Interlining means that trains traveling from Tacoma would operate in the existing DSTT before diverting into a new tunnel to Ballard in the vicinity of Westlake and Symphony stations. Approaches to interlining were examined in detail during this study and include both at-grade and grade-separated configurations.

Another approach would be to terminate ("stub-end") the new tunnel from Ballard where it meets the existing DSTT in the vicinity of Westlake Station (**Figure 1-3**). Stub-ending means that trains would not be able to travel from the existing DSTT into the new tunnel (i.e., the Ballard Line would operate as a standalone line). Passengers would transfer between these lines at Westlake.

For each approach, the study examined in detail the construction implications (constructability, cost, risk, system and City construction disruptions, and other potential effects), operational implications (headways, on-time performance, journey times, resilience, and other measures), and other implications (environmental process, delivery implications, future compatibility, and other considerations).

Findings

The interlining approach would operate three lines within the existing DSTT between IDS and Symphony stations while the stub-end approach would require operating three lines beyond Westlake Station to the north into the University Link tunnel. Forecasted capacity needs require a six-minute headway on each of the three lines, which equates to a two-minute combined headway in the interlined segment. The current system has a number of constraints that limit the ability of Sound Transit to achieve a two-minute combined headway. If upgrades are not implemented (ventilation, traction power, platform capacity, special trackwork, communications, train control/signaling system) the system would not be able to accommodate a headway less than nine minutes on each of the three lines. Recognizing that implementing such upgrades in the near term would be a prerequisite to operating three lines through the existing DSTT, the following is a summary of the benefits and challenges of the interlining and stub-end approaches referenced above:

Benefits:

1. **Light rail service to Ballard:** Either of the approaches (interlining or stub-end) could facilitate a light rail connection to Ballard.
2. **Cost savings:** Two interlining configurations were studied (at-grade and grade-separated). The at-grade interlined configuration could save between $1.3 billion and $5 billion compared to the full-build Preferred Alternative, while the grade-separated interlined configuration ranges from no cost savings to up to $4.5 billion in savings. The stub-end approach ranges from no cost savings to up to $4 billion in savings. The high end of each range represents an optimistic scenario and the low-end accounts for potential additional capital cost risk and expenditures to ensure consistent service and system reliability.
3. **Passenger transfers:** The interlining approach would allow for same-platform transfers for the 1 Line (Tacoma to Ballard), 2 Line (Redmond to Mariner) and 3 Line (West Seattle to Everett) at the International District (IDS), Pioneer Square, and Symphony stations. The stub-end approach would provide same-platform transfers for the 1, 2 & 3 lines; however, it would not provide same-platform transfers to Ballard.
4. **Future tunnel completion:** The stub-end approach could be configured to be forward-compatible with building the remaining portion of tunnel from Westlake to SODO, which would add system capacity and resilience in the future. The interlining approach could also facilitate forward compatibility at additional cost but would result in some redundant infrastructure (i.e., the interlined tunnel connection from the Ballard Line to the existing DSTT). This additional investment could, however, enhance future operational flexibility by serving as train storage or a connection between lines in the long term.

Challenges:

1. **Construction disruption:** The interlining approach would require that existing light rail service through downtown and up to Lynnwood be shut down for an extended period (approximately three years or more) to accommodate construction associated with connecting the new tunnel from Ballard to the existing DSTT. Additionally, it is uncertain where trains running from the south and east could turnback during the DSTT interlining

construction closure, as turnbacks are currently only achievable at SODO to the south and Judkins Park to the east. Third Avenue would also need to be closed for an extended period (approximately 10 months or more) with effects on bus routes using that corridor.

2. **Construction risk:** The interlining approach requires substantial tunneling activities along the footprint of the DSTT tunnel bores between Westlake and Symphony stations. Poor soil conditions in this area led to tunneling issues during the original DSTT construction, creating construction delays and cost escalation. The existing tunnels are also thin, unreinforced with a lower-quality temporary lining, making them prone to movement and damage during construction. There is considerable risk of performing any additional tunneling activities in this area to facilitate the interlining alternatives. In addition, beginning tunneling at congested Seattle Center rather than the currently planned BLE tunnel launch site in SODO would introduce construction, staging, and right-of-way implications.
3. **Maintenance facility needs:** The stub-end approach would require construction of a new maintenance facility somewhere along the Ballard line – likely in the Interbay area – with associated cost, environmental review, and potential process delay implications (as well as additional costs to operate and maintain this facility). If this new BLE maintenance facility is unable to be constructed, the standalone Ballard line associated with the stub-end approach would not be able to operate. The interlining approach would not require a new maintenance facility.
4. **System reliability and resilience:** Both approaches would necessitate extensive near-term infrastructure upgrades to the existing DSTT; additional implementation challenges (such as cost, risk, service disruption, and schedule) are still unknown but could add significantly to the baseline estimate and schedule. While such investments help accommodate running multiple lines, there is increased risk of a single tunnel as a critical point of failure – any disruption could halt the entire system. A second tunnel would allow ST to run more trains per hour through the downtown core offering higher long term system capacity and operate lines and service patterns without pushing one tunnel's dwell times and signaling to the edge of reliability. The second tunnel also provides passengers using the spine with an alternate route through downtown when one tunnel is blocked, without the need for a bus bridge.
5. **Project schedule delay:** Additional environmental review and design effort would likely delay the overall project schedule by at least two years – likely longer and is required for both approaches. Even though the tunnel section between SODO and Westlake would be eliminated, the overall construction schedule would be similar or even slightly longer due to the need to begin tunneling at Seattle Center rather than SODO, which shifts the critical path to Seattle Center Station.

Conclusions

With near-term investments in technology and reliability upgrades, it could be technically feasible to interline all three lines through the existing DSTT and avoid building the portion of the new tunnel between SODO and Westlake as outlined within the BLE Preferred Alternative. While the interlining and stub-end approaches would provide a light rail connection to Ballard with potential cost savings, there would be implications in terms of future tunnel completion, service disruption, maintenance facility needs, system reliability/resilience, and project schedule delay.

The at-grade interlined configuration could save between $1.3 billion and $5 billion compared to the full-build Preferred Alternative, while the grade-separated interlined configuration ranges from no cost savings to up to $4.5 billion in savings. The interlining approach would enable same-platform transfers for the 1, 2, and 3 Lines at IDS, Pioneer Square and Symphony stations. To create the necessary tie-in to the existing DSTT south of Westlake Station, existing service would need to be shut down for an extended period, – potentially years – during construction, and Third Avenue would be closed for potentially 10 months or more. Additionally, poor soil conditions and thin, unreinforced DSTT tunnel lining at the interlining junction location (which impacted the cost and schedule of the original DSTT construction) create considerable tunneling risk with implementing the interlining approach. The overall project schedule would be delayed by at least two years. The interlining approach could be configured to be forward-compatible with building the remaining portion of tunnel from Westlake to SODO at additional cost, but results in some redundant infrastructure (though this redundancy could enhance future operational flexibility by serving as train storage or a connection between lines).

The stub-end approach could potentially save $0-$4 billion (compared to the full build); it would provide same-platform transfers for the 1, 2 and 3 lines but would not provide same-platform transfers to Ballard. A new maintenance facility would be required, likely in the Interbay area, and the overall project schedule would be delayed by at least two years. The stub-end approach would be forward-compatible with completing the remaining portion of the new tunnel from Westlake to SODO in the future.

As compared with the BLE Preferred Alternative (for which design development has progressed much further, relative to this study), both approaches to avoiding construction of the second downtown tunnel introduce substantial risk of cost and schedule escalation; any estimated savings could be eroded as alternatives advance. The risk is greater for the interlining approach due to risks associated with the tie-in to the existing tunnel, but the need for a new maintenance facility becomes critical path for the stub line, creating schedule implications. Station capacity updates at existing stations could be triggered by these scenarios and could also carry substantial risk for cost and scope escalation, as well as further operations implications. Both approaches would result in a system that is less resilient to service disruptions compared to the Preferred Alternative configuration, creating serious concerns for the reliability of operations of the full Link system operating through the DSTT.

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Acronyms and Abbreviations

Item	Definition
BLE	Ballard Link Extension
CDF	Controlled Density Fill
CFD	Computational Fluid Dynamics
CID	Chinatown/International District
CBTC	Communications-Based Train Control
DSTT	Downtown Seattle Transit Tunnel
EIS	Environmental Impact Statement
EMI	Electromagnetic Interference
IDS	International District Station
LRV	Light Rail Vehicle
NB	Northbound
NFPA	National Fire Protection Association
OMF	Operations and Maintenance Facility
PE	Preliminary Engineering
ROM	Rough Order of Magnitude
RoW	Right of Way
RSS	Rail Simulation Scenarios
SB	Southbound
SEM	Sequential Excavation Method
SLU	South Lake Union
SME	Subject Matter Expert
SODO	South of Downtown
SOE	Support of Excavation
SOGR	State of Good Repair
ST3	Sound Transit 3 Plan
TBM	Tunnel Boring Machine

1 INTRODUCTION AND BACKGROUND

1.1 Current Preferred Alternative for Ballard Link Extension

Sound Transit is advancing the Ballard Link Extension (BLE) project through Phase 3 of project development: Final Environmental Impact Statement (Final EIS) and Preliminary Engineering (PE). BLE would provide fast, reliable light rail connections to dense residential and job centers throughout the region and, under the Preferred Alternative, add a new downtown Seattle light rail tunnel to provide efficient operating capacity for the entire regional system. BLE would operate on a 7.7-mile guideway from downtown Seattle to Ballard's Market Street area. It would include a new 3.3-mile rail-only tunnel from the Chinatown-International District (CID) to South Lake Union and Seattle Center/Uptown. The BLE Preferred Alternative would serve six downtown tunnel stations (at International District/Chinatown, Midtown, Westlake, Denny, South Lake Union, and Seattle Center), an elevated station at Smith Cove, a retained cut station at Interbay, and a tunnel station in Ballard. The BLE project would disconnect the 1 Line from the existing Downtown Seattle Transit Tunnel (DSTT) north of SODO Station and connect it to a new light rail tunnel under downtown Seattle. The BLE project would also construct a connection from the 3 Line from West Seattle to the existing DSTT north of SODO Station, as well as a roadway overcrossing at S Holgate Street.

1.2 Study Objectives

Given rising cost pressures facing the ST3 Program, Sound Transit is investigating whether technology and reliability upgrades could allow interlining all three lines through the existing DSTT, instead of building the portion of the new tunnel between SODO and Westlake – and whether this could be a feasible and practical alternative that could save costs while maintaining reliable service. If cost savings are achievable through implementing one of these alternatives, this may allow resources to be prioritized to achieve the ST3 plan of bringing light rail to both Ballard and West Seattle.

To determine the feasibility of removing the second downtown tunnel from the BLE project, the following alternatives were developed and assessed:

- Alternative 1: Three variations were assessed for interlining the BLE alignment with the existing DSTT.
    - Alternative 1A: 3rd Ave DSTT At-grade Tie-in
    - Alternative 1B: 3rd Ave DSTT Grade-separated Tie-in
    - Alternative 1C: DSTT Tie-in at Pine Street Stub
- Alternative 2: BLE Terminus at Westlake (Stub End Alternative)

These alternatives will be discussed in detail in the sections below.

2 SUMMARY OF ANALYSIS AND REPORTS ON THE SECOND DOWNTOWN TUNNEL

Previous studies that provide context on the BLE-DSTT interlining configuration and the existing DSTT State of Good Repair (SOGR) assessment have been reviewed and summarized in **Appendix A**, to support the reporting on the BLE-DSTT interlining feasibility analysis. This section provides a summary of the previous studies.

2.1 Summary of Previous Analyses on Interlining and System Resiliency

A series of studies established the rationale that interlining operations to Ballard through the existing DSTT would be constrained, necessitating the construction of a second downtown tunnel. The second tunnel introduced the spine segmentation configuration to avoid operating one long rail line (or "spine") between Everett and Tacoma, with the associated service reliability issues along such a long, continuous corridor. This configuration was advanced in the ST3 Program to enable more manageable line lengths, necessitate fewer maintenance facilities, help balance rider volumes through downtown Seattle, and provide more operational flexibility.

Previous studies support this rationale for building the second tunnel, with a 2013 memo identifying the minimum headways, passenger loads, and high construction risks as major constraints for a DSTT connection. The 2015 and 2016 ST3 Operating Planning memos and 2015 ST3 System Structure Memo concluded that a second tunnel best mitigates long one-way runtimes, load imbalances, reliability risks, and fleet/OMF constraints. These reports framed the operational, capacity, safety, and cost constraints that drove the decision to design for a second downtown tunnel. Lastly, the 2024 Sound Transit Resiliency Assessment Report studied recent incidents that have impacted Link operations, outlining key system upgrades and management of operational performance that are required to improve the reliability of the system. This report also indicated that the governance structure between Sound Transit as the Owner and King County Metro as the Operator limits Sound Transit's ability to prioritize maintenance, enforce performance standards, and directly address operational issues that affect the reliability of the system.

2.2 Summary of Relevant Assessments of DSTT State of Good Repair

The DSTT was built in the late 1980s by King County Metro (KCM) as a bus tunnel before being converted to support light rail operations in 2009. To support the ownership transfer from KCM to Sound Transit in 2020, Sound Transit initiated the DSTT State of Good Repair (SOGR) Program to assess the condition of all systems and infrastructure within this facility and determine systems that must be upgraded to ensure safety, reliability, and operational resilience of the DSTT. The series of reports developed under this program were reviewed and summarized within **Appendix A**. Technical needs identified across the DSTT study reports include:

- Modernization and redundancy of train control and signaling.
- Replacement and improved monitoring of the 26kV traction power distribution feeders.

- Enhanced emergency and ventilation capabilities (including the Emergency Response Modes (ERM) revisions.
- Ventilation zone consolidation.
- Architectural modifications at station entrances.
- Upgrades to fire suppression and detection system.

Inspection programs also identified targeted repairs and maintenance for tunnel lighting, emergency communications, drainage, and sump systems. Each of these form a baseline of capital and maintenance work that must be completed to support safe and reliable operations within the existing DSTT. Some of these items are already planned for design and construction within the DSTT SOGR, and continual coordination between the DSTT SOGR Program and Service Delivery is on-going to schedule and implement these facility upgrades.

3 MODELING OPERATIONAL FEASIBILITY THROUGH RAIL SIMULATION SCENARIOS

Using the agency's operational performance model built in OpenTrack, the project team simulated Link operations under different extension configurations and activation sequences. The project team worked in collaboration with other agency partners to determine the Rail Simulation Scenarios (RSS) to model and to outline the parameters of each modeled operational configuration, including the sequences of activation, normal and degraded modes, vehicle configurations, and timetables. Included in this larger RSS analysis effort are the various alternatives that do not include a second Downtown Seattle Tunnel.

The purpose of modeling and simulation of revenue service is to:

- Enable Sound Transit to understand the operating and resiliency implications of different infrastructure configurations
- Allow evaluation of overall performance, and comparison of alternatives to support critical decision making.
- Support the identification and scoping of system upgrades required to support reliable and safe service.
- Inform future operational performance for each configuration, including providing insight on the following:
    - Capital cost and total cost of ownership
    - Fleet sizing
    - OMF design (facility size / layout and configuration of access tracks)
    - Non-revenue duration for maintenance activities
    - Operator crewing & scheduling, and deadheading to / from Operations and Maintenance Facility (OMF)
    - Concept of Operations – including degraded operations contingencies

3.1 RSS Modeling Process

Operational performance of different scenarios is analyzed using three techniques depending on the nature of the scenario:

- **Full modeling** using representative infrastructure configuration, sample timetable for each line, and ten simulation runs that randomize station dwell and MLK intersection delays based on defined variability distribution.
    - Full modeling predicts on-time performance, headway variability between two trains on the same service line, and journey time variability.
- **Capacity analysis** narrowly focused on small sections of the system that constrain capacity (e.g. terminals (intermediate and end of line), junctions, and tunnel vent zones). This type of analysis focuses on separation between trains under ideal conditions, then uses a factor (25%) rather than simulation of variable parameters to predict the practical operational headway.
    - Capacity analysis calculates theoretical headway between any two trains at a particular location, and between two trains on the same service line.
- **Service frequency, train length and fleet sizing** focused on assessing system capacity produced by varying service frequencies and train lengths, and forecast ridership. Analysis included 2045 ridership projections, and low and high ridership bounds for 2070 ridership projections.
    - This analysis shows passengers per direction per hour that can be moved with different fleet sizes and length of train.

4 ALIGNMENT ALTERNATIVES

Several potential configurations (Alternatives 1A, 1B, and 1C) for interlining the new Ballard line into the existing DSTT were assessed, as well as one potential configuration (Alternative 2) for a standalone Ballard line that would terminate at the Westlake Station (Stub End Alternative). Figures for each alternative are included in **Appendix B**. The sections below describe:

- Alternative descriptions and technical feasibility.
- Delivery and constructability constraints and considerations.
- Operational feasibility, resiliency and impacts.

4.1 Alternative 1A – Third Ave DSTT Tie-in (at-grade)

This alternative connects the Ballard Link Extension from Denny Station to the existing DSTT tunnel just north of the existing Symphony Station. The tracks would interline with the existing tracks at-grade (flat Y-junction). However, this alternative would not be able to meet the location of the preferred Denny and SLU stations. More study would be needed to determine alignment and station locations. Refer to Figure 4-1 for alignment.

Figure 4-1 Alternative 1A Alignment

4.1.1 Alternative Description and Technical Feasibility for Implementation

This alternative requires tunnel construction from north to south, launching Tunnel Boring Machines (TBMs) from a Republican Street portal with cut-and-cover construction at each station (Seattle Center, South Lake Union, and Denny).

The connection to the existing DSTT north of existing Symphony Station requires cut-and-cover construction, including an independent cut-and-cover section for retrieval of the TBM. It also requires demolition and reconstruction of a portion of the existing tunnel and track (as shown in Figure 4-2). This construction will require full closure of Third Avenue and full acquisition of properties on the west side of Third Avenue for two blocks (Union Street to Pike Street and Pike Street to Pine Street).

The proposed geometry can be achieved within Sound Transit standards. The at-grade interlining with the existing tracks requires a diamond crossing, which allows one track to cross another at-grade (in this case the northbound Ballard track will cross the southbound existing track). Diamond crossings are not intended for high frequency crossings and will require frequent maintenance.

This concept would not accommodate station locations at the preferred Denny and SLU and new alignments and station locations would need to be studied. A potential stub tunnel with a flat Y-junction and diamond crossing can be constructed via cut-and-cover construction somewhere north of Pine Street to accommodate the future completion of a second downtown tunnel and track to SODO Station. This will require the profile to be slightly deeper at the station.

Implementing this alternative would result in major surface-level impacts and effects on ongoing Sound Transit operations. Construction of this alternative would require very detailed staging to limit impacts to City of Seattle streets, sidewalks, and other facilities.

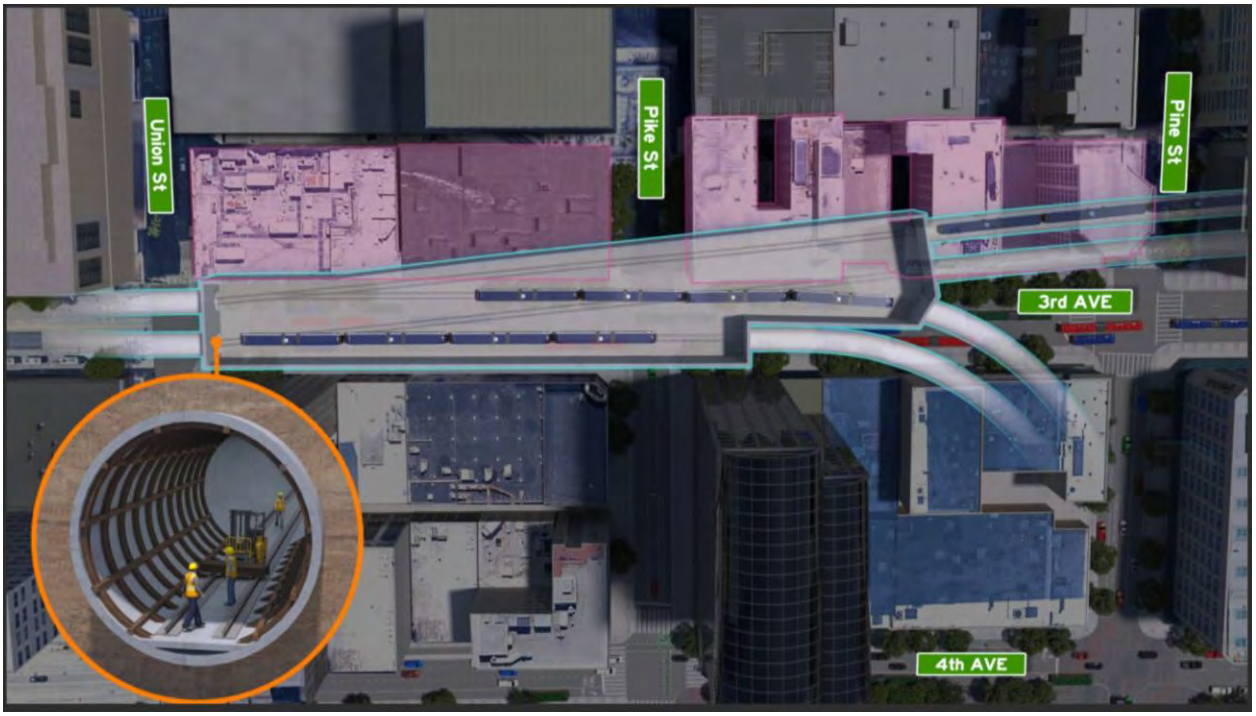


Figure 4-2 Third Ave DSTT At-Grade Tie-in

4.1.2 Delivery and Constructability Constraints and Considerations

Environmental Considerations

This configuration introduces an alternative not presently studied in the Draft EIS, which is set to publish in January 2026. Formally introducing this alternative would result in either delaying Draft EIS publication to include this alternative or publishing the Draft EIS and preparing a supplemental Draft EIS to include the alternative – both of which would add a minimum of two years to the project.

Additional Property Acquisitions

This concept requires acquisition and demolition of two full blocks of existing buildings on the west side of Third Ave, from Union Street to Pike Street and from Pike Street to Pine Street (as indicated in pink in Figure 4-2). Many of these properties are potentially historic (subject to Section 106 of the National Historic Preservation Act of 1966) and are not contained within the current environmental footprint for the BLE project.

Technical Challenges

All tunnel boring activities would need to initiate from the Republican Street portal north of Seattle Center. There would be no opportunity to mitigate the effects to the residential neighborhood near Seattle Center by tunneling from the south as with the current construction concept of the Preferred Alternative.

This configuration requires the construction of an independent cut-and-cover section as a retrieval shaft for TBMs.

Original DSTT Tunneling issues

Tunneling for the existing DSTT in the late 1980s was carried out using two open face tunneling machines. In the section between the north end of Symphony Station (formerly University Street Station) and the 90-degree right turn to Westlake, both TBMs encountered problems which delayed tunneling.

1) Both TBMs began to drift off-line, veering downwards from their intended alignment. Steering of the machines became impossible.
2) The tailskins of both machines (the steel cylinders at the rear of the TBM where temporary lining segments were erected) deformed due to ground pressure, preventing erection of lining segments.

Upon investigation, the problems were found to be caused by a thick layer of saturated fine silty sands immediately below the TBM inverts. This stratum has been encountered elsewhere in recent Sound Transit tunnel projects and is known to be prone to instability when exposed at a tunnel face (for example, cross passage CP23 on Northgate Link). The silty sands (known as ESU6) are also difficult to stabilize, requiring specialized dewatering equipment such as vacuum eductor wells.

For the DSTT, dewatering was carried out, causing delay to the tunneling. The section of misaligned tunnel was lined using steel ribs and timber lagging before casting the final unreinforced concrete lining. At CP23, ground freezing was used to stabilize the soils.

In the context of the proposed interlining works, it will be necessary to consider that the existing tunnels are unreinforced, have a poor-quality temporary lining and are likely to be prone to movement during construction because they sit on a weak layer of soil. Any Support of Excavation (SOE) for cut-and-cover tunneling and Sequential Excavation Method (SEM) work associated with the proposed schemes would require significant ground stabilization measures in advance of excavation. The poor soil conditions in this area created construction delays and cost escalation during the original DSTT construction, which is a risk for any additional tunneling performed in connection with this alternative.

Due to these historical tunneling challenges in the DSTT, the poor soil conditions for tunnel construction in this specific location would result in challenging and risky Support of Excavation (SOE) construction. The SOE considerations for this alternative include:

1) Required construction of SOE for cut-and-cover box adjacent to existing northbound tunnel. The tunnel may require bracing in proximity to Right of Way (RoW) limits and existing building facades.
2) Required construction of SOE across existing tunnel at four locations. Very high risk of damage to existing tunnels even with advanced protective works/strutting. Potential advanced mined activity to remove lining at each location and replacement with Controlled Density Fill (CDF) for follow on SOE installation.

Tunnel ventilation systems would still need to be studied. This alternative may require a new fan plant headhouse. Adding a tunnel branch creates a complicated system that has the potential to expose non-incident trains to smoke and can reduce the needed ventilation airflow to the fire site. A new fan plant would likely be needed in the connection branch north of Symphony Station. Additional fan capacity may be needed at the north end of Symphony Station to prevent smoke from entering the station in the case of fire in the new tunnel junction.

Further study is needed to determine the number of trains per vent zone due to adding additional service lines. Maintaining one train per vent zone during an emergency is critical. Currently, only specific segments of the Sound Transit system allow two trains in a vent zone. When additional trains are allowed in a vent zone there needs to be a provision for extracting the non-incident trains out of the tunnel so that they are not exposed to smoke from the incident train (i.e., the ventilation system could direct smoke into the non-incident train). The added trains also create more resistance in the tunnel, which may increase demand on the ventilation system. Creating new ventilation zones by adding additional fan plants is another way to meet the criteria of one train per vent zone. Any requirement for more than one train per vent zone may require operational mitigation and or addition of mid-tunnel vent shafts.

Previous assessment found that several of the ventilation zones in the DSTT tunnels could not meet the required ventilation criteria with one fan out of service. Conceptual interventions were studied and recommended, including modifying station entrances with reduced opening sizes or enclosing the concourses/mezzanines aerodynamically from the platform. Adding additional ventilation capacity to the system would also potentially meet ventilation requirements with one fan out of service.

Station Egress and Station Ventilation Analysis within Existing DSTT Stations

1) Existing Westlake Station and Symphony Station ventilation systems and evacuation were previously studied. The stations cannot meet the 4- and 6-minute exiting time required by National Fire Protection Association code 130 (NFPA 130). NFPA 130 allows an engineering analysis to prove that the system is safe and that there is safe evacuation. Computational Fluid Dynamics (CFD) analysis paired with evacuation analysis determined that the current station ventilation systems struggle to keep the stations tenable for the required evacuation and time of tenability for forecasted passenger loads.
2) To maximize the performance of the current ventilation system, additional station CFD analyses of Westlake and Symphony were performed. The design concept enclosed the concourse and altered the current ventilation modes. The analysis showed that all able-bodied people could evacuate and remain in a tenable environment when modeled against the CFD smoke results. Coordination with Seattle Fire Department and additional study was recommended.
3) The forecasted passenger loads used in the Station Egress and Ventilation study were for 2026 (1 and 2 Lines). The interlining alternatives introduce 3 lines within the existing tunnel. This will likely increase the volume of passengers on the platform boarding and de-boarding trains and entering and exiting the stations. This puts further demands on the egress capacity, which was already found to be inadequate based on the forecasted passenger loads. To move forward with alternatives that interline the 1, 2, and 3 lines in the existing tunnel, additional study is needed based on revised ridership forecast, which would most likely result in a requirement for additional enhanced ventilation upgrades as well as additional, larger exits, both emergency and normal egress. The new extension will require emergency egress and station emergency ventilation analysis and coordination with the Seattle Fire Department.

Existing DSTT facilities adhere to older codes and standards than those required today. The interlining of the third line presents the risk of requiring all facilities within the DSTT to be upgraded to current codes and standards, including NFPA 130. If this occurs, which is likely for any new expansion or augmentation of the existing facility, all NFPA 130 requirements need to be evaluated and facilities updated to meet requirements, including:

1) A full emergency ventilation analysis (emergency, normal analysis, pressure transient, station CFD analysis) of the system would be required (including U-Link and Northgate Link from the International District Station (IDS) to the Maple Leaf portal.
2) Egress and evacuation analysis at each station.
3) Development of a design solution such as evaluation of architectural modifications such as closing off mezzanine/concourse from the platform needs to be fully evaluated along with architectural modifications of station entrances.
4) The South Staging Area where the 2 Line ties into International District Station (IDS) may also require an emergency ventilation analysis per NFPA 130 section 7.1.2.4.
5) Potential impacts include larger exits and addition of sidewalk level exits, which will be challenging in an already-built up area with existing developments in place.

Operational Impacts

- Requires 1 Line closure for at least three years (during the final three years of BLE project), in addition to the time required for any critical ventilation and systems upgrades to the existing system.
- Requires Third Avenue to be closed during SOE installation for the cut-and-cover box.
- The three-year schedule breakdown:
  - Supporting existing tunnels (6 months).
  - SOE Installation for cut & cover box (10 months).
  - Excavation (8 months).
  - Permanent concrete structural works (6 months).
  - Trackwork including special trackwork (4 months).
  - Tunnel services including OCS (6 months).
  - Testing and Commissioning coincident with later phase of BLE extension Level 3 or 4 (4 months).
- Once construction is complete, transfers from the BLE line to the rest of the system will occur at Symphony Station. Station capacity to support these transfer activities will require further assessment.

Future Completion of Second Downtown Tunnel

Future completion of a Second Downtown Tunnel can be accommodated with a cut-and-cover stub tunnel that branches off of the new BLE tunnel. The details of this stub tunnel are not captured in this preliminary alternative study nor within the cost estimate developed for this alternative, so introducing this stub tunnel branch for forward compatibility would introduce additional project costs. TBMs will launch from the south at a Massachusetts Street portal and will be retrieved at a stub tunnel south of the Denny/South Lake Union station.

4.1.3 Operational Feasibility, Resiliency, and Impacts

The interlining configuration was modeled in OpenTrack with ten simulations performed to evaluate operational performance. In this configuration, the interaction of trains from three lines traversing the at-grade Y-junctions required full modeling to understand the performance of trains that must arrive precisely on-time at the junction to avoid delaying trains on conflicting routes. This alternative also features an at-grade Y-junction at SODO where the 1 Line and 3 Line merge. Operations were simulated from the start of service, through the morning (AM) peak to the midday service period.

Results show that the system could operate in this configuration with acceptable passenger experience under ideal conditions. However, schedule adherence at the two at-grade Y-junctions (Symphony and SODO) must be nearly perfect. Simulations revealed situations in which 1 Line trains heading north from the Rainier Valley could delay northbound 3 Line trains from Alaska Junction. Off-schedule 3 Line trains experienced further delays due to the merge with northbound 2 Line trains at International District Station. These delays could not be recovered until after Northgate due to the tight headways and infrastructure constraints in the single tunnel section from Chinatown/International District to near Northgate. Any service disruption that results in trains arriving off-schedule at junctions could result in delays that propagate through the system. Examples of such disruptions include removal of disabled light rail vehicles (LRVs) from service, security and medical emergencies, incidents in the Rainier Valley, activation of LRV emergency door release, and other situations. Further analysis to determine the resilience of this configuration against real-world service disrupting events is in progress at the time of writing this report. Based on preliminary analysis, moderate service disruptions are likely to have a cascading effect on the system.

4.2 Alternative 1B – Third Ave DSTT Tie-in (grade-separated)

Like Alternative 1A, this configuration interlines the BLE tunnel into DSTT between the existing Symphony and Westlake Stations under Third Avenue. It would transfer riders from BLE to the rest of the system at Symphony Station or further south, rather than at Westlake as in the Preferred Alternative.

In this alternative, the new northbound line to Ballard would travel under the existing 1 Line as it curves to the east, and the existing northbound 1 Line would be relocated further to the east from the current alignment to make room for a grade-separated tie-in, as opposed to 1A, which features an at-grade tie-in. Alternative 1B would also require design deviations for the short vertical curves necessary to avoid an at-grade tie-in and to avoid conflicts with building foundations. Refer to Figure 4-3 for alignment.

Figure 4-3 Alternative 1B Alignment

4.2.1 Alternative Description and Technical Feasibility for Implementation

This alternative requires tunnel construction from north to south, launching the TBMs from the Republican Street portal with cut-and-cover construction at each station.

The connection to the existing DSTT north of existing Symphony Station requires cut-and-cover construction, including an independent cut-and-cover section for retrieval of the TBM located within the Third Avenue right-of-way. It also requires demolition and reconstruction of a portion of the existing tunnel and track, including the section that transitions between Third Avenue and Pine Street. This construction will require full closure of Third Avenue and full acquisition of selected properties on the east and west sides of Third Avenue between Pike and Pine Streets, with risk of impacts to additional properties.

The proposed geometry would require deviations from Sound Transit standards. The grade-separated interlining with the existing tracks requires vertical curves that are shorter than those allowed under current Sound Transit design standards (more similar to curves found in the existing DSTT). These would allow the new northbound tunnel to dive under the existing DSTT on Pine Street.

A stub tunnel with a flat Y-junction and diamond crossing can be constructed via cut-and-cover construction south of Denny Station to accommodate the future completion of the second downtown tunnel and track to SODO Station.

Implementing this alternative would result in major surface-level impacts and effects on ongoing Sound Transit operations. Construction of this alternative would require very detailed staging to limit impacts to City of Seattle streets, sidewalks, and other facilities.

Figure 4-4 Third Ave DSTT Tie-in (grade-separated)

4.2.2 Delivery and Constructability Constraints and Considerations

Environmental Considerations

This configuration introduces an alternative not presently studied in the Draft EIS set to publish in January 2026. Formally introducing this alternative would result in either delaying Draft EIS publication to include this alternative or publishing the Draft EIS and preparing a supplemental Draft EIS to include the alternative, both of which would add a minimum of two years to the project.

Additional Property Acquisitions

This configuration requires full acquisition of selected properties on the east and west sides of Third Avenue between Pike and Pine Streets, with substantial risk of effects to additional properties given the close proximity and the preliminary level of assessment. Many of these properties are potentially historic (subject to Section 106 of the National Historic Preservation Act of 1966) and are not contained within the current environmental footprint for the BLE project.

Technical Challenges

All tunneling boring activities would need to initiate from the Republican Street portal north of Seattle Center. There would be no opportunity to mitigate the effects to the residential neighborhood in Seattle Center by tunneling from the south as with the current phasing of the Preferred Alternative.

This configuration requires construction of an independent cut-and-cover section as a retrieval shaft for TBMs within the Third Avenue right-of-way.

Like Alternative 1A, the historically poor soil conditions in the area between Symphony and Westlake Stations led to tunneling issues, schedule delays, and cost escalations during the original DSTT construction. This poor soil condition creates risk for any future tunneling activities in this same location.

Due to these historical tunneling challenges in the DSTT, the poor soil conditions for tunnel construction in this specific location would result in challenging and risky SOE construction. The SOE considerations for this alternative include:

1) Required construction of SOE for cut-and-cover box adjacent to existing northbound tunnel. Tunnel may require bracing in proximity to RoW limits and existing building facades.
2) Required construction of SOE across existing tunnel in four locations. Very high risk of damage to existing tunnels even with advanced protective works/strutting. Potential advanced mined activity to remove lining at each location and replacement with CDF for follow on SOE installation.
3) Construction of SOE close to property lines would result in high risk of effects to additional properties, including the Century Square high-rise building (1501 Fourth Ave).

As outlined for Alternative 1A, further studies of tunnel ventilation systems, the number of trains per vent zone, and an assessment of the need for additional ventilation capacity will be required to more fully understand the feasibility of this alternative. The additional technical challenges noted for Alternative 1A concerning station egress, platform capacity, and NFPA 130 Code adherence are also applicable for Alternative 1B.

Operational Impacts

- Requires 1 Line closure for at least three years (during the final three years of the BLE project), in addition to the time required for any critical ventilation and systems upgrades to the existing system.
- Requires Third Avenue to be closed during SOE installation for the cut-and-cover box.
- The three-year schedule breakdown:
  - Supporting existing tunnels (6 months).
  - SOE Installation for cut & cover box (10 months).
  - Excavation (8 months).
  - Permanent concrete structural works (6 months).
  - Trackwork including special trackwork (4 months).
  - Tunnel services including OCS (6 months).
  - Testing and Commissioning coincident with later phases of BLE extension Level 3 or 4 (4 months).
- Once construction is complete, transfers from the BLE line to the rest of the system will occur at Symphony Station. Station capacity to support these transfer activities will require further assessment.

Future Completion of Second Downtown Tunnel

A second downtown tunnel can be accommodated in the future with a cut-and-cover stub tunnel. TBMs would launch from the south at the Massachusetts Street portal and will be retrieved at stub tunnel south of Denny Station.

4.2.3 Operational Feasibility, Resiliency, and Impacts

Modeling of this alternative has not yet been completed. Grade separation of the Symphony Y-junction would produce a slightly more reliable system since the northbound 1 Line tracks would pass under (not across) the 2 and 3 Line southbound tracks. The grade separated junction would result in a system that is better able to recover from service disruptions than the Alternative 1A at-grade alternative.

4.3 Alternative 1C – DSTT Tie-in at Pine Street

This alternative connects the Preferred Alternative of the Ballard Link Extension from Denny Station at Denny Way and Westlake Avenue into the existing DSTT tunnel north of the existing Westlake Station. The tracks would interline with the existing tracks at-grade (flat Y-junction). Refer to Figure 4-5 for alignment.

Figure 4-5 Alternative 1C Alignment

4.3.1 Alternative Description and Technical Feasibility for Implementation

This alternative requires tunnel construction from north to south, launching the TBMs from Republican portal with cut-and-cover construction at each station (Seattle Center, South Lake Union, and Denny). South of Denny Station, a 250-foot radius is required to turn the alignment towards the existing stub tunnel north of existing Westlake Station at Pine Street and Ninth Avenue (at Seattle Convention Center). This tight radius is achievable with special TBM technology, but it is risky.

The connection to the existing DSTT tracks at the stub tunnel requires cut-and-cover construction and the acquisition and demolition of the new building on the corner of Ninth Ave and Pine Street, along with the adjacent hotel, which is historic. It also requires the acquisition of the parking lot at Eighth Ave and Pine Street. Cut-and-cover construction is required along Ninth Ave from about Olive Street to about Eighth Ave.

The geometry for this alternative is near fatally flawed due to the junction capacity constraints imposed by the tight radius slow speed curve. A 100-foot radius horizontal curve is required to make the connection to the existing tracks. This is the minimum recommended horizontal curve for yard tracks, not revenue service track, and limits the speed of operation to five miles per hour. The at-grade interlining with the existing tracks requires a diamond crossing, which allows one track to cross another at-grade (in this case the northbound Ballard track will cross the southbound existing track). Diamond crossing is not intended for high frequency crossings and will require frequent maintenance. Furthermore, this special track would need to be constructed in the existing tunnel where the grade is 5%. The placement of special track on these grades is not recommended due to higher maintenance, reduced reliability, and shortened useful life of special track components.

4.3.2 Delivery and Constructability Constraints and Considerations

Environmental Considerations

Environmental considerations were not evaluated given the fatal flaw analysis of operations.

Additional Property Acquisitions

- Requires acquisition and demolition of the new building on the corner of Ninth Ave and Pine Street, along with the adjacent hotel, which is historic.
- Requires acquisition of the parking lot at Eighth Ave and Pine Street.

Technical Challenges

All tunneling activities would need to initiate from the Republican Street portal north of Seattle Center. There would be no opportunity to mitigate the effects to the residential neighborhood in Seattle Center by tunneling from the south as with the current phasing of the Preferred Alternative.

The 250-foot radius curve south of Denny Station is less than the minimum accepted radius for tunnel boring machines and requires special TBM technology. There is residual high risk of steering difficulties and not achieving the alignment through this curve.

The tie-in to the DSTT requires demolition and rebuilding of a portion of the tunnel and track section.

Like Alternative 1A, the existing DSTT tunnel ventilation capacity and egress challenges would exist for Alternative 1C. Further studies would be needed to evaluate the ability of the existing tunnel ventilation system to maintain tenable conditions within the tunnel and stations. The addition of a new fan plant would likely be required at the new tunnel junction in addition to upgrades of the existing tunnel ventilation system at Westlake Station and the Pine Street Ventilation Facility. Facility modifications of existing DSTT Stations, including separation of platform from concourse levels, would need to be included in evaluation. Train operations in which more than one train occupies any given vent zone would require evaluation to understand impacts and the extent of necessary capacity upgrades for the entire DSTT tunnel ventilation system. Assessments would also need to consider increased passenger loads for affected stations.

Operational Impacts

Requires an approximately 2.5-year service closure of all trains on the 1 Line and 2 Line from International District Station to the north.

Future Completion of Second Downtown Tunnel

Given the fatal flaw analysis of operations (see below), the team did not evaluate completion of the second downtown tunnel and track to SODO Station.

4.3.3 Operational Feasibility, Resiliency, and Impacts

This alternative was modeled in OpenTrack with ten simulations performed to evaluate operational performance. Operations were simulated from the start of service, through the morning peak to the midday service period. **The results show that the system cannot be operated in this configuration.** The combination of the at-grade Y-junction and slow speed through the tight radius curve at the stub tunnel exit produced extensive delays (particularly to southbound 2 and 3 Line trains). Only 15-23% of southbound 2 and 3 Line trains met Sound Transit’s on-time performance definition of arrival within three minutes of the scheduled time. In this scenario, train delays become so great that schedules cannot be recovered at the terminal by reducing turn-around time. Headway adherence (variance in headway between two trains serving the same line) was extremely poor, particularly on the southbound 2 and 3 Lines where headway variance was consistently in the order of 160 to 180 seconds. This will result in particularly poor passenger experience at stations on the branch lines.

This alternative includes a 100-foot radius curve. Curves of this radius are typically only used in yards where trains travel empty at very low speeds. In a mainline situation, with fully loaded trains traversing the track every six minutes, the rails in these curves will wear very quickly and require replacement at a much higher frequency than all other rails in the system.

4.4 Alternative 2 – Westlake Station Terminus for BLE tunnel (Stub End)

This alternative builds the Preferred Alternative from Ballard Station to new Westlake Station, terminating the line at new Westlake Station (Stub End) with accommodation to complete the second downtown tunnel and tracks to SODO Station in the future. Passengers traveling from Ballard to the 1 Line, 2 Line, or 3 Line would need to transfer to the existing Westlake Station. Refer to Figure 4-6 for alignment.

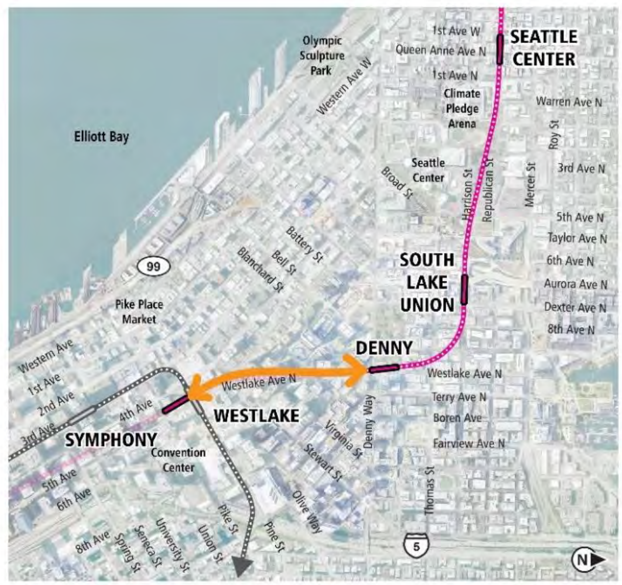


Figure 4-6 Alternative 2 Alignment

4.4.1 Alternative Description and Technical Feasibility for Implementation

This alternative follows the exact alignment and geometry of the Preferred Alternative, with the addition of short Sequential Excavation Method (SEM) tunnel sections south of the station. This would allow TBM extraction for future build-out of the second downtown tunnel (TBMs would launch from the south at the Massachusetts Street portal). A short length of tracks and bumping posts would be accommodated within the SEM extensions.

An Operations and Maintenance Facility (OMF) would need to be built to accommodate the vehicle fleet running on this stand-alone line. A candidate location for the OMF would be the Armory Property north of proposed Smith Cove Station. An analysis of the site feasibility and resulting operations for this site were assessed and are summarized in **Appendix C***.*

4.4.2 Delivery and Constructability Constraints and Considerations

Environmental Considerations

Implementing this configuration would require environmental documentation for a new OMF. Additionally, this alternative has not yet been studied as part of the Draft EIS set to publish in January 2026. Formally introducing this alternative would result in either delaying Draft EIS publication to include this alternative or publishing the Draft EIS and preparing a supplemental

Draft EIS to include the alternative, both of which would add a minimum of two years to the project.

Additional Property Acquisitions

Additional parcels (potentially full acquisition of Armory parcel) required for an OMF.

Technical Challenges

Trackwork mostly ties into the current design.

SEM extensions south of station for operational bumping posts beneath Pike Street and existing buildings. Cost and schedule implications exist, but these present manageable technical risks as the tunnels are individual, medium-sized tunnels.

Like Alternatives 1A, 1B, and 1C, the existing DSTT tunnel ventilation and egress capacity challenges would exist for Alternative 2. Further studies would be needed to evaluate the ability of the existing tunnel ventilation system to maintain tenable conditions within the existing tunnel and existing stations. The addition of new fan plants would be required for the new Westlake station. Upgrades to the existing tunnel ventilation system at Westlake Station would likely be required. Facility modifications of existing DSTT stations, including separation of platform from concourse levels, would need to be included in evaluation. Train operations in which more than one train occupies any given vent zone would require evaluation to understand impacts and the extent of necessary capacity upgrades for the entire DSTT tunnel ventilation system. Assessments would also need to consider increased passenger loads for affected stations.

Operational Impacts

Requires a new, unplanned OMF to operate service.

Does not impact existing service on the 1 Line or 2 Line during construction.

Future Completion of Second Downtown Tunnel

Requires a longer SEM tunnel sections with a larger mined section to create fire separation and shield chambers for receipt of TBMs.

4.4.3 Operational Feasibility, Resiliency, and Impacts

To quickly gather the information needed for a preliminary assessment of this alternative, the project team analyzed the capacity of the existing infrastructure — focusing on the DSTT and U-Link/Northgate tunnels — to determine how frequently three lines could operate through these tunnels, as well as through tunnel vent zones and at terminals. The capacities of junctions between the 1 and 3 lines at SODO and between the 1, 2, and 3 lines at International District Station were also analyzed.

The capacity analysis demonstrated that a signal system upgrade capable of providing shorter separation between trains and semi-automatic train operation is essential for each of the interlining options.

Full simulation of this alternative (assuming an upgraded semi-automatic signaling system) was ongoing at the time of producing this report. Preliminary results from the first three simulation runs are consistent with the findings of the capacity analysis. That is, the system can be operated in this configuration. On-time performance, headway, and journey time variability are acceptable under ideal conditions.

The simulation of this alternative modified the ventilation zone constraints between Capitol Hill and University of Washington, and between the Roosevelt and Maple Leaf portal, in a manner that is not consistent with the Seattle Fire Department letter of concurrence under which the current system is operated. Further study of the ventilation and traction electrification systems is required. The physical addition of another ventilation shaft in the middle of the tunnel sections is theoretically possible, but not practical (which is why they were not constructed when the tunnels were built). Extensive consultation and cooperation from the Seattle Fire Department will be required as the ventilation, traction power and train control systems are re-engineered, and operating rules and procedures are re-written. As the authority having jurisdiction, the Seattle Fire Department must concur with these changes for certificates of occupancy to remain valid. Concurrence of the fire department with potential solutions should not be assumed. These are significant safety matters, and the mitigations require highly complex engineered systems and operating procedures.

While computer models indicate that this alternative is feasible under ideal conditions, there are significant implications for the resilience of the system. For this alternative, the Northgate Station pocket track would be utilized as an interim terminus for trains from Tacoma. If Communications-Based Train Control (CBTC) is implemented and trains run under semi-automatic train operation, 1 Line trains could be turned at Northgate without delaying 2 Line or 3 Line trains. However, it must be noted that using the Northgate pocket for planned operations denies King County Metro the use of this pocket for storing trains that must be removed from service. Without this pocket track, there are no storage options between Stadium and Lynnwood. Removing trains from service that experience failure around the middle of this section could cause significant delays to the whole system. In the twelve months prior to September 2025, six LRVs were disabled in this section of track, causing disruptions lasting from fifteen minutes to two hours. The impacts of these types of events would be more significant with the single tunnel serving three lines.

Any delays in the tunnel section between International District and Northgate could have significant implications for a much larger portion of the future system. In the twelve months prior to September 2025, there were seventeen incidents in this portion of the system creating disruption for longer than ten minutes. While state of good repair programs might reduce the frequency of some of these events, the significant increase in the number of trains serving three lines in the tunnel will likely result in more frequent disruptions despite improvements in state of good repair. Incident causes included overhead catenary system / pantograph failure, loss of power, emergency service response, LRV mechanical issues and emergency door handle release. None of these incident root causes will be less likely to occur with the implementation of CBTC.

5 OPERATIONAL RESILIENCY AND LESSONS LEARNED FROM PEER AGENCY INTERLINING

To better understand the implications of interlining service within the existing tunnel and the system upgrades and enhancements required to facilitate operations under this configuration, a review was performed both of the agency’s state of good repair along with peer agencies across the globe who have interlined transit rail service along a single corridor. A summary of the review of peer agencies is provided in **Appendix D**.

5.1 Operational Resiliency Recommendations – Achieving Reliable and Frequent Service

Each alternative configuration would require operating all three Link lines within the existing DSTT between International District Station and Symphony Station. The stub-line option would require operating three lines beyond Westlake Station to the north into the University Link tunnel. To achieve a six-minute headway on all three lines, the system would need to able to accommodate a two-minute combined headway in the interlined segment.

The current system has a number of constraints that limit the ability of Sound Transit to achieve a two-minute combined headway including:

- Ventilation zones in the U-Link tunnel (between Capitol Hill Station and University of Washington Station) and Northgate Link tunnel (between Roosevelt Station and the Maple Leaf Portal) limit the achievable combined headway to three minutes within the existing 1 Line tunnel.
- Studies are currently underway to understand the extent of traction power and overhead catenary system upgrades required. Based on prior analysis of less demanding scenarios, the existing traction electrification system will likely need to be supplemented with more capacity. This analysis must be coordinated with the ventilation zone studies, as the two systems must have the same zone/section boundaries. It should be noted that, due to agreements between Sound Transit and the University of Washington that place constraints on electromagnetic interference (EMI) at certain campus locations, the traction power system in the EMI zone must be single-end fed and thus cannot achieve the same redundancy and reliability that exists in other parts of the system that have power fed to both ends of each section.
- Operational inflexibility of the DSTT due to no crossovers constructed within this tunnel that was originally designed and constructed for buses without accounting for modern rail operations. This condition creates long single-track headways during degraded service. Note that while adding a crossover at one of the DSTT stations could improve single-track performance, it would also mean the station with the crossover would not be served by trains during the single-tracking event.
- Station platform and egress capacity limitations of the legacy DSTT stations affect the ability of accommodating large transfer activities and increased platform dwell times that result from added frequency and adding an additional line in the tunnel, which is exacerbated during service disruptions when rider dwell times on the platform increase.

In addition to these constraints, the system is continually experiencing frequent service disruptions that affect the reliability of ongoing operations. Based on the data captured by the Service Delivery Department, the incidents that most commonly cause tunnel service disruptions lasting longer than 10 minutes are overhead catenary system/pantograph failure, loss of power, emergency service response, LRV mechanical issues, and emergency door handle release.

If these constraints and the underlying issues triggering these most common tunnel disruptions are not addressed, the system would not be able to accommodate a headway greater than nine minutes on each of the three lines. Table 5-1 below provides a summary of the potential system upgrades that are required to support the system resiliency to achieve the desired headways along with reducing (not avoiding) the cascading impacts that service disruptions would have on the full system.

Table 5-1 Summary of Potential System Upgrades

Upgrade	Planned	Timing of Initiating Upgrade	Cost	Risk
26kV Power Distribution Replacement	Yes		$$	Low
Traction Power Upgrades	No	Assessment On-going	$$$	High
CBTC/Advanced Signaling Implementation	No	N/A	$$$	High
Added track crossovers within existing underground alignment	No	N/A	$$$	High
Fire & Life Safety System Upgrades	Yes*		$$	Med
Ventilation Zone Modifications	No	N/A	$$$	High
Station Upgrades (Lighting, emergency egress, Security, ADA)	Yes		$$	Low
Station Capacity Improvements (Expansion of Platforms & Egress)	No	N/A	$$$	High

*Partial implementation planned; additional upgrades required to facilitate implementation of Alts 1 or 2

Implementing an advanced signaling system, such as Communications-Based Train Control (CBTC), is being explored by Sound Transit independently of this study to improve system reliability and resiliency. CBTC enables shorter train headways, higher service frequency, and faster recovery from disruptions. However, improving signaling alone does not solve for fire-life safety and code requirement issues that the DSTT has, nor does it solve for resiliency and capacity of the system, as it does not account for the lack of redundancy and lack of special trackwork in the existing tunnels to accommodate operations during service disruptions.

With a single tunnel, closing one downtown station due to service disruptions, maintenance or construction can quickly cascade into long dwell times at adjacent stations and unstable headways, because Sound Transit would have nowhere else to route trains and passengers. Table 5-2 summarizes how CBTC and the second downtown tunnel could address system resiliency issues.

Table 5-2 Summary of CBTC and Second Downtown Tunnel Benefits on System Resiliency

Problem to solve	CBTC helps?	Second Tunnel helps?	Best solution
Train capacity	✔ Major improvement	✔ Adds even more capacity	Both together
Reliability (small delays)	✔ Smooths operations	— Moderate	Both together
Major disruption mitigation	✖ Cannot help	✔ Bolstered redundancy	Tunnel
Recovery after major disruption	✔ Expedites safe recovery	✔ Reduces platform overcrowding	Both together
Multi-line interlining	— Partial	✔ Separates lines	Both together
Maintenance windows	✖ Still disruptive	✔ One tunnel stays open	Tunnel
Seismic/climate redundancy	✖ None	✔ Yes	Tunnel

5.2 Lessons Learned from Peer Agencies

Advanced signaling subject matter experts (SMEs) within the project team worked to develop the ***Appendix D: Interlined Transit Rail Systems Case Study Memo*****,** capturing lessons learned from peer agencies to assess the effectiveness of advanced signaling when paired with modern infrastructure to support resilient and reliable system operations and highlighting best practices for interlining and tunnel operations. The peer agencies reviewed include Vancouver, London, Stuttgart, BART, San Francisco Muni, New York City Transit, Stuttgart, and other agencies who have introduced some level of advanced signaling and who utilize interlining multiple lines somewhere within their system.

Table 5-3 below provides a system comparison of a selected subset of these peer agencies, pointing to the range of applications of advanced signaling and interlining within the full system, as well as the redundancies within each system that support sustaining resilient operations. These case studies point to advanced signaling technology such as CBTC having a great impact on building the system's long-term capacity, resiliency and dependability. However, even with CBTC, a single tunnel with on-going reliability concerns and frequent service disruptions creates a single point of failure for the system, creating cascading service impacts throughout the system. The physical and regulatory constraints (ventilation, fire codes) and infrastructure reliability (power, communications, vehicles) can limit CBTC's benefits unless addressed. As displayed by the peer agencies studied, achieving optimal operational resiliency and system capacity requires both advanced signaling paired with infrastructure upgrades, maintaining a state of good repair of the system's infrastructure, along with system redundancy to complement CBTC and mitigate risks. The second downtown tunnel provides this system redundancy, as trains can still run when a disruption is present in the other tunnel.

Table 5-3 System Comparison of Selected Peer Agencies

	System Comparison of Selected Peer Agencies		
	London Underground	**Vancouver SkyTrain**	**BART**
Signaling System	Mixed legacy and CBTC signaling with interlining throughout system increasing operational complexity.	CBTC on all lines; headways as low as 75 seconds.	Legacy ATO with on-going CBTC upgrades
Key Similarities	CBTC and advanced train control used to improve capacity and reliability; all face challenges with interlining and operational constraints.	CBTC and advanced train control used to improve capacity and reliability; all face challenges with interlining and operational constraints.	Heavy reliance on single corridor. Lack of sufficient crossovers or pocket tracks in 2-track interlined segments creates ongoing resilience issues especially during service disruptions.
Key Differences	Extensive redundancy of multiple lines and modes.	High degree of automation and integration with parallel transit routes for redundancy.	Operational Flexibility: Multi-track sections and flying junctions mitigate delays and support resilience.
Key Findings	CBTC has improved throughput and reliability with constraints due to interlining. Additional tunnels/extensions are being considered to relieve congestion.	Modern train control and automation enable high-frequency, resilient service, but must be paired with redundant infrastructure to realize reliability.	Like Madrid, Munich, Sydney, Brisbane: advancing building new tunnel to supplement constrained 2-line tunnels.

6 SCHEDULE IMPLICATIONS FOR IMPLEMENTATION

The project team is currently considering multiple options for downtown tunnel construction. Tunneling only from a portal at the south end of the tunnel (at Massachusetts Street in SODO) offers multiple benefits, including reduced community effects in the Seattle Center neighborhood, construction efficiencies, and overall schedule optimization. All of the concepts discussed in this report would require tunneling from the north. As shown in Figure 6-1 below, because station excavation must be complete before tunneling, these concepts would not result in a reduction in project construction duration, despite the physically shorter tunnel.

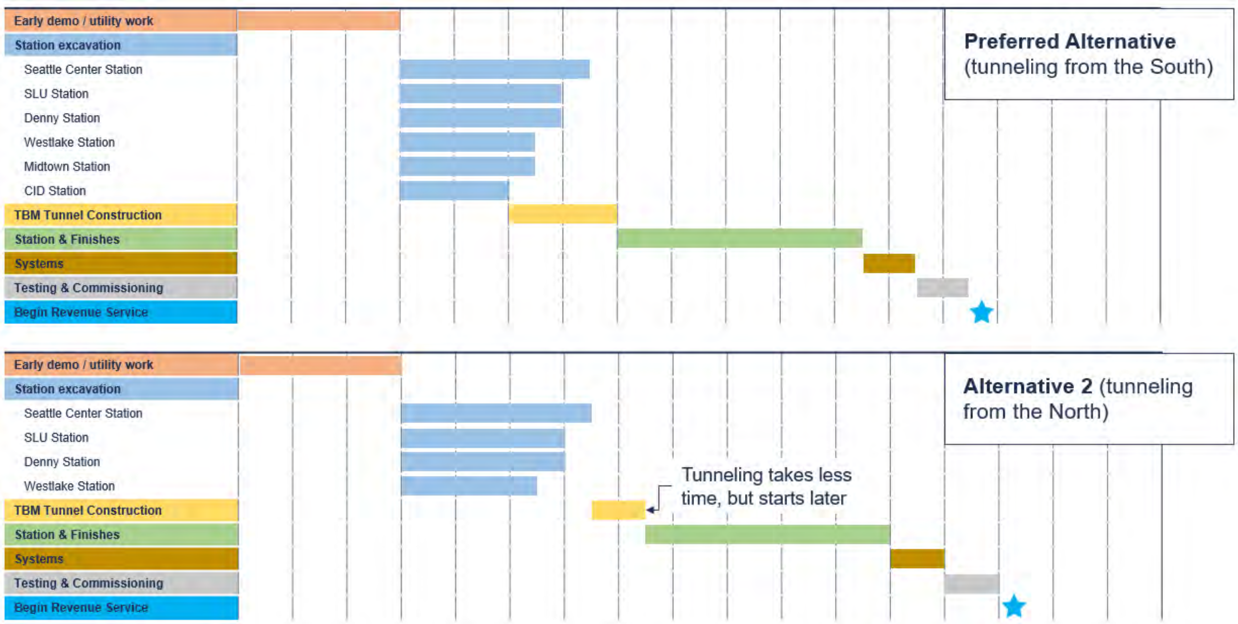


Figure 6-1 Downtown Tunnel Construction Schedule Comparison

Because these concepts have not been studied in the BLE environmental process to date, additional environmental study would be required. It is estimated that this additional environmental review would result in a minimum of two years of delay to the completion of the project. Figure 6-2 below illustrates this result in comparison to the current potential BLE construction schedule.

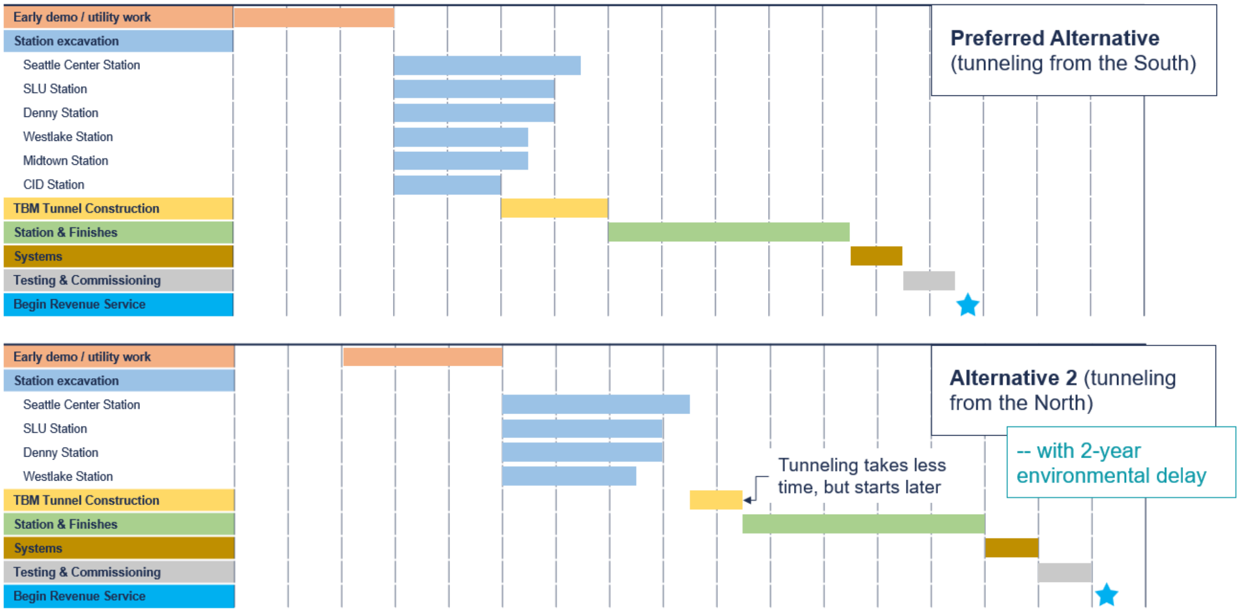


Figure 6-2 Downtown Tunnel Construction Schedule Comparison with Environmental Delay

7 COST ESTIMATES FOR IMPLEMENTATION

High-level rough-order-of-magnitude (ROM) cost estimates were developed for the alternatives, based on conceptual design and potential construction approach. For each alternative, the full project cost was reduced by the portion of the new downtown tunnel that would not be built (between SODO and Westlake). Additional costs for construction, property acquisition, service disruption mitigation, system upgrades, and project delay were then estimated and added to develop a potential ROM project cost. For each alternative, costs were developed for an optimistic scenario (shown as "low" in the figures below) and a pessimistic scenario (shown as "high"). Although cost allowances were provided for system upgrades required to deliver each alternative, due to the preliminary level of this assessment, additional upgrades could be required as the alternative designs develop, resulting in increased costs. Similarly, substantial risks associated with the interlining alternatives that cannot be fully vetted at this preliminary assessment level introduce additional risk of increased costs that cannot currently be accounted for. A cost estimate for Alternative 1C was not developed as that alternative is considered fatally flawed. Summary tables for construction cost estimates are provided in **Appendix E**.

7.1 Alternative 1A – Third Ave DSTT Tie-in (at-grade)

With deferral of the segment from SODO to Westlake (including Westlake Station), the BLE project cost would be reduced by approximately $8.4 billion. This would reduce the project cost to approximately $13 billion. For the optimistic scenario, construction cost for implementing the tie-in on Third Avenue is estimated at approximately $0.4 billion, along with approximately $0.4 billion in property cost. The cost of providing supplementary bus service to mitigate the disruption of light rail service is estimated at approximately $0.5 billion. An allowance of $1.0 billion is identified for system upgrades needed to support additional light rail operations on the existing system. Finally, the cost of project delay for additional environmental evaluation is estimated at approximately $1.2 billion. The total low-end cost for this alternative is estimated at $16.5 billion (approximately $5 billion in cost savings compared to the current full build Preferred Alternative.)

For the high-end cost scenario, additional costs are derived from additional project delay of 24-months ($1.2 billion), additional construction cost risk ($0.2 billion), additional service mitigation cost ($0.25 billion), and additional system/station upgrades cost ($0.2 billion) leaving a total project cost of $20.1 billion ($1.3 billion in savings).

Table 7-1 Alternative 1A ROM Cost

Cost Component	Low	High
Full BLE project	$21.4B	$21.4B
Deferred segment (SODO to Westlake including Westlake Station)	-$8.4B	-$8.4B
Subtotal	$13.0B	$13.0B
New construction (interlining on 3rd Avenue)	+$0.4B	+$0.6B
New ROW (interlining on 3rd Avenue)	+$0.4B	+$0.4B
Service disruption mitigation	+$0.5B	+$0.75B
System upgrade allowance	+$1.0B	+$3.0B
Project delay (24 – 48 months)	+$1.2B	+$2.4B
Total*	**$16.5B**	**$20.1B**

*High end of range reflects additional cost risk for construction, service mitigation, system upgrades, and project delay

7.2 Alternative 1B – Third Ave DSTT Tie-in (grade-separated)

With deferral of the segment from SODO to Westlake (including Westlake Station), the BLE project cost would be reduced by approximately $8.4 billion. This would reduce the project cost to approximately $13 billion. For the optimistic scenario, construction cost for implementing the tie-in on 3rd Avenue is estimated at approximately $0.7 billion, along with approximately $0.3 billion in property cost. The cost of providing supplementary bus service to mitigate the disruption of light rail service is estimated at approximately $0.5 billion. An allowance of $1.0 billion is identified for system upgrades needed to support additional light rail operations on the existing system. Finally, the cost of project delay for additional environmental evaluation is estimated at approximately $1.2 billion. The total low-end cost for this alternative is estimated at $16.7 billion (approximately $4.5 billion in cost savings compared to the current full build Preferred Alternative.)

For the high-end cost scenario, additional costs are derived from additional project delay of 24-months ($1.2 billion), additional construction cost risk ($0.35 billion), additional ROW ($0.95 billion), additional service mitigation cost ($0.25 billion), and additional system/station upgrades cost ($2 billion) leaving a total project cost of $21.4 billion (no savings).

Table 7-2 Alternative 1B ROM Cost

Cost Component	Low	High
Full BLE project	$21.4B	$21.4B
Deferred segment (SODO to Westlake including Westlake Station)	-$8.4B	-$8.4B
Subtotal	$13.0B	$13.0B
New construction (interlining on 3rd Avenue)	+$0.7B	+1.0B
New ROW (interlining on 3rd Avenue)	+$0.3B	+1.3B
Service disruption mitigation	+$0.5B	+0.75B
System upgrade allowance	+$1.0B	+$3.0B
Project delay (24 – 48 months)	+$1.2B	+$2.4B
Total*	**$16.7B**	**$21.4B**

*High end of range reflects additional cost risk for construction, ROW, service mitigation, system upgrades, and project delay

7.3 Alternative 2 – Westlake Station Terminus for BLE tunnel (Stub End)

With deferral of the segment from SODO to Westlake (excluding Westlake Station), the BLE project cost would be reduced by approximately $7.2 billion. This would reduce the project cost to approximately $14.2 billion. For the optimistic scenario, construction cost of a new OMF to serve this line is estimated at approximately $0.8 billion, along with approximately $0.3 billion in property cost. An allowance of $1.0 billion is identified for system upgrades needed to support additional light rail operations on the existing system. Finally, the cost of project delay for additional environmental evaluation is estimated at approximately $1.2 billion. The total low-end cost for this alternative is estimated at $17.4 billion (approximately $4 billion cost savings compared to the current full build preferred alternative.)

For the high-end cost scenario, additional costs are derived from additional project delay of 24-months ($1.2 billion), additional construction cost risk ($0.4 billion), additional ROW cost ($0.1 billion), and additional system/station upgrades cost ($2 billion) leaving a total project cost of $21.1 billion ($0.2 billion in savings).

Table 7-3 Alternative 2 ROM Cost

Cost Component	Low	High
Full BLE project	$21.4B	$21.4B

Cost Component	Low	High
Deferred segment (SODO to Westlake excluding Westlake Station)	-$7.2B	-$7.2B
Subtotal	$14.2B	$14.2B
New construction (OMF)	+$0.8B	+$1.2B
New ROW (OMF)	+$0.3B	+0.4B
System upgrade allowance	+$1.0B	+3.0B
Project delay (24 – 48 months)	+$1.2B	+$2.4B
Total*	**$17.4B**	**$21.1B**

*High end of range reflects additional cost risk for construction, ROW, system upgrades, and project delay

8 SUMMARY OF FINDINGS

Given rising cost pressures facing the ST3 Program, Sound Transit is investigating whether technology and reliability upgrades could allow interlining all three lines through the existing Downtown Seattle Transit Tunnel (DSTT) – instead of building the portion of the new tunnel between SODO and Westlake identified in the Preferred Alternative – and whether this could be a feasible and practical alternative that could save costs while maintaining reliable service.

Sound Transit leveraged consultant resources, as well as a broad group of resources within Sound Transit, with expertise in tunneling, track, construction, rail operations modeling, maintenance facility assessment, and cost estimating to investigate several approaches that could eliminate the need to build the portion of the new downtown tunnel between SODO and Westlake.

One of the approaches, Alternative 1, involves connecting ("interlining") the new tunnel from Ballard with the existing DSTT while another approach, Alternative 2, would terminate ("stub-end") the new tunnel. The results of this study indicate that the at-grade interlining configuration (Alternative 1A) could save between $1.3 billion and $5 billion compared to the full-build Preferred Alternative, while the grade-separated interlining configuration (Alternative 1B) ranges from no cost savings to up to $4.5 billion in savings. The study results indicate that the stub-end approach ranges from no cost savings to up to $4 billion in savings. The high end of each range represents an optimistic scenario and the low-end accounts for potential additional capital cost risk and expenditures to ensure consistent service and system reliability.

Key findings

1. **Construction disruption:** The interlining approach (Alternative 1) would require that existing light rail service through downtown and up to Lynnwood be shut down for an extended period (approximately three years or more) to accommodate construction associated with connecting the new tunnel from Ballard to the existing DSTT. Third Avenue

would also need to be closed for an extended period (approximately 10 months or more) with effects on bus routes using that corridor.

2. **Construction risk:** The interlining approach (Alternative 1) requires substantial tunneling activities along the footprint of the DSTT tunnel bores between Westlake and Symphony stations. Poor soil conditions in this area led to tunneling issues during the original DSTT construction, creating construction delays and cost escalation. The existing tunnels are thin, unreinforced, and have a poor-quality temporary lining, making them prone to movement and damage during construction. There is considerable risk of performing any additional tunneling activities in this area to facilitate the interlining alternatives. In addition, beginning tunneling at congested Seattle Center rather than the currently planned BLE tunnel launch site in SODO would introduce construction, staging, and right-of-way implications.
3. **Maintenance facility needs:** The stub-end approach (Alternative 2) would require construction of a new maintenance facility somewhere along the Ballard line – likely in the Interbay area – with associated cost, environmental review, and potential process delay implications (as well as additional costs to operate and maintain this facility). If this new BLE maintenance facility is unable to be constructed, the standalone Ballard line associated with the stub-end approach would not be able to operate. The interlining approach (Alternative 1) would not require a new maintenance facility.
4. **System reliability and resilience:** Both Alternatives 1 and 2 would necessitate extensive near-term infrastructure upgrades to the existing DSTT; additional implementation challenges (such as cost, risk, service disruption, and schedule) are still unknown but could add significantly to the baseline estimate and schedule. While such investments help accommodate running multiple lines, there is increased risk of a single tunnel as a critical point of failure – any disruption could halt the entire system. A second tunnel would allow Sound Transit to run more trains per hour through the downtown core (offering higher long term system capacity), as well as operate lines and service patterns without pushing dwell times and signaling to the edge of reliability. The second tunnel also provides passengers using the spine with an alternate route through downtown when one tunnel is blocked, without the need for a bus bridge.
5. **Project schedule delay:** Additional environmental review and design effort would likely delay the overall project schedule by at least two years (or likely longer) and is required for both approaches. Even though the tunnel section between SODO and Westlake would be eliminated, the overall construction schedule would be similar or even slightly longer due to the need to begin tunneling at Seattle Center rather than SODO, which shifts the critical path to Seattle Center Station.

Table 8-1 below shows a summary of the key implications of the alternative approaches.

Table 8-1 Summary Comparison Table

Criteria	Interlining **Alt 1A:** Third Ave DSTT Tie-in (at-grade) **Alt 1B:** Third Ave DSTT Tie-in (grade-separated)	Stub End **Alt 2:** Ballard to Westlake Terminus
Potential cost savings (2025$)	• At grade: $1-5B • Grade separated: $0-4.5B	• $0-4B

Criteria	Interlining **Alt 1A:** Third Ave DSTT Tie-in (at-grade) **Alt 1B:** Third Ave DSTT Tie-in (grade-separated)	Stub End **Alt 2:** Ballard to Westlake Terminus
Constructability and risk	• High-risk construction at DSTT tie-in location could **add substantial cost** • High risk of affecting expensive downtown property	• **New operations and maintenance facility (OMF) required** to operate service with unknown risks, including property and permitting • Could trigger expensive and disruptive capacity upgrades at Westlake Station
Schedule	• Delays revenue service date minimum 2 years compared to the full build • Potential for additional environmental process delay beyond agency control	• Same as Alt 1A/B
Construction effects	• Long-term **Link service shutdown** from Intl District to Lynnwood (likely years) • Full Third Ave closure for extended period • Requires tunneling from north (at Seattle Center Station) • Avoids near-term effects around CID and Midtown	• Adds construction in Interbay area for OMF • Requires tunneling from north (at Seattle Center Station) • Avoids near-term effects around CID and Midtown
System performance	• Existing constraints would limit headway, reliability and capacity • **Increased pressure on single-point of failure** through downtown • System upgrades could potentially mitigate constraints; additional study required to assess potential cost and construction effects	• Similar to Alt 1A/B except: o Avoids interlining near Westlake o Runs more lines through University Link tunnel
Forward compatibility to complete second tunnel	• Stub tunnel near Denny Station could facilitate future tunnel completion • **Substantial inefficiencies** in overall tunnel construction including redundant tunnel north of Symphony	• Short stub tunnel south of the new Westlake Station could facilitate future expansion • **Adds inefficiencies in overall tunnel construction**
Additional considerations	• **Likely revenue loss during Link closure** plus cost of replacement service • Potential for **short/long-term rider loss** due to long-term shut down • **Effects to potentially historic properties** not currently in DEIS • Assessing potential effects on grant opportunities and effects on existing grants due to Link closure.	• Assessing potential effects on grant opportunities • Potential capacity upgrades at Westlake Station could add substantial cost • Additional costs for operations and maintenance of the new OMF not captured in study

Should the Sound Transit Board request advancing the design of any of the alternatives assessed, multiple future evaluations and implementation steps would be required to further identify risks and opportunities and to fully validate feasibility. Necessary next steps would include:

- Further assessments of the existing system's infrastructure for traction power, ventilation, existing station egresses, and station platform capacity. This would also necessitate studying the level of system improvements required to facilitate implementation.
- Technology upgrades such as full implementation of the agency's CBTC strategy to ensure any major construction within the DSTT is fully integrated with signal upgrades or the roll-out of advanced signaling within the existing infrastructure.
- Development of a new Concept of Operations (ConOps) for operating the Link system both in the short-term during construction and in the final configuration. This work would be supported by additional detailed RSS modeling to inform operational decision making.
- Detailed preliminary design of the alternative to more fully capture and quantify the risks, constraints, and opportunities that cannot be understood at the feasibility assessment level. This preliminary design would include detailed constructability analyses of interlining, assessing if appropriate methods of construction could be deployed to mitigate the risk of the interlining junction tunneling activities adjacent to the fragile existing DSTT tunnel lining in historically poor soil.

APPENDIX A

Summary of Previous Studies and Reports on Interlining and DSTT

Summary of Previous Studies and Reports on Interlining and DSTT

To support the larger reporting on the BLE-DSTT Interlining feasibility analysis, this document provides a summary of the reports on previous studies into interlining BLE or WSLE service within the DSTT and studies into upgrades in the DSTT that will be affected by these alternatives to interline service.

- ***Report Name/Location:*** clean draft Ballard tunnel memo -130709 cm.pdf
  - Date of Report: July 2013
  - Issued by: Sound Transit & SDOT
  - Short summary (1-3 sentences): Connecting a Ballard LRT in the existing DSTT is not feasible because:
    - Once the ST2 plan is complete and fully in operation, DSTT will not contain enough additional capacity to reliably accommodate another line serving downtown.
    - Adding another line through DSTT while maintaining the required minimum 3-min headway through DSTT for FLS and service reliability reasons would result in delays and mismanaged passenger loads.
    - Construction challenges of connecting a Ballard line to the DSTT would result in high costs, substantial construction risks, system closures and/or service disruptions.
  - Relevance to BLE-DSTT Interlining analysis:
    - The RSS analysis will study this particular scenario where all three lines are running through the existing DSTT which will enable Sound Transit to understand the impacts on headways and systematic service reliability. The interlining task is also evaluating the construction feasibility of connecting the Ballard line into the DSTT.
- ***Report Name: Ballard-to-Downtown Seattle Transit Expansion Study, 2014***
  - Issued by: Sound Transit & SDOT
  - Location: Transit Expansion Study_Ballard to Downtown Seattle_2014.pdf – May 30, 2014

  - Sound Transit and the City of Seattle collaborated on a conceptual study to explore opportunities for improving transit connections between Ballard and downtown Seattle to inform future transit development decisions. The memo summarized the process of alternatives development and evaluation with public engagement. Out of the final 5 corridors/options, the tunnel options (Corridor A Interbay West and Corridor D Queen Anne Tunnel) provide the most benefits in ridership, service reliability, travel time improvements, highest potential for station area development, and causes the least disruptions to other transit modes, and the least environmental impacts, despite being the most expensive and complex options.
- Location: AE 0169-12 Task A.9 B2D Design Report.pdf – June 2014
  - The design report presented a record of design assumptions made during the planning process of the Ballard-to-Downtown Seattle Transit Expansion Study, including design criteria, design considerations related to various engineering disciplines, issues at critical guideway/roadway interface locations, decision-making processes coordinated with involved parties.
- Relevance to BLE-DSTT Interlining analysis: The Level 2 evaluation in the study provides a performance baseline (ridership, reliability, travel time, disruption, cost, complexity) that can be directly applied to stress-test how a Ballard line interlined through the DSTT would perform.

- ***Report Name/Location:*** ST3 LRT Operating Plans Memo Sep 2015.pdf
  - Date of Report: September 3, 2015
  - Issued by: Sound Transit (ST3 Consultant)
  - Short summary (1-3 sentences):
    - The baseline ST3 Operating Plan as of 2015 (Ballard-West Seatle, Everett-Tacoma, Everett-Redmond) creates operation issues such as long one-way running time, ridership imbalances (especially in the north corridor), service reliability and train capacity concerns. The memo proposes three preliminary operating strategies (involving line segmentation and a second downtown tunnel) that could potentially address the issues identified. It also recognized that some operation issues may remain even with the introduction of DSTT2.
  - Relevance to BLE-DSTT Interlining analysis:
    - The memo recognized potential operation benefits of a second downtown tunnel for the spine system. It also recommended further model simulations on these proposed scenarios to further evaluate the operational impacts – these are analyzed under the RSS work stream.
- ***Report Name/Location:*** ST3 Operating Plans Memo_10.12.2015.docx
  - Date of Report: October 12, 2015
  - Issued by: AECOM

- Short summary (1-3 sentences):
    - The memo offered a few insights into the development of a second tunnel for light rail through downtown Seattle upon reviewing the ST3 LRT Operating Plans Memo Sep 2015.pdf:
        - **Alignment**: Both the IDS and Westlake Station should be transit hubs for both tunnels and the challenge will be passenger connections; The interface between the light rail system and the longer-distance express bus system needs to be studied;
        - **Tunnel configuration**: The new DSTT should have station capacity similar to the existing DSTT and be capable of handling four-car trains;
        - **Network configuration and operation strategies**: Single line one-way run time (under 90mins), ridership forecast (consider long-term/100-year scenarios and geographic differences), and characteristics of new extensions should all be considered in the system planning.
- Relevance to BLE-DSTT Interlining analysis:
    - The memo acknowledged that when evaluating the investment of a new DSTT tunnel, it is important to look at the ridership forecast beyond a typical 20 or 30-year horizon.

- ***Report Name/Location:*** 102915 ST3 System Structure Memo - Revised (1).docx
    - Date of Report: October 29, 2015
    - Issued by: WSP/PB
    - Short summary (1-3 sentences):
    - The memo compared trade-offs between two operation scenarios under the common assumption that *a second LRT-only DSTT (DSTT2) will be constructed* in the lead up to the ST3 system planning:
        - Scenario 1 (baseline): both the central "spine" (Everett-Tacoma) and Everett-Redmond line are routed through the existing DSTT. DSTT2 is dedicated to West Seattle-Ballard line.
        - Scenario 2: the Everett-Tacoma "spine" is segmented into Everett-West Seattle line and Ballard-Tacoma line. Both lines from/to Everett still run through the existing DSTT, and the Ballard-Tacoma line runs through DSTT2.

        - Conclusion: While Scenario 1 offers advantages in allowing smaller fleets and independent operation for West Seattle-Ballard line, and fewer transfers for riders in the region, it creates potential long-term operational issues such as service reliability, rider load imbalance, labor availability, and the need for additional O&M facility. Most of these could be resolved by Scenario 2, contingent on further ridership forecasts and operation simulation analysis.
    - Relevance to BLE-DSTT Interlining analysis:
        - The RSS analysis will support ST in understanding the system performance and service reliability under both scenarios discussed in the memo where DSTT2 is utilized.
- ***Report Name/Location:*** ST3_LRT_Ops_Fleet_OMF_TechMemo_8-30-16.pdf
    - Date of Report: August 2016
    - Issued by: Sound Transit
    - Short summary (1-3 sentences):
        - The memo provided a review of the two ST3 light rail operating schemes as described in the Oct 2015 ST3 System Structure Memo, and confirmed that Scheme 2 was adopted in the final ST3 plan from June 2016. Scheme 1 shows the Ballard-to-West Seattle concept. Scheme 2 shows the spine segmentation concept. In addition to the Oct 2015 memo, this memo included a summary of the fleet requirements and OMF phasing for the ST3 plan.
    - Relevance to BLE-DSTT Interlining analysis:
        - The RSS can help validate if the assumed headways can be achievable under both schemes.
- ***Report Name/Location:*** AE 0036-17 09.05 Interim Terminus Operational Feasibility Study Draft 5.pdf
    - Date of Report: September 23, 2019
    - Issued by: HNTB
    - Short summary (1-3 sentences):
        - The report evaluated the advantages and challenges for a few interim terminus options for WSLE before BLE can be open. The options include: the ST3 representative project (interim terminus at SODO Station), early construction of New CID station, Stadium Station Interim Terminus, and three interlining options (using an existing station as turn-back). While posing a few challenges such as potential capacity constraints, requiring passengers to transfer for travel north of SODO and limited West Seattle ridership, the SODO option has the most promise because of its least impact on the reliability of Central Link and its least requirement on upgrading the existing system.

- Relevance to BLE-DSTT Interlining analysis:
  - The RSS study can further validate the system reliability performance of the ST3 representative project.

- ***Report Name/Location:*** HNTB-Sound_Transit_Resiliency_Assessment_Report_FINAL.pdf
  - Date of Report: February 2025
  - Issued by: Sound Transit/HNTB
  - Short summary (1-3 sentences):
    - Sound Transit commissioned a study on recent incidents that impacted operations along portions of the Link light rail system, and the study indicated traction power and signal equipment issue were the two most common causes. The report evaluated all findings qualitatively based on four categories (Impact to the Public, Safety, Operational Risk, and Complexity) and recommended the need for improvement in operating partnerships and organizational changes, standards and operating procedures, commissioning (e.g., project documentation, testing and training), asset management and long-range planning.
  - Relevance to BLE-DSTT Interlining analysis:
    - The report proposed a series of recommendations to the existing DSTT system that ST should consider adopting to improve system resiliency. The recommended DSTT upgrades include train control and signals system, emergency ventilation, distribution control automation and monitoring, and track configuration and monitoring. All of these issues will need to be revaluated and addressed before ST chooses to interline BLE in the existing DSTT.

- ***Report Name/Location:*** DSTT SOGR Program – TO 17.00 - DSTT Tunnel NTIS / TOMIE Inspection – Vol 1 thru 3
    - 160415 Task17 DSTT GEC NTIS_FinalReport_Vol1 - Structural.pdf - September 2021
    - 160415 Task17 DSTT GEC NTIS_FinalReport_Vol2 - Electrical.pdf - September 2021
    - 160415 Task17 DSTT GEC NTIS_FinalReport_Vol3 - Mechanical.pdf - May 2021

- Short summary (1-3 sentences):
  The three report volumes present the results of inspection and condition assessment of the DSTT tunnel (stations were not included) following National Tunnel Inspection Standards (NTIS) & Tunnel Operations, Maintenance, Inspection and Evaluation (TOMIE) Manual.
  Structural Report determined that there were no structural inspection findings that warranted critical or immediate repair and observed the tunnel to be in good to fair condition. Repairs recommended were noted as being critical or hindering the structural integrity of the tunnel.
  Electrical Report assessed tunnel lighting, normal and emergency power systems (not including traction power, or 26kV primary power), tunnel security systems, fire alarm and communications systems. No emergency repairs were discovered. Moderate maintenance activities were identified to improve and maintain operational reliability. 3 serious failures were revealed: emergency telephone system had significant failed devices, fire alarm system for zones 202 and 203 in the cut-and-cover section north of WLS did not function, lighting outages in the tunnel beneath PSVF.
  Mechanical Report assessed tunnel ventilation system, tunnel drainage, fire suppression systems, sump pump system, and other mechanical equipment in ancillary spaces dedicated to the tunnel system. Mechanical and fire suppression systems were found to be in good to fair condition. No major rehabilitation or system overhaul was determined to be required, and noted that existing systems could be brought back to complete working order with spot repairs and replacements.
- Relevance to BLE-DSTT Interlining analysis:
  The reports provide a baseline of the condition of the tunnel on which to support development of interlining analysis. The assessment of tunnel segments assists in determining any additional concerns which may preclude alternatives for interlining or add additional complexity or cost for any systems that may need further upgrade than planned as part of SOGR.

- ***Report Name/Location:*** DSTT SOGR Programs – DSTT Emergency Ventilation Resilience Evaluation: Phase 1 /DSTT Emergency Ventilation Resilience Evaluation Phase 1.pdf
  - *Date of Report:* February 26, 2021
  - Short summary (1-3 sentences):
    - Report provides results from inspection of the DSTT Emergency Ventilation System (EVS) to determine the resilience of the system, condition and remaining projected life of the equipment. All fans inspected appeared to be in good overall physical condition. No visual indication of defects that could prevent the fans from operating normally or failing prematurely.

        - The report also details Subway Environmental Simulation (SES) study to evaluate how the existing fire emergency ventilation modes in the DSTT tunnels and the tunnels south of CHS would be impacted with one-fan-out-of-service. Part of this analysis was to determine whether station exhaust fans could be decommissioned. The analysis noted that the PSS fans are needed and that it is recommended that the USS and WLS are kept. Equipment maintenance recommendations were detailed, as well as further analysis including computational fluid dynamics (CFD) analyses, studying revising the existing Emergency Response Modes to optimize ventilation operations, and further SES analysis.
    - Relevance to BLE-DSTT Interlining analysis:
        - It provides context on studies done to date, condition of existing equipment, and future recommendations regarding tunnel ventilation to support in understanding potential upgrades needed beyond SOGR to allow for interlining efforts.
- **Report Name/Location:** DSTT SOGR Program – Task Order 30 DSTT Emergency Ventilation Resilience Evaluations – Phase 2
        - Tunnel Fire Ventilation Analysis (SES Fire Simulations) - November 2022
        - PSS CFD Fire Simulations Report - November 2022
        - USS (SYS) CFD Fire Simulations Report - December 2022
        - WLS CFD Fire Simulations Report - December 2022
        - Phase 2 ROM Cost Estimate - November 2022
    - Short summary (1-3 sentences):
        - This Phase 2 of DSTT ventilation study, further evaluated the scenarios that did not achieve critical airflow in the Phase 1 study to determine what measure could be taken to meet criteria, with 3 tasks analyzed to improve ventilation system: architectural modifications to station entrances, consolidating existing ventilation zones, modifying the Emergency Response Modes (ERMs).
    - Relevance to BLE-DSTT Interlining analysis:
        - It provides context on studies done to date, condition of existing equipment, and future recommendations regarding tunnel ventilation to support in understanding potential upgrades needed beyond SOGR to allow for interlining efforts.
- ***Report Name/Location:*** DSTT SOGR Program – 26kV Distribution System Assessment Report
    - Date of Report: October 2nd, 2025
    - Short summary (1-3 sentences):

In-depth inspection and condition assessment of the 26kV Power Distribution System in the DSTT. The 26kV MVSS at PSVF serves both facilities and traction power systems. Critical findings are noted with recommendations to address. One of the critical findings include the feeders from IDS to N00 (this spans the whole DSTT) are at end-of-life. ST has a design complete for their replacement, and is planning for replacement in 2027. Other critical findings include maintenance and operations.

- Relevance to BLE-DSTT Interlining analysis:
    - It provides context on studies done to date, condition of existing equipment, and future recommendations regarding tunnel ventilation to support in understanding potential upgrades needed beyond SOGR to allow for interlining efforts. ST is already planning for a major asset replacement to be completed within 2 years, potentially having to pay twice for replacement of this asset if alternative occurs.

- **Report Name/Location:** DSTT SOGR Program – TO 38.00 – DSTT Fire Suppression and Detection Compliance Plan
    - *Date of Report:* November 11, 2024
    - Short summary (1-3 sentences):
      Study to analyze the potential decommissioning and removal of tunnel deluge system and linear heat detection. Study determined this is possible including converting existing wet stand pipe to dry stand pipe, along with proposed phasing of work plan.
    - Relevance to BLE-DSTT Interlining analysis:
      Provided background of existing fire life safety systems in the tunnel, and future proposed SOGR projects related to them. Understanding that these systems are possible to decommission reduces number of systems that would need to be upgraded/ replaced as part of potential interlining efforts.
- **Report Name/Location:** DSTT SOGR Program – TO 23.00 – DSTT System Water Intrusion Mitigation
    - *Date of Report:* November 17, 2023
    - Short summary (1-3 sentences):

Assessment of water infiltration in the DSTT includes both tunnels and stations, including identifying existing and likely potential points of water ingress, along with findings and recommendations. The study determined that overall the tunnel is in relatively good condition with nine unique CS-4 defects (CS-4 is defined by NTIS inspection manual as follows: Severe condition, the condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel.) Each of the four stations had at least one condition that required immediate attention along with specific repair recommendations. Recommendations for repairs are provided in the report for all defects identified. Follow-on design effort is currently on-going to address defects.

- Relevance to BLE-DSTT Interlining analysis:
  Provides background information on existing condition of the tunnel and stations, existing water infiltration issues can help analysis of future groundworks to note where water may cause issues during potential interlining construction, and ensure contingency is adequately included.

APPENDIX B

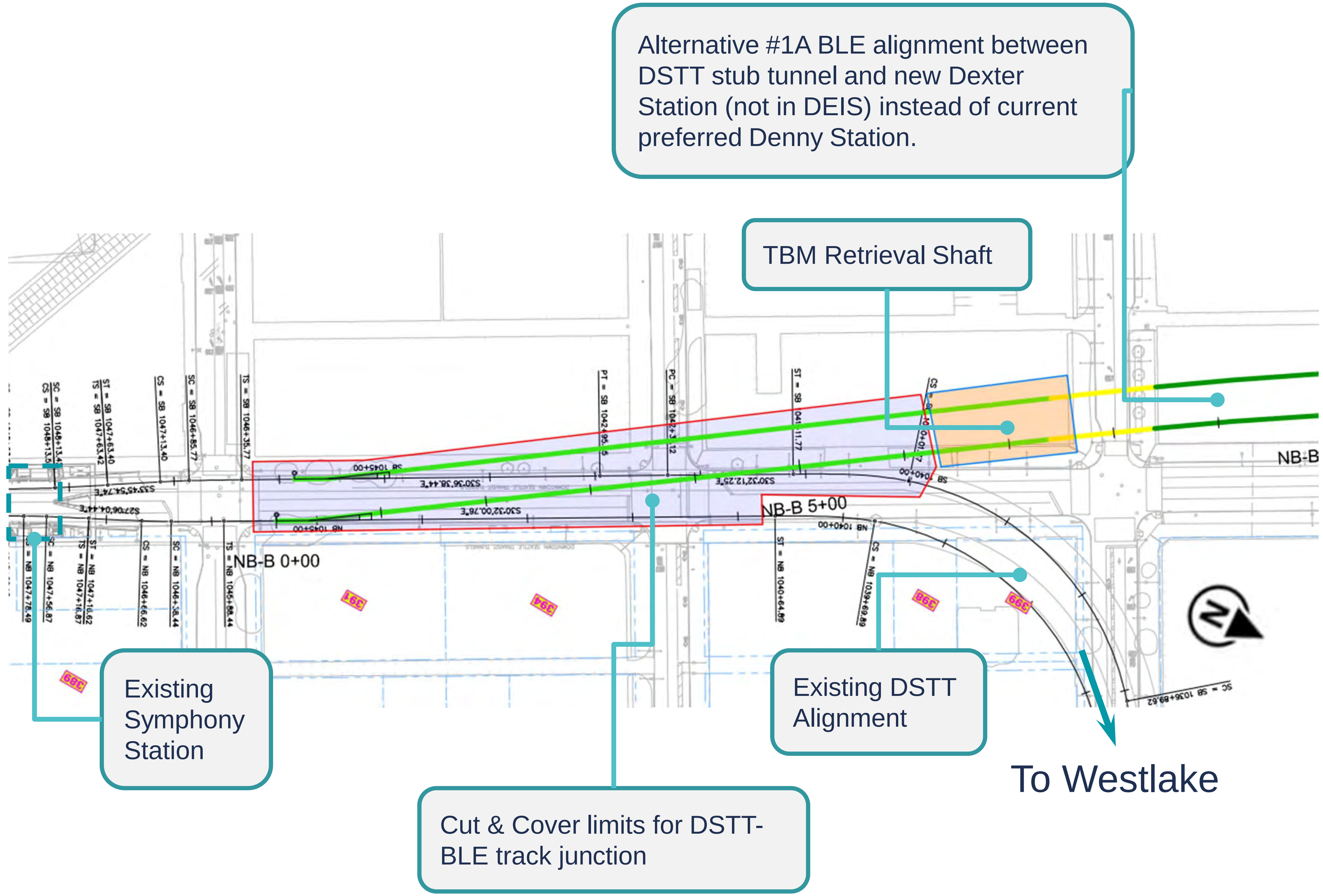
Alternative Figures

Alternative #1A

3rd Ave DSTT At-Grade Tie-in

Interlining BLE tunnel into DSTT curve between the existing Symphony and Westlake Station, right under 3rd Avenue.

- Alignment curve around deep building foundations in SLU.
- Track at high elevation north of Symphony; steep grade dive due to adjacent building foundations.
- Transfers from BLE to the rest of the system to occur at Symphony or further south.



Alternative alignments, limits of construction and potential property impacts, and considerations identified are based on early feasibility assessments and do not reflect detailed Preliminary Engineering level of design.

Alternative #1A

3rd Ave DSTT At-Grade Tie-in

- Property Acquisition Requirements
- Operational Considerations
- Technical Considerations

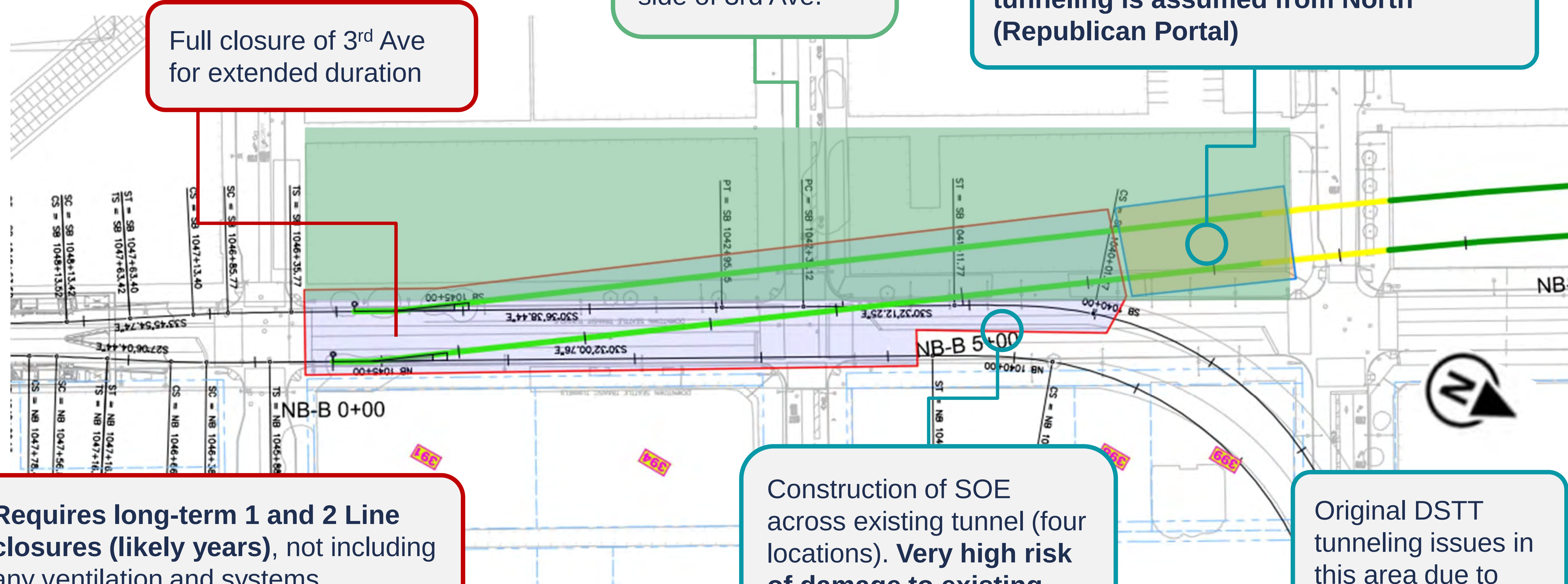
Operational performance constraints dictated by at-grade junction.

Two full blocks of acquisition / demolition on West side of 3rd Ave.

Ventilation and Systems would need to be studied. May require a new fan plant headhouse.

Cut & Cover box for TBM retrieval shaft, as **tunneling is assumed from North (Republican Portal)**

Full closure of 3rd Ave for extended duration



Requires long-term 1 and 2 Line closures (likely years), not including any ventilation and systems upgrades, which may be required.

Construction of SOE across existing tunnel (four locations). **Very high risk of damage to existing unreinforced tunnels** even with advanced protective works/strutting.

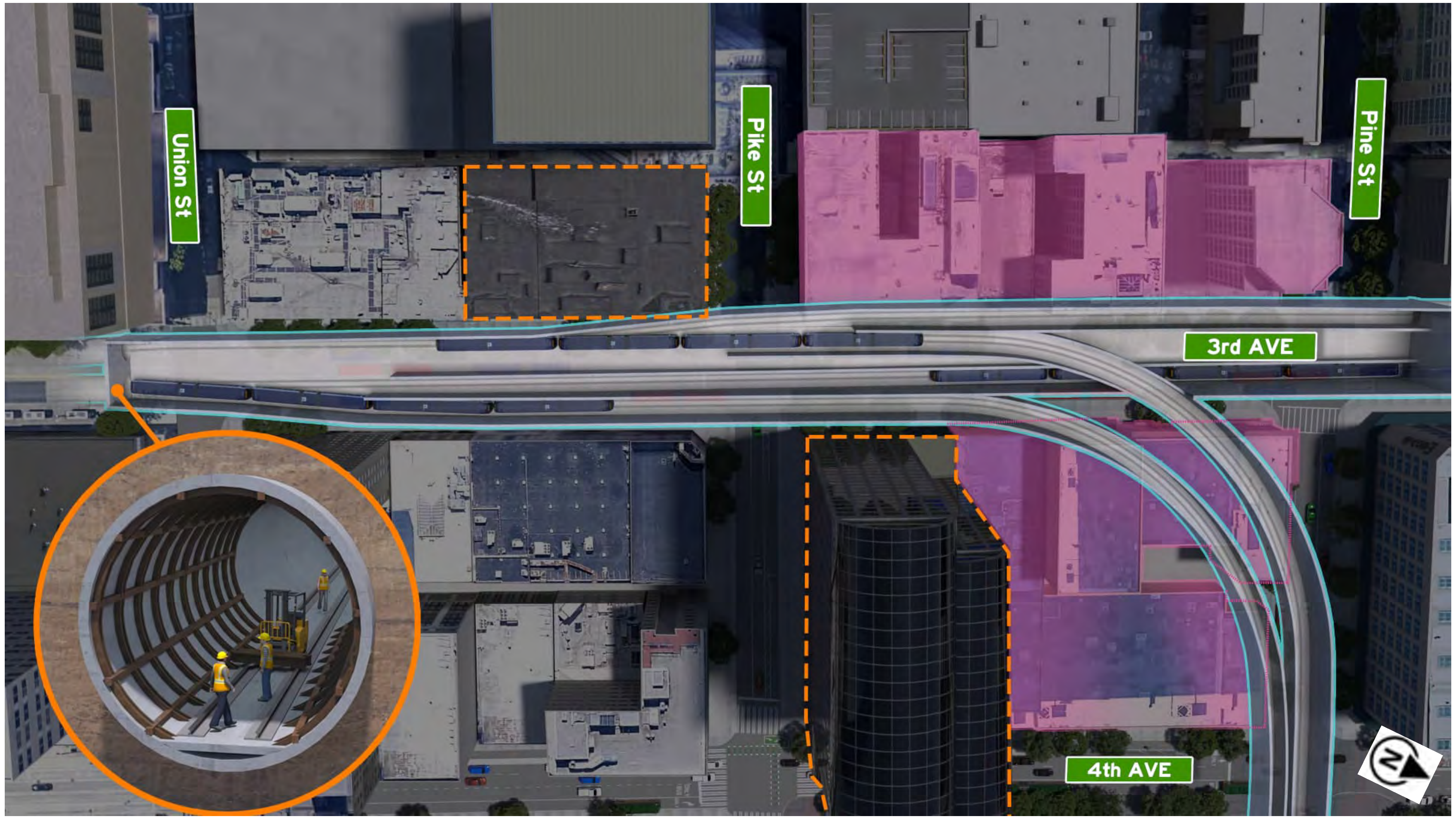
Original DSTT tunneling issues in this area due to extremely poor soil conditions.

Alternative alignments, limits of construction and potential property impacts, and considerations identified are based on early feasibility assessments and do not reflect detailed Preliminary Engineering level of design.

Alternative #1B

3rd Ave DSTT Grade-Separated Tie-in

- **Full closure of 3rd Ave** during SOE and tunnel construction
- **Requires 1 Line and 2 Line closure** during construction
- Fewer properties affected than Alt 1A. Need to acquire properties on the east side of Pine St between 3rd Ave and 4th Ave for relocating NB 1 Line tunnel. **High risk of affecting Century Plaza building**.
- Tunnelling from the North (Republican Portal) - prolonged effects to the Seattle Center neighborhood
- Existing DSTT needs to be supported (internally braced)
- Ventilation and systems would need to be studied. May require a new fan plant headhouse.



Alternative alignments, limits of construction and potential property impacts, and considerations identified are based on early feasibility assessments and do not reflect detailed Preliminary Engineering level of design.

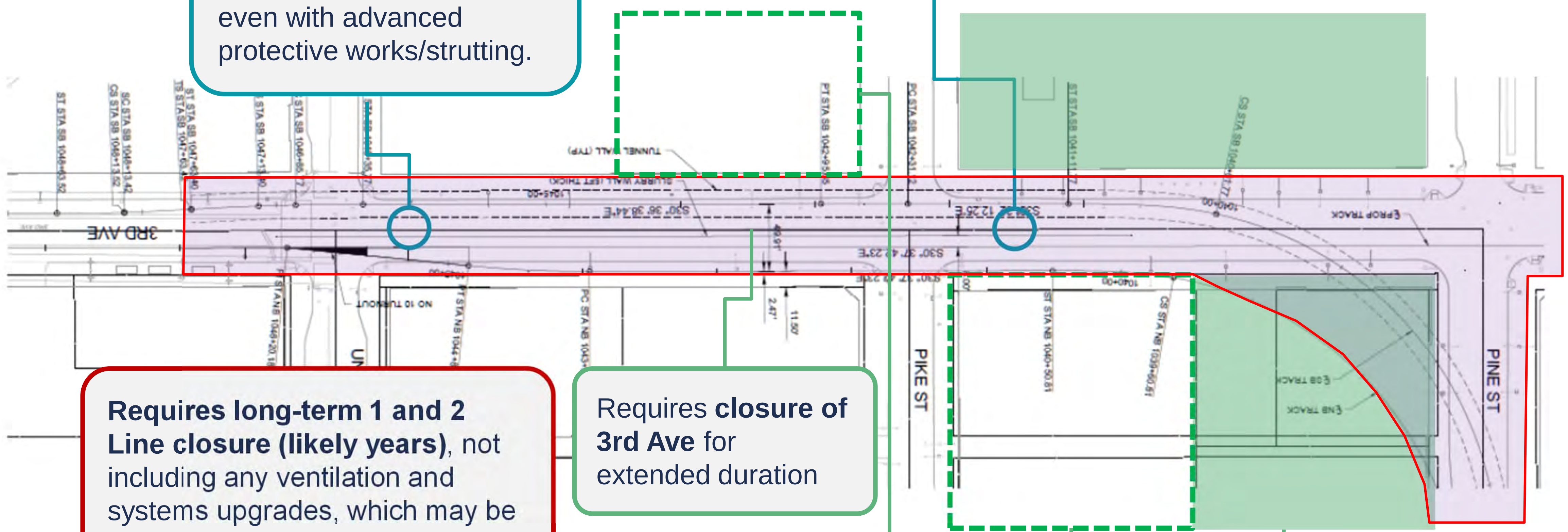
Alternative #1B

3rd Ave DSTT Grade-Separated Tie-in

- Property Acquisition Requirements
- Operational Considerations
- Technical Considerations

Construction of SOE across existing tunnel (four locations). **Very high risk of damage to existing unreinforced tunnels** even with advanced protective works/strutting.

Requires deviation from ST design requirements to avoid at-grade tie-in.



Requires long-term 1 and 2 Line closure (likely years), not including any ventilation and systems upgrades, which may be required.

Requires **closure of 3rd Ave** for extended duration

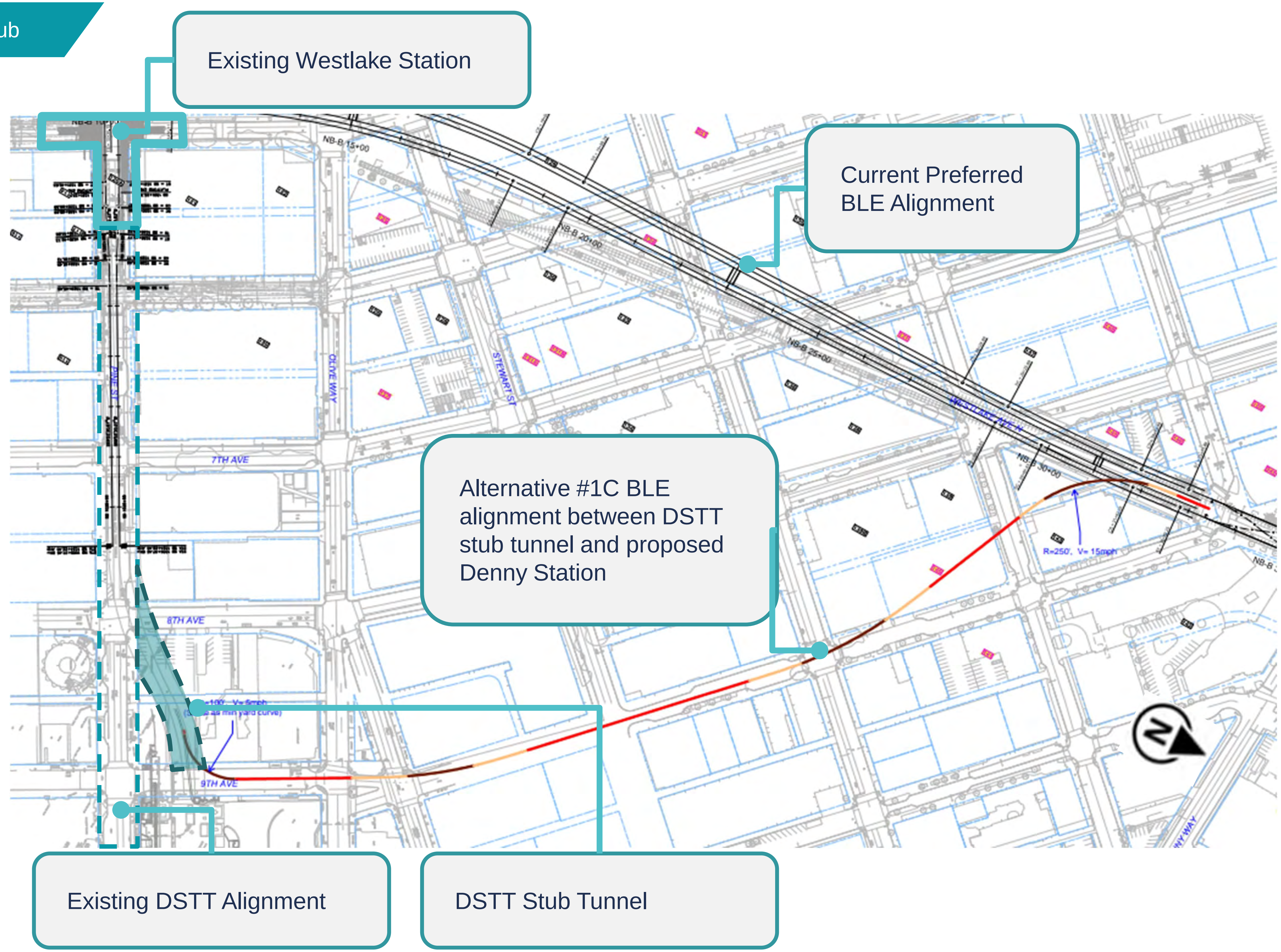
High risk of affecting additional properties including Century Square building

Acquisition of properties on west and east sides of 3rd Avenue required for track realignment

Alternative alignments, limits of construction and potential property impacts, and considerations identified are based on early feasibility assessments and do not reflect detailed Preliminary Engineering level of design.

Alternative #1C
DSTT Tie-in at Pine Street Stub

Construction of a **new cut and cover (C&C) connection** to the DSTT following the alignment of the DSTT Stub Tunnel, the abandoned bus tunnel access to the former Convention Place bus station.

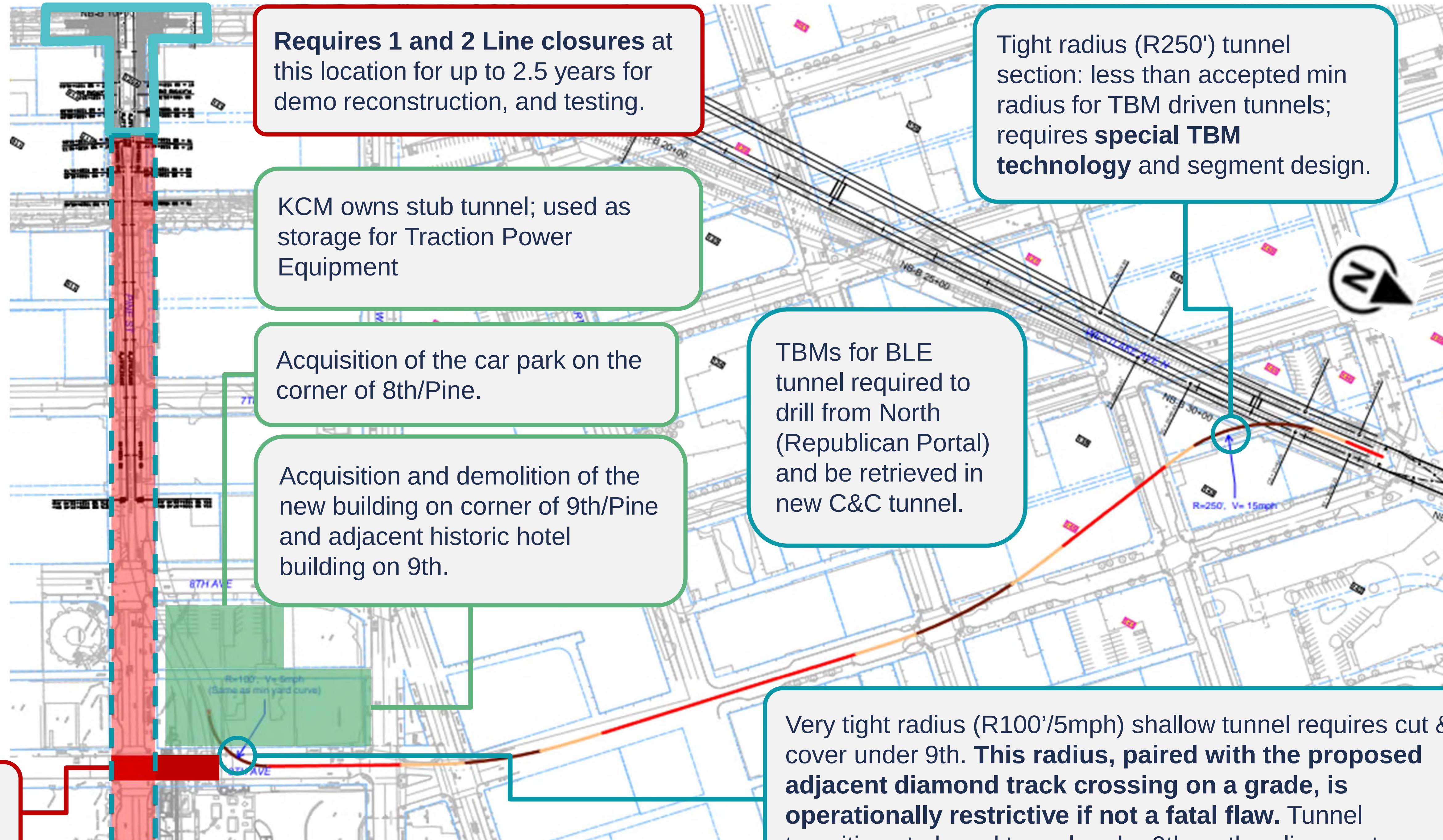


Alternative alignments, limits of construction and potential property impacts, and considerations identified are based on early feasibility assessments and do not reflect detailed Preliminary Engineering level of design.

Alternative #1C

DSTT Tie-in at Pine Street Stub

- Property Acquisition Requirements
- Operational Considerations
- Technical Considerations



Requires 1 and 2 Line closures at this location for up to 2.5 years for demo reconstruction, and testing.

KCM owns stub tunnel; used as storage for Traction Power Equipment

Acquisition of the car park on the corner of 8th/Pine.

Acquisition and demolition of the new building on corner of 9th/Pine and adjacent historic hotel building on 9th.

Tight radius (R250') tunnel section: less than accepted min radius for TBM driven tunnels; requires **special TBM technology** and segment design.

TBMs for BLE tunnel required to drill from North (Republican Portal) and be retrieved in new C&C tunnel.

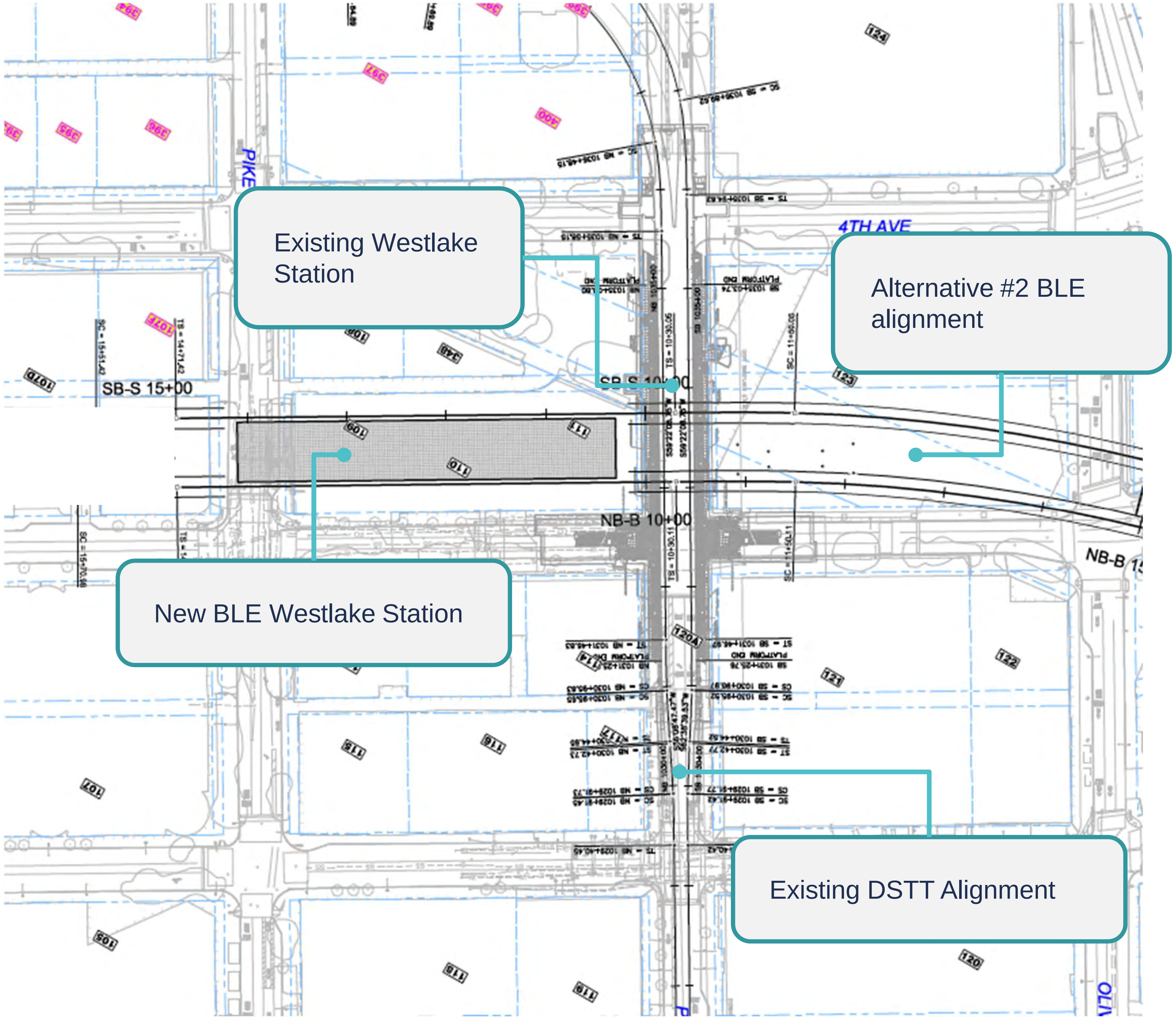
Traffic impacts on 9th Ave

Very tight radius (R100'/5mph) shallow tunnel requires cut & cover under 9th. **This radius, paired with the proposed adjacent diamond track crossing on a grade, is operationally restrictive if not a fatal flaw.** Tunnel transitions to bored tunnel under 9th as the alignment deepens near Olive.

Alternative #2

Westlake Station BLE Terminus

BLE tunnel along current preferred alternative alignment with terminus at the new Westlake Station, with forced transfer from BLE to the rest of the system at the existing Westlake Station.



Alternative alignments, limits of construction and potential property impacts, and considerations identified are based on early feasibility assessments and do not reflect detailed Preliminary Engineering level of design.

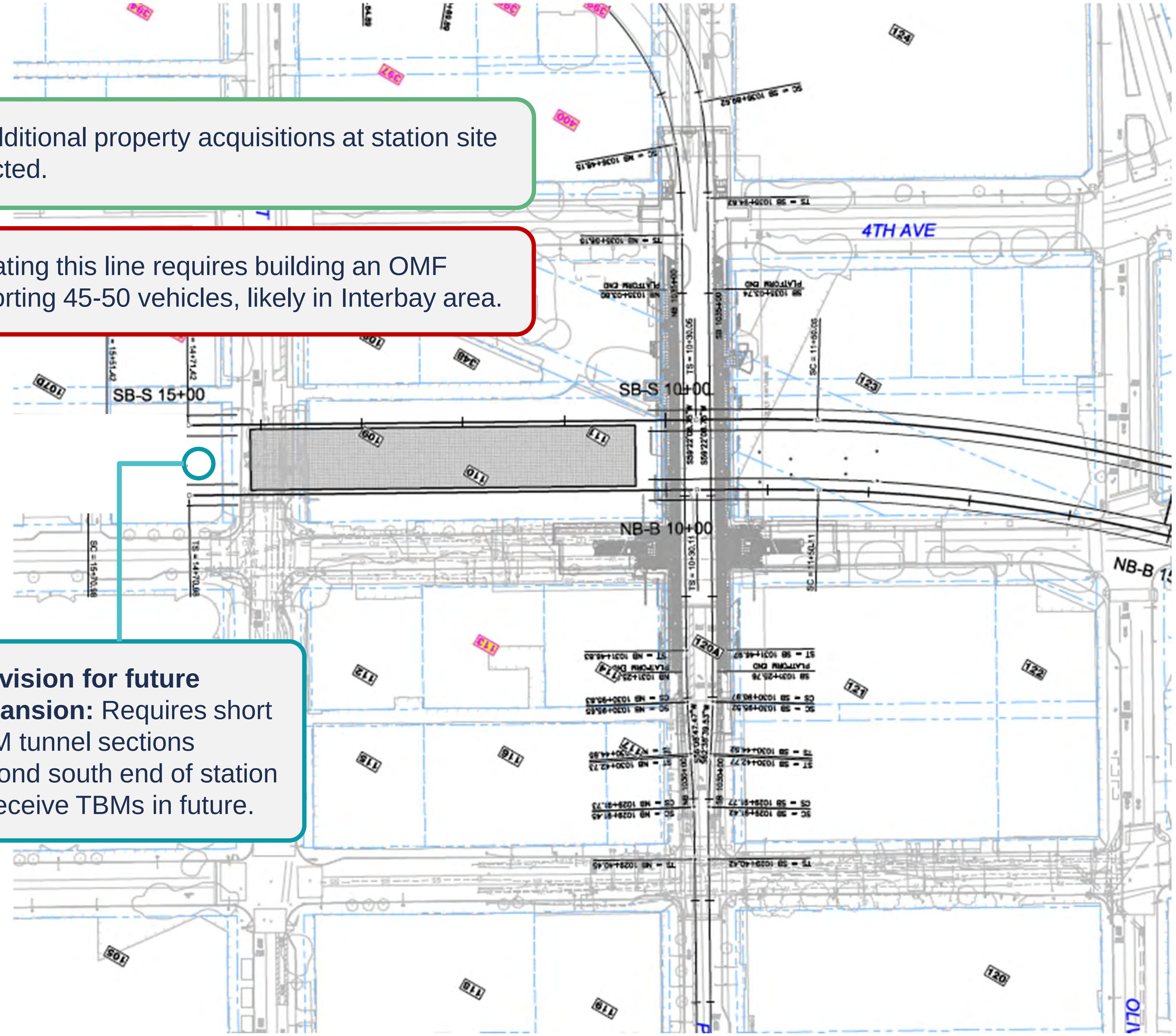
Alternative #2
Westlake Station BLE Terminus

- Property Acquisition Requirements
- Operational Considerations
- Technical Considerations

No additional property acquisitions at station site expected.

Operating this line requires building an OMF supporting 45-50 vehicles, likely in Interbay area.

Provision for future expansion: Requires short SEM tunnel sections beyond south end of station to receive TBMs in future.



APPENDIX C

Ballard Link Extension Concept: Assessment of potential OMF-Interbay

ST Ballard Link Ext Interbay Site
OMF Interbay DRAFT

SEATTLE, WA

CONCEPTUAL COST ESTIMATE
December 4, 2025

Prepared By

SOUNDTRANSIT

SOUNDTRANSIT

TABLE OF CONTENTS

Sound Transit

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Basis of Estimate	1
Overall Summary	6
OMF Building	7
OMF Site	8

Basis of Estimate

General

This Conceptual Estimate provides an high level opinion of probable construction costs for the OMF Interbay DRAFT for the Ballard Link Extension, Seattle, WA.

The estimate consists of Sound Transit OMF Facility at the Interbay Armory Site.

Method

This document is based on the measurement and pricing of quantities wherever information is provided and/or a reasonable assumptions for other work not covered in the drawings or specifications, as stated within this document.

Unit rates have been obtained from historical records. The unit rates reflect current bid costs in the area. Historical consultant estimates Krebs OMFS estimate.

All unit rates relevant to subcontractor work include the subcontractors overhead and profit unless otherwise stated. This overhead and profit covers each subcontractor's cost for labor burden, materials and equipment sales taxes, filed overhead, home office overhead and profit. Depending on the trade, these mark-ups can range from 15% to 20% of the raw cost for that particular item of work. The general contractor's overhead and profit is shown separately on the summary page.

Documentation

This estimate has been prepared from the following documents and information:

- Ballard Link Extension Concept: Assessment of potential OMF-Interbay - Fit test and conceptual layout
- Review of June 3, 2025 West Seattle and Ballard Link Extension - Conceptual Cost Estimate Package

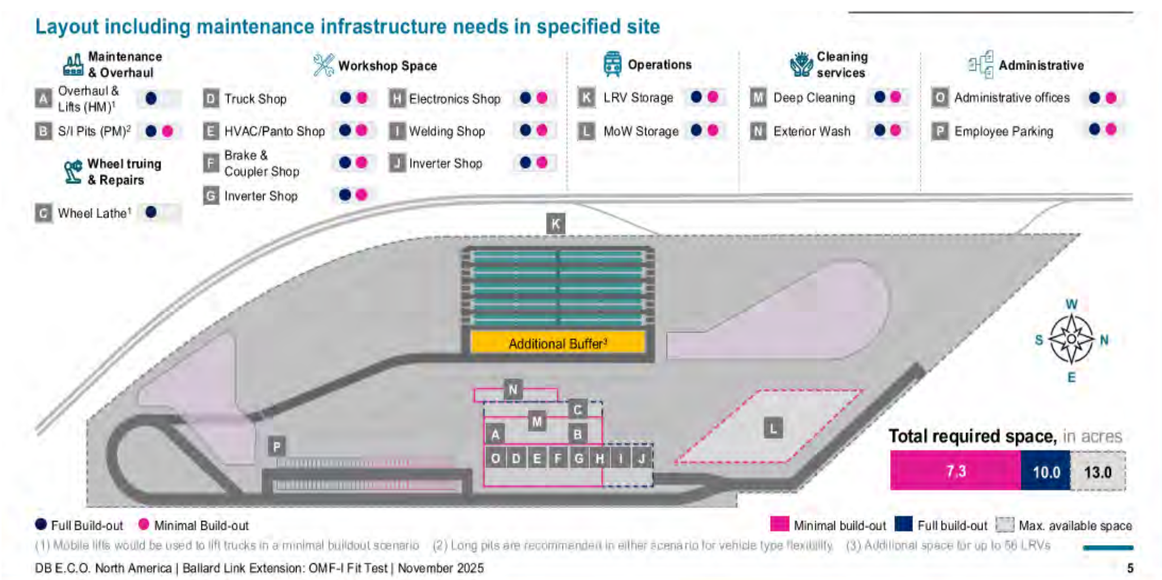
Conversations and Email With Subject Level Experts (SMEs)

Sean Shin - Jacob's Engineering Geotechnical Engineer

Stefan Leistner & Patrick Guette - DB-ECO

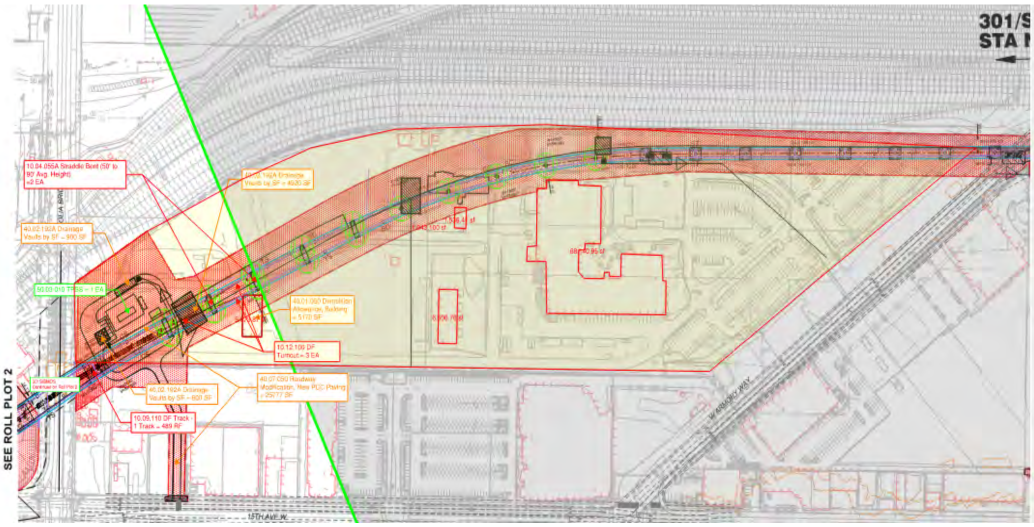
OMF Interbay

Drawings provided by DB-ECO

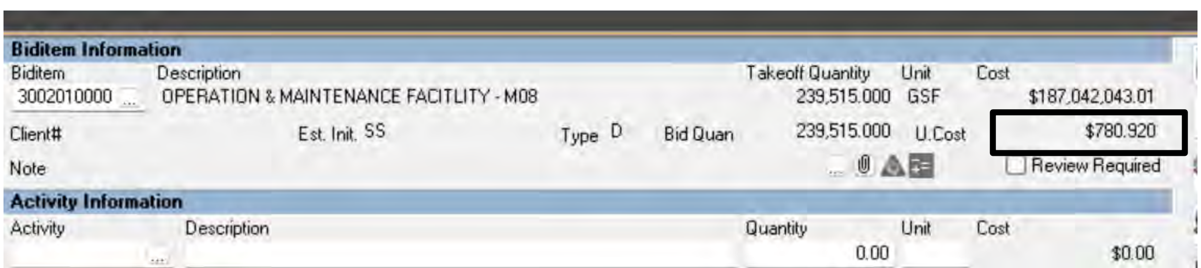


Basis of Estimate

Ballard Link - Interbay Conceptual Plans



OMFS Krebs Estimate



Biditem Information

Biditem	Description	Takeoff Quantity	Unit	Cost
3002010000	OPERATION & MAINTENANCE FACITLITY - M08	239,515.000	GSF	$187,042,043.01

Client#   Est. Init. SS   Type D   Bid Quan 239,515.000   U.Cost $780.920

Note   Review Required

Activity Information

Activity	Description	Quantity	Unit	Cost
		0.00		$0.00

OMFS RFP - Adjustments To Krebs Estimate Based On Information In The OMFS RFP Documents

Examples:

Recent code changes requiring electric only system without gas

More sophisticated cladding system

Allowance for these adjustments assumed to be $50/sf in addition to the Krebs $781/sf estimate for OMFS

OMFS Project Team

- Per Comments from Sean Shin - Jacobs Geotechnical Engineering no contaminates were found around the Western edge of the site based on boring samples. However, consideration for structural suitability of existing soil has been allowed for per Geotech's suggestions.

- Any indication or suspicion of contaminated or hazardous materials at this site? If yes, we'd need to remove them. Would the removal of contaminated or hazardous materials be expected to extend to the same limits as the over-excavation?

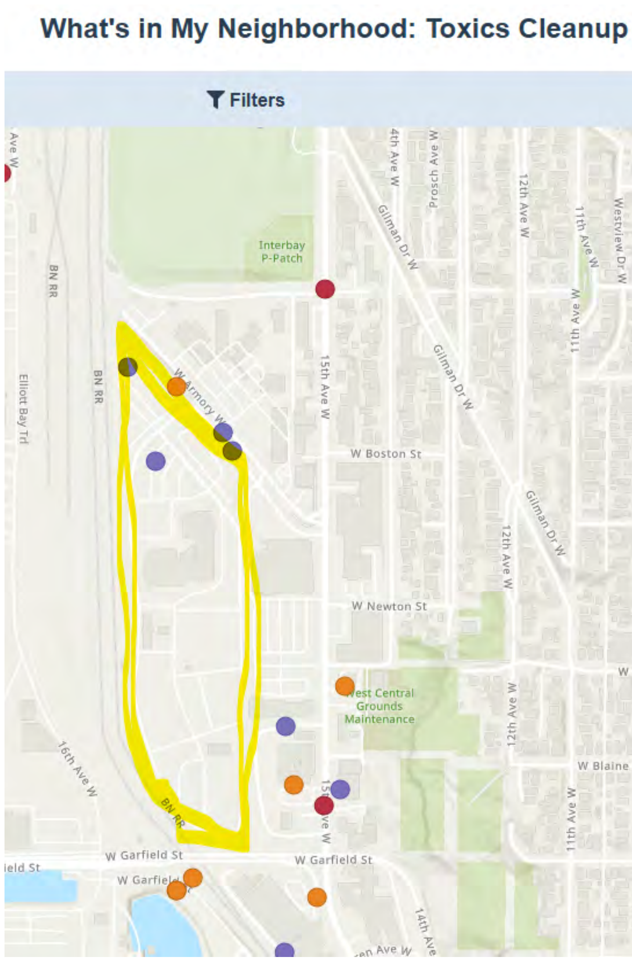
We have drilled several soil borings along the western side of the property (see the screen capture below for the locations). During drilling, we used a PID to screen for potential contaminants. No contaminated soil was encountered. However, given the site's historical use as an armory, there might be a risk of contamination. Additional study will be required to identify potential contaminants

Basis of Estimate

within the property. Regarding the limits for removal of contaminated soils, this needs to be discussed with the environmental team.

However, given the site's historical use as an armory, there might be a risk of contamination. Additional study will be required to identify potential contaminants within the property. Regarding the limits for removal of contaminated soils, this needs to be discussed with the environmental team.

In addition surround site are showing contamination



Basis of Estimate

Assumptions and Clarifications

This estimate is based on the following assumptions and clarifications:

1 Cost estimate is based upon current price levels.
2 There will be small business set aside requirements.
3 The contractor will be required to pay prevailing wages.
4 The general contractor will have full access to the site during normal business hours with the addition of afterhours for disruptive work.
5 GC liability included Bonds and B&O
6 Assume OMF will be under the larger civil contract

Exclusions

This Conceptual Estimate does not provide for the following:

1 Compression of schedule, premium or shift work, and restrictions on the contractor's working hours
2 Environmental impact mitigation
3 Land and easement acquisition
4 Assessments, finance, legal and development charges (impact fees), off site development
5 All enabling works are excluded.
6 Handling and removal of contaminated excavated materials. All excluded.
7 **Feasibility and requirements for the OMF to fit on site is excluded. It is known that current guideway design is elevated. This estimate is based on the conceptual plan relying on guideway to enter and leaving the site at grade. Either elevated or at grade, any guideway is excluded.**
8 Potential change of existing Ballard Link design maybe required. Additional ROW may need to be purchased. Relocation of planned TPSS (shown on the same site as OMF facility) maybe required

Overall Contingency of ~50% of OPCC due to highly conceptual plan

Design Allowance

Contingency of 30% for the undeveloped design details has been included in the summary of this estimate. This allowance is intended to cover the cost of such details and will be decreased as those details are incorporated in the body of the estimate

Unallocated Contingency

Contingency of 15% has been included.

Escalation Allowance

All unit prices are priced to current day and **NO** Escalation has been included. Estimate is in 2025 dollars.

Opinion of Probable Construction Cost

Pricing reflects probable construction costs obtainable in the project locality on the date of this statement of probable costs. This estimate is an opinion of probable construction cost based on fair market value for the construction of this project. It is not a prediction of low bid. Pricing assumes competitive bidding for every portion of the construction work for all subcontractors and general contractors, with a minimum of 4 bidders for all items of subcontracted work and 4-5 general contractor bids. Experience indicates that a fewer number of bidders may result in higher bids, conversely an increased number of bidders may result in more competitive bids.

Basis of Estimate

Since Sound Transit has no control over the cost of labor, material, equipment, or over the contractor's method of determining prices, or over the competitive bidding or market conditions at the time of bid, the statement of probable construction cost is based on industry practice, professional experience and qualifications, and represents Sound Transit's best judgment as professional construction consultant familiar with the construction industry. Sound Transit cannot and does not guarantee that the proposals, bids, or the construction cost will not vary from opinions of probable cost prepared by them. Sound Transit has prepared this opinion of probable construction cost in accordance with generally accepted cost estimating and practices and standards.

Contracting Method

Assumed Design Bid Build

GC/CM or PDB procurement premiums EXCLUDED

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Conceptual Estimate

ST Ballard Link Ext Interbay Site — **December 4, 2025**

OMF Interbay DRAFT

OVERALL SUMMARY SAMPLE TEST STATIONS	Gross Floor Area	Unit Cost $/SF	Total ($x1,000)
OMF Interbay	56,000 SF	1,797.86	100,680,372
OMF Interbay Site and Yard	1,043,000 SF	286.58	298,904,289
Total			399,584,661
Design Allowance	399,584,661	30%	119,875,398
TOTAL Project Cost			**519,460,060**
AGENCY ADMINISTRATION		5%	31,011,766
PRELIM ENGINEERING/ENV REVIEW		3%	15,064,342
FINAL DESIGN+SPECIFICATIONS		7%	33,764,904
ROW ACQUISITION			Excluded
PERMITS		1%	2,597,300
CONSTRUCTION			Ref. Above
CONSTRUCTION SERVICES		8%	41,556,805
THIRD PARTY		2%	7,791,901
VEHICLES			Excluded
UNALLOCATED CONTINGENCY		15%	77,919,009
TOTAL PROJECT COST SUMMARY			**729,166,086**

Item Description	Quantity	Unit	Rate	Totals
OMF Interbay				
OMF building, cost per OMFS Krebs Estimate	56,000	SF	780.92	43,731,520
Adjustment allowance based on code and OMFS design requirements	56,000	SF	50.00	2,800,000
Cost adjustment for size	43,731,520	%	0.35	15,306,032
Allow for pile caps	56,000	SF	4.00	224,000
Adjust for piles, assume 4 piles at 30' grid, 18" steel 100ft deep	33,600	LF	200.00	6,720,000
Seattle/Interbay premium, location, tax, etc.	61,837,552	%	0.10	6,183,755
				74,965,307
Markup Per Percentage of Krebs OMFS Estimate				
Commercial costs	74,965,307	%	5.04%	3,775,212
Job related overhead	74,965,307	%	4.80%	3,596,009
Operational and compliance support	74,965,307	%	2.08%	1,560,461
Professional engineering	74,965,307	%	0.11%	81,151
Safety and security	74,965,307	%	0.66%	493,786
Quality control	74,965,307	%	1.26%	943,023
Temporary facilities	74,965,307	%	1.15%	858,796
Field engineering	74,965,307	%	0.49%	366,555
Escalation	74,965,307	%		Excluded
Scope growth	74,965,307	%		Excluded
Design	74,965,307	%		Excluded
Contractor markups	74,965,307	%	18.73%	14,040,074
Subtotal Per Station				**100,680,372**

Item Description	Quantity	Unit	Rate	Totals
OMF Interbay Site and Yard				
OMF Interbay Site and Yard, cost per Krebs OMFS estimate	1,043,000	SF	66.00	68,838,000
Allow for surface ground improvements - *over-excavate approximately ~ 4 feet. Install a high-strength geotextile layer, followed by about ~ 2 feet of gravel beneath the track sub-ballast. For OMF building, over-excavate approximately 1 ~ 2 feet.*	1,043,000	SF	25.00	26,075,000
OMF Interbay Site Demo	1,043,000	SF	2.54	2,647,280
OMF Interbay Site Utilities, OMFS	1	LS	24,000,000.00	24,000,000
Temp facilities, per OMFS	1	LS	9,000,000.00	9,000,000
Train control	1	LS	32,500,000.00	32,500,000
Traction Power	1	LS	22,000,000.00	22,000,000
OCS	1	LS	20,500,000.00	20,500,000
Communications	1	LS	8,000,000.00	8,000,000
Spare parts	1	LS	9,000,000.00	9,000,000
				222,560,280
Markup Per Percentage of Krebs OMFS Estimate				
Commercial costs	222,560,280	%	5.04%	11,208,014
Job related overhead	222,560,280	%	4.80%	10,675,988
Operational and compliance support	222,560,280	%	2.08%	4,632,766
Professional engineering	222,560,280	%	0.11%	240,923
Safety and security	222,560,280	%	0.66%	1,465,973
Quality control	222,560,280	%	1.26%	2,799,687
Temporary facilities	222,560,280	%	1.15%	2,549,630
Field engineering	222,560,280	%	0.49%	1,088,244
Escalation	222,560,280	%		Excluded
Scope growth	222,560,280	%		Excluded
Design	222,560,280	%		Excluded
Contractor markups	222,560,280	%	18.73%	41,682,784
Subtotal				**298,904,289**

Ballard Link Extension Concept: Assessment of potential OMF-Interbay

Fit test and conceptual layout

November 2025 | Seattle

Executive Summary: Isolated OMF-Interbay is feasible at the selected location - basic functions recommended to limit O&M inefficiencies

Fit test:

Available Space:	Minimal Build-Out:	Full Build-Out:
		
13 acres	7.3 acres	10 acres

Key takeaways:

Fleet: 40 vehicles are sufficient to operate the isolated BLE

Yard: Only 40 LRV parking spaces necessary; LRVs at the workshop enabling smooth train movements within the yard

OMF: Minimal maintenance facility requires at least 2 S/I pits, 1 deep cleaning track and 1 vehicle wash, to sustain day-to-day operations

Recommendations:

OMF space need: Maximum need of 10 acres, fits within proposed site

Systemwide view: Built a minimal OMF and connect the 5 line to the main network in the future to enable overhauls of LRVs at another OMF

Temporary solution: Transport parts for repairs and overhauls by truck to bridge heavy maintenance needs in the meantime

Flexible equipment: Plan for adaptable 190ft equipment to remain future-proof for longer vehicles

Impacts & Next steps:

Fleet maintenance expected to be **heavily underutilized** in both build-outs, with average equipment utilization below 50%

Additional ~$15M labor costs annually for the **full build-out** scenario and increased effort to **hire** and train future **staff** in a **competitive, scarce labor market**

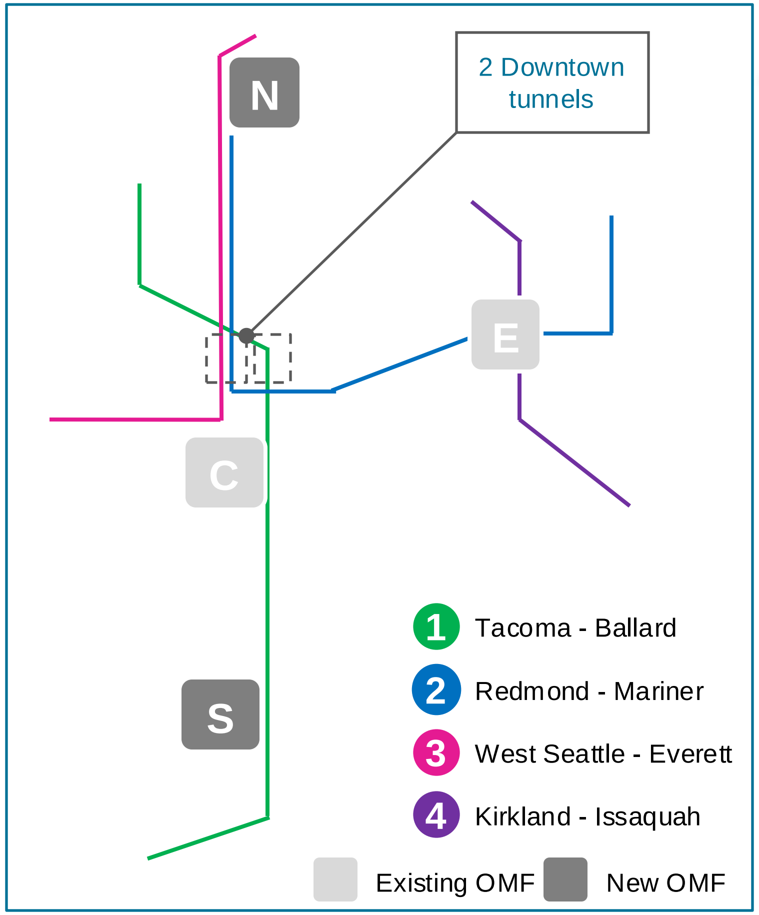
Calculate a **dedicated business case** for an isolated BLE ConOps to determine the CapEx threshold for a minimal OMF-I, based on the outlined minimum requirements

Exclude opportunity costs related to potential savings from avoiding a **second DSTT** as these are not part of the 5 line

The alternative Link structure creates a new isolated 5 Line to Ballard and by this eliminates the need for a second downtown tunnel

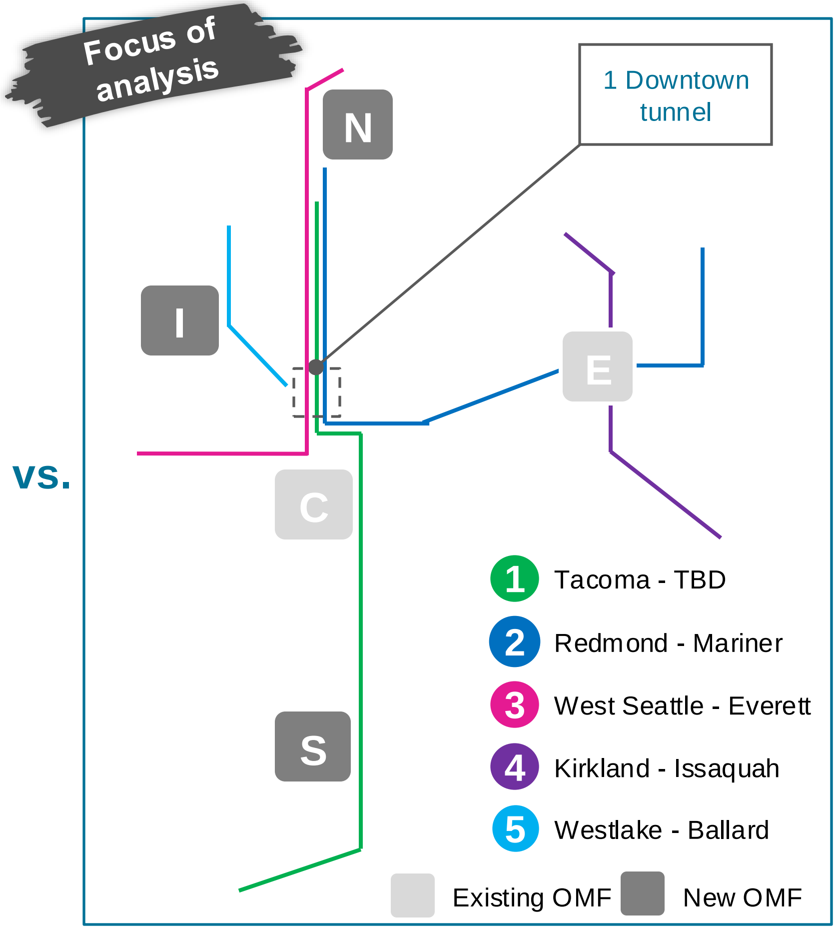
SOUNDTRANSIT

Future Link System as planned (2044)



vs.

Alternative Link Scenario (2044)



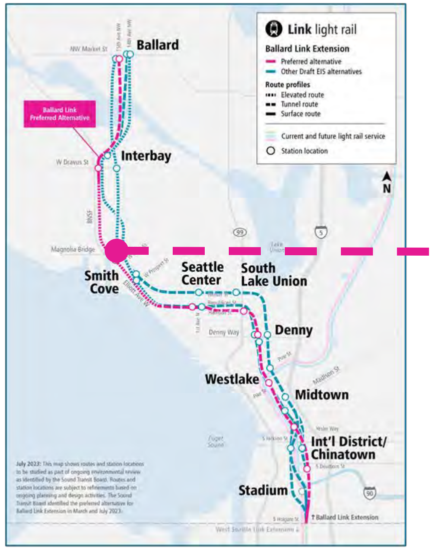
Key facts of alternative scenario

- **Additional isolated line**: Independent corridor from a new Westlake station to Ballard downtown served by 5 line
- **Length & Stations of BLE:** ~5.3 miles[1] with 6 new stations and extend to Westlake station
- **Link downtown tunnel(s):** No second DSTT required to connect Ballard extension to mainline
- **West Seattle:** Extension from SoDo to Alaska Junction built as planned
- **Future Link line structure:** 5 lines
  - 1 *Line:* Tacoma – North Seattle *(TBD)*
  - 2 *Line:* Unchanged
  - 3 *Line:* Unchanged
  - 4 *Line:* Unchanged
  - 5 *Line*: Isolated Ballard extension

(1) The planned extension length is ~7.7 miles from SoDo - excluding the Downtown tunnel section skips approx. 1.5 miles of the total length

Our task is to determine the fleet maintenance needs of an isolated Ballard extension and test the fit of a proposed space at Interbay

Area being considered for OMF – Interbay, Total size ~13 acre



Analysis Process

Simulate operations

- Calculate mileages for service[1]
- Calculate total vehicle need based on min. spare ratio[2]
- Determine yard space needs

Model maintenance needs

- Model maintenance & overhaul capacity needs for fleet
- Estimate other spaces and storage needs

Fit test

- Allocate space needs to available space
- Account for sufficient clearance and pathways

(1) Based on planned 6 min headways (2) Minimum spare ratio of 20% required according to ST operational planning

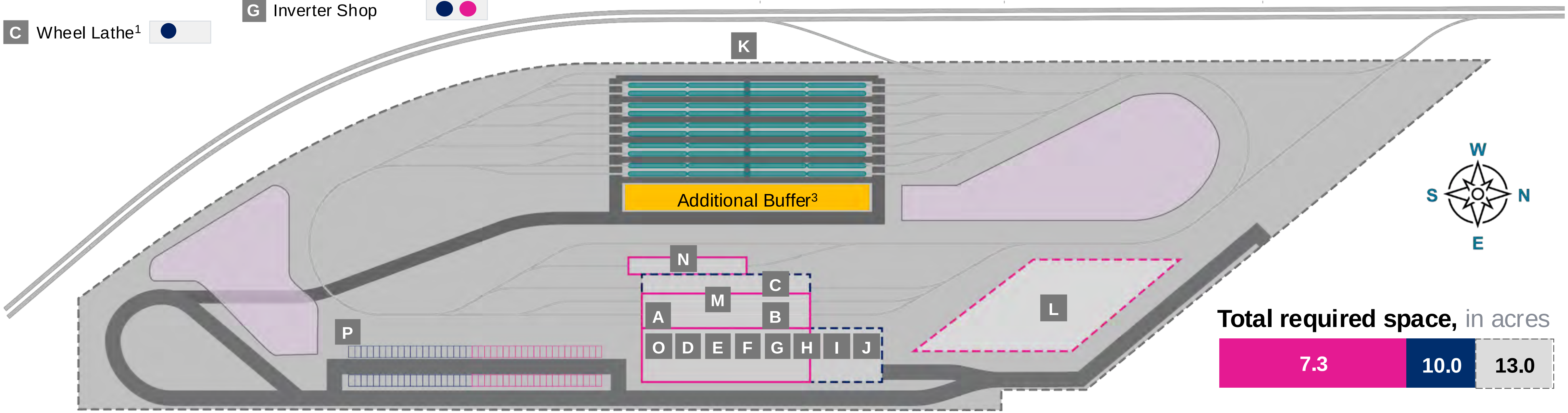
OMF-I fit test: Both scenarios fit within the proposed 13-acre parcel, with differences in space, build-out, and resource needs

SOUNDTRANSIT

Illustrative sketch - Not exact scale

Layout including maintenance infrastructure needs in specified site

			Full Build-out	Minimal Build-out
Maintenance & Overhaul	A	Overhaul & Lifts (HM)[1]	●	
Maintenance & Overhaul	B	S/I Pits (PM)[2]	●	●
Wheel truing & Repairs	C	Wheel Lathe[1]	●	
Workshop Space	D	Truck Shop	●	●
Workshop Space	E	HVAC/Panto Shop	●	●
Workshop Space	F	Brake & Coupler Shop	●	●
Workshop Space	G	Inverter Shop	●	●
Workshop Space	H	Electronics Shop	●	●
Workshop Space	I	Welding Shop	●	●
Workshop Space	J	Inverter Shop	●	●
Operations	K	LRV Storage	●	●
Operations	L	MoW Storage	●	●
Cleaning services	M	Deep Cleaning	●	●
Cleaning services	N	Exterior Wash	●	●
Administrative	O	Administrative offices	●	●
Administrative	P	Employee Parking	●	●



● Full Build-out ● Minimal Build-out

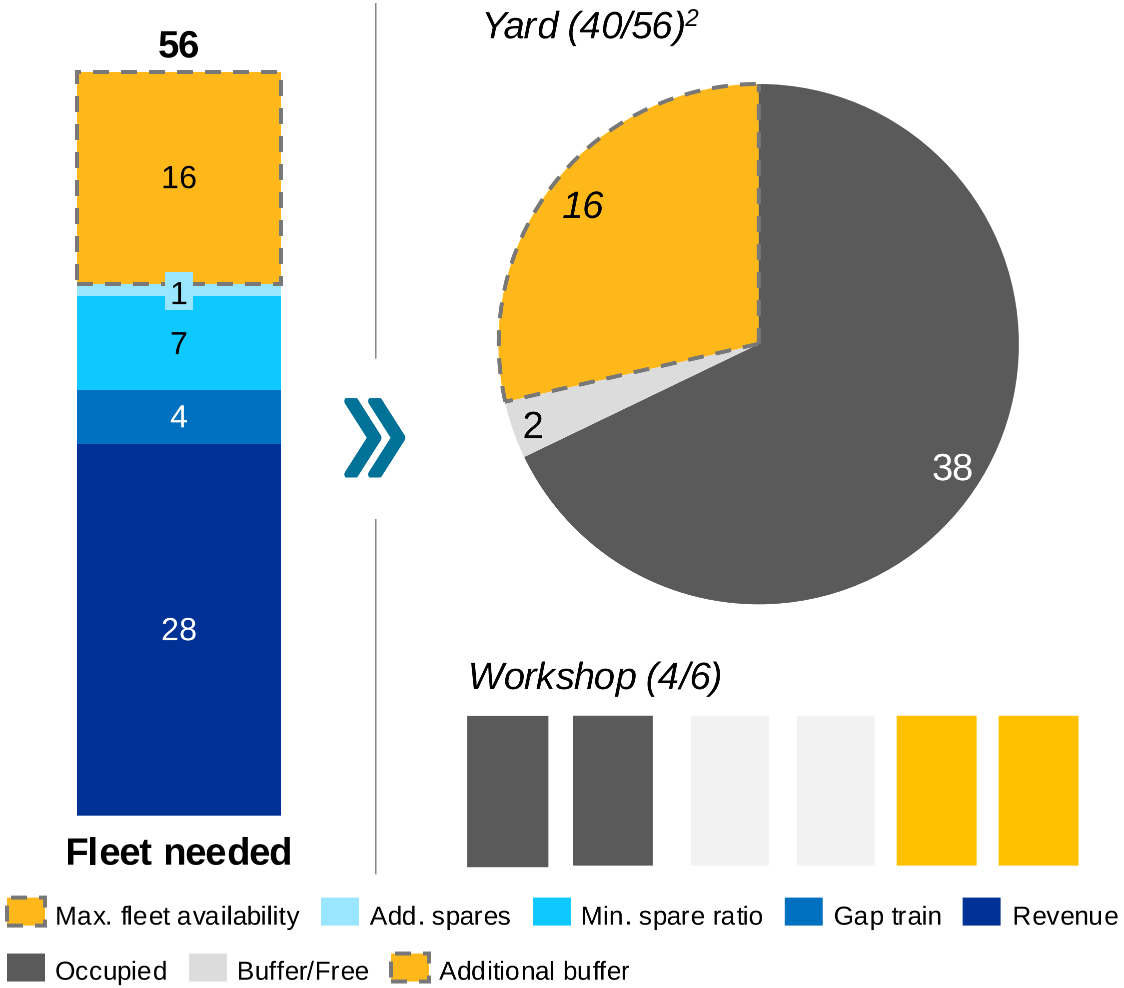
Minimal build-out Full build-out Max. available space

(1) Mobile lifts would be used to lift trucks in a minimal buildout scenario (2) Long pits are recommended in either scenario for vehicle type flexibility (3) Additional space for up to 56 LRVs

40 vehicles are sufficient to operate the isolated Ballard extension; Yard capacity of up to 56 spaces can accommodate additional vehicles

SOUNDTRANSIT

Fleet and LRV storage needs[1], in 95ft equivalents



Operational simulation takeaways

- **Revenue service** requires 28 vehicles (7 trains)
- **Gap train** ensures operational resilience with 4 vehicles (one train skip at Ballard terminus to stabilize service at 6-minute headways)
- **Minimum spares** of 7 needed (20%); 8 available, achieving 24%
- **Additional vehicles** (15) from proposed total of up to 55 not required and recommended for reliable service
- **Up to 56 parking spaces** feasible; recommendation is 40 to match fleet needs, with workshop-positioned LRVs providing buffer for smooth train yard movements

Min. built-out storage & lay-down yard needs[3]:

~124,000 sf

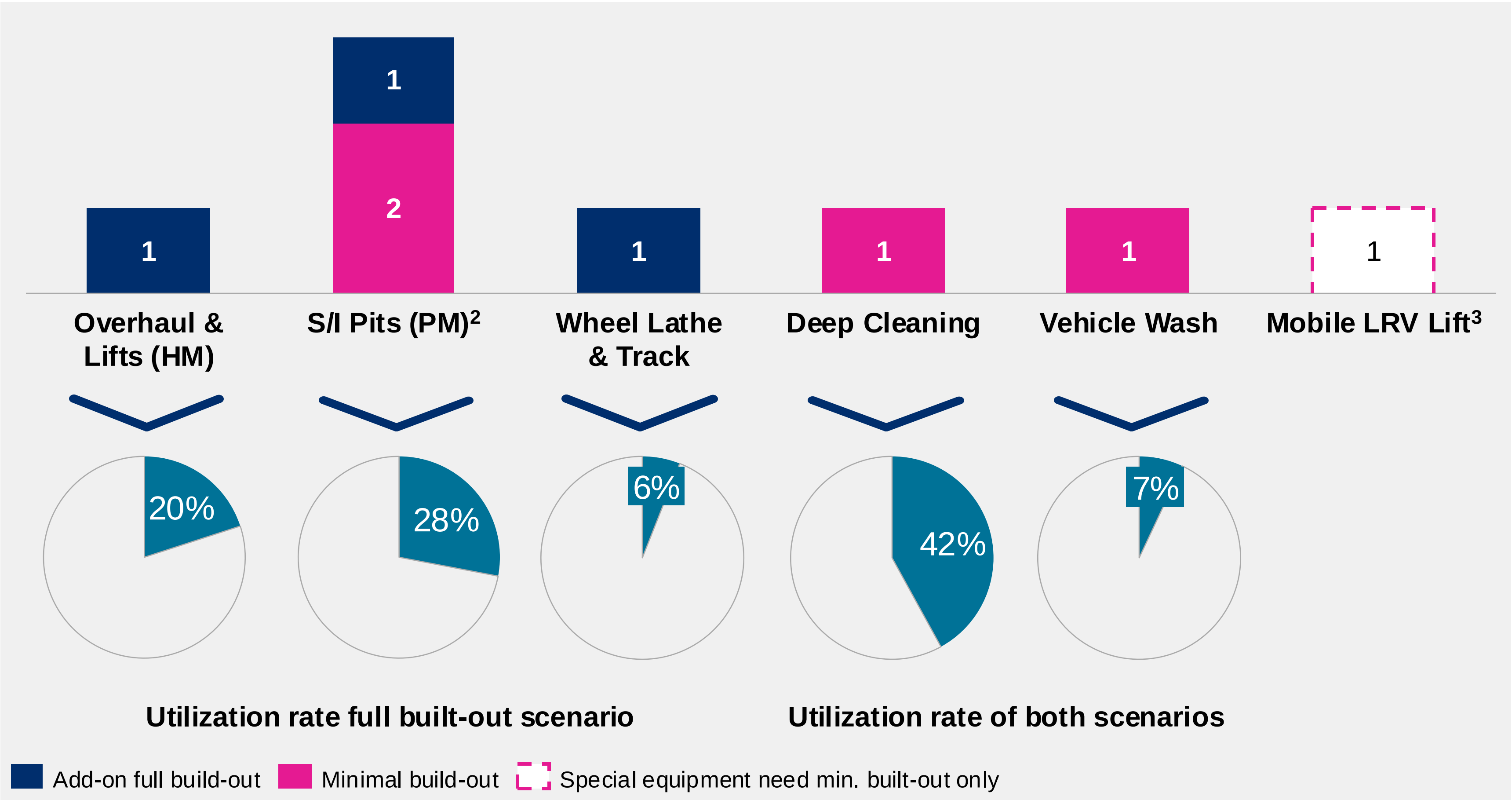
Full built-out storage & lay-down yard needs[3] :

~157,600 sf

(1) Given 6-minute headways
(2) Yard and workshop sizes related to scenario and max. fleet allocated to BLE
(3) Size includes 40,000 sf buffer lay-down yard for MoW parts

A full build-out workshop requires ~50% more space than preventive maintenance, yet equipment utilization remains below 50% in both scenarios

Service & Maintenance equipment[1], in 95ft



Assumptions

- **Minimal scenario:** Preventive maintenance incl. daily inspections, minor repairs, and exchanges onsite; overhaul parts trucked to larger OMFs
- **Minimal build-out only:** Mobile lift recommended for truck exchanges, usable on extended deep-cleaning track in place of wheel lathe
- **Full build-out:** Overhauls, extensive repairs, and wheel truing performed onsite

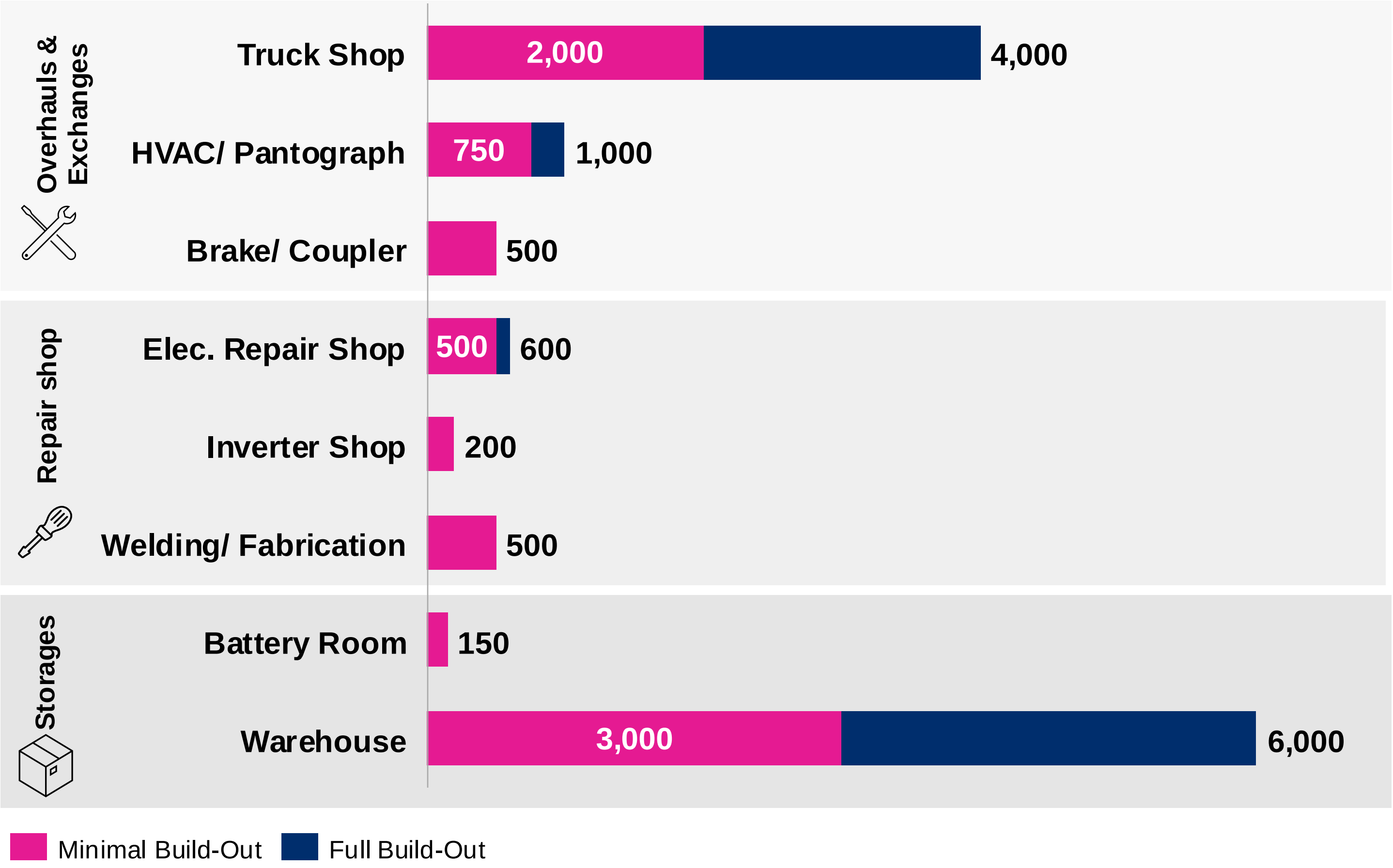
Min. build-out workshop: **~20,700 sf**

Full build-out workshop: **~33,200 sf**

(1) Equipment for OMF-I only, optimized for 95ft vehicles, harmonized maintenance program applied, min. of 20% rounding buffers per equipment
(2) Full built-out includes one S/I pit buffer for commissioning/OEM and projects (3) Recommended - No additional space need to be placed at extended deep cleaning track (Min. build-out only)

A full build-out requires ~80% more footprint for shops and storages, driven mainly by truck overhaul needs and added material storage

Maintenance & Repair shop space needs, in sf (1st and 2nd floor)



Assumptions

- **Overhauls & Exchanges:** Minimal build-out accounts for spares storage and minor repair workstations; Full build-out with expanded workspace and storage
- **Repair Shops:** Minimum space for tools, machinery, and repair stations; Requirements similar for full overhauls vs. preventive/minor repairs
- **Storages:** Minimum battery room sized for storage, charging, and safety equipment; Warehouse expansion in full build-out for added materials; Freight lift and cranes recommended for 2nd-floor storage and mezzanine access for both build-out scenarios

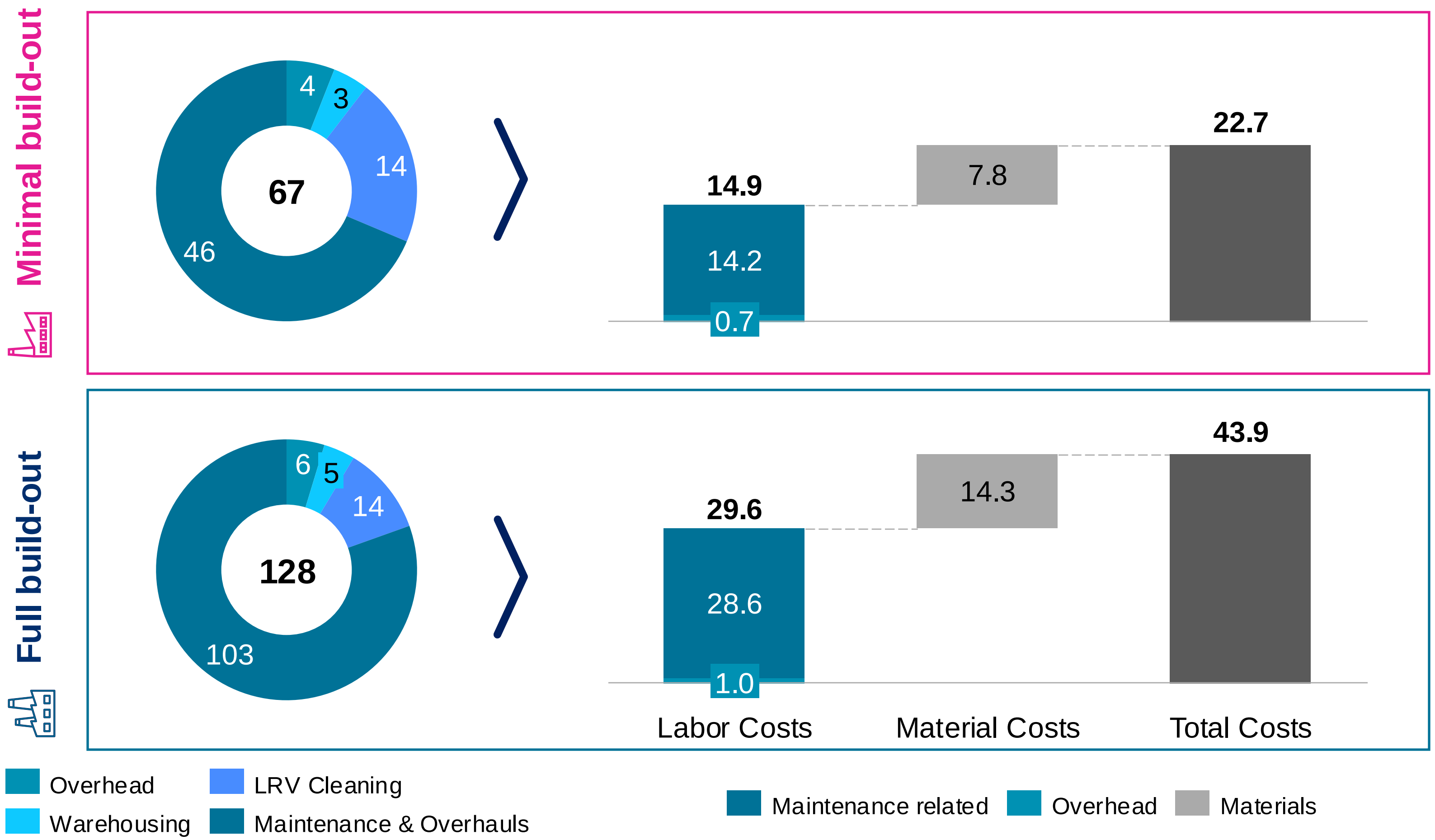
Min. build-out shop footprint[1]:
~6,100 sf

Full build-out shop footprint[1]:
~10,500 sf

(1) Indicated footprint includes spaces on 1st floor only: 25% of warehouse and HVAC/Pantograph area to be assumed on 2nd floor/mezzanine level

Full build-out requires double the staffing to perform onsite overhauls and repairs, driving an almost doubled annual maintenance budget

FTE requirements, # | **OMF-I maintenance costs per year[1], in $M** | **Assumptions**



- **Maintenance FTE requirements** based on current shift targets and pit-to-FTE ratios; includes superintendents, chiefs, and team leads
- **Warehousing** based on needed MSC employees for warehouse management, operating across two shifts
- **Overhead staffing** equal to 10% of other staff needs for one day shift
- **Operational materials need** assumed at 33% share of total costs, consistent with Sound Transit and peer systems (30–40%)

Min. build-out admin & add-on spaces[2]: **~22,100 sf**

Full build-out admin & add-on spaces[2]: **~40,200 sf**

(1) Direct costs based on 2023 King County data (median/average); Labor costs projected to 2039 with 3.18% YoY wage inflation
(2) Includes space for offices, break room; meeting, training, locker, uniforms, tools and outdoor space such as parking for staff, NRVs, visitors; Number incl. 1st-floor footprint only

OMF-I scenarios: Both options fit within proposed footprint even after accounting for add-ons such as roadways, tracks, and buffer

Minimal build-out with trucking alternative for heavy maintenance

Facility equipped for light maintenance service (preventive, inspections, washing); Overhauls centralized elsewhere, trains and parts to be transported

Benefits

- ☑ Lower capital spending required, especially on maintenance infrastructure with low utilization rates
- ☑ Lower maintenance labor need
- ☑ Improved flexibility for vehicle model

Drawbacks

- ☒ Low utilization of most equipment and labor
- ☒ Requires urban trucking of components for overhauls and repairs
- ☒ Limited flexibility for unexpected vehicle failures requiring heavy maintenance

Full build-out with heavy maintenance performed on site

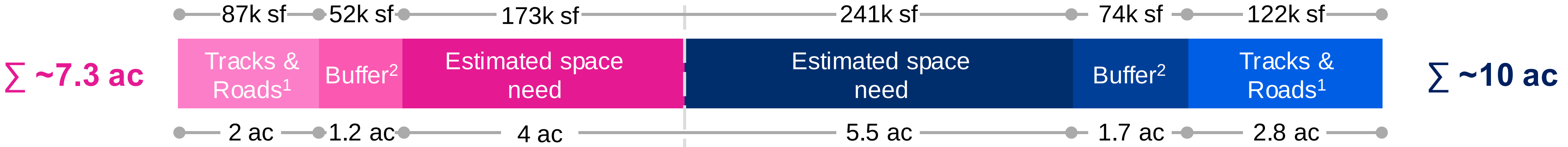
Facility equipped for preventive maintenance, inspections, washing, and most overhauls/repairs onsite

Benefits

- ☑ Capacity to perform all required maintenance on-site without trucking
- ☑ Higher system reliability and redundancy

Drawbacks

- ☒ Very low utilization of most equipment and labor
- ☒ Higher capital expense and inefficient redundancy
- ☒ Requires higher total FTEs



(1) Track and road space estimated based on "Estimated space need" including a 50% contingency margin
(2) Accounted for an additional 30% buffer beyond "Estimated space need" to include pathways, clearances, and landscaping

An isolated 5 Line would forfeit overhaul centralization, reduce operational flexibility, and limit passenger experience

SoundTransit

Our recommendation

Decision

In the case of an isolated BLE, a minimal build-out OMF at the Interbay location would be recommended

Reasoning

A minimal build-out uses resources slightly more efficiently, leverages available heavy-maintenance capacity at other OMFs, and delivers savings in capital and operating expenditures

Impact of an isolated BLE and minimal build-out scenario

Low Efficiency & Centralization	Operational Inflexibility	Reduced Ridership
Building OMF-I to operate an isolated small fleet reduces the benefits of prior centralization and lowers equipment utilization	Reliance on external OMFs may create inflexibility in heavy maintenance and reduce LRV availability due to repair backlogs	A forced transfer at Westlake station would reduce initially estimated ridership and revenue

Evaluating alternatives to avoid a new maintenance facility requires a dedicated business case that captures the full costs of an isolated BLE

SOUNDTRANSIT

Alternative solutions to isolating BLE

Due to the shortcomings from isolating the Ballard extension, we suggest exploring alternatives which eliminate the need for an additional maintenance facility

Avoiding an isolated new line and instead evaluating options to connect the Ballard Link Extension to existing lines

A Connect 5 line to the existing DSTT without constructing a second tunnel or creating crossings; Service vehicles at OMF-C/S

B Extending the 5 line toward north to connect to existing 1/2 line and planning for sufficient capacity at OMF-N

Next steps and additional analyses

- **Conduct a ridership analysis for the isolated BLE and the remaining system to assess impacts on planned passenger numbers**
- **Calculate an isolated business case[1] based on an isolated 5 Line including revenues. Use estimate to identity target costs of OMF-I**
- **If necessary:** Resize fleet need for the entire system based on chosen Interbay scenario
- **If necessary:** Resize planned new OMFs (S/N) based on targeted scenario and new capacity requirements

(1) Excluding impacts from/on other parts of the network like Capex savings for second DSTT

Backup

Similar base assumptions as from ConMaint LRV being taken into consideration to estimate vehicle maintenance needs for BLE

SOUNDTRANSIT

Assumptions for “Fit Test”

Vehicle spare ratio • Minimum target ratio of additional vehicles needed to ensure reliable service	**>20%**
Maintenance program • Harmonized program set as standard for calculations • S3 maintenance hours are derived from S2, scaled by a factor of two (x2)	**HP**
Repair ratio • Share of labor hours spent on corrective maintenance relative to planed maintenance labor hours	**46%**
Efficiency factor • Factor for time per workorder needed relative to originally estimated time (based on harmonized maintenance program) • Allows to model process or technology improvements	**100%**
Pit utilization • Ratio of productive working time at the pit (wrench time) relative to the total time available per FTE per shift	**70%**

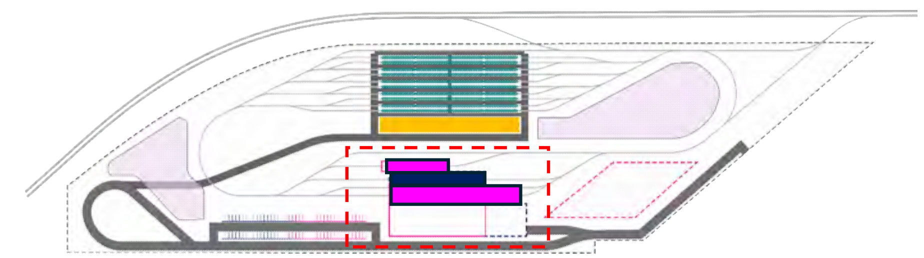
Shift model • Shift system based on ST targets: 2 shifts for LRV cleaning, Overhauls and MSC warehousing staff / 3 shifts for Preventive Maintenance / 1 Shift for Overhead and Admin FTEs	**Current Shift Models**
Washing intervals • Interval of light interior cleaning, exterior vehicle cleaning (vehicle wash) and deep vehicle cleaning	**Exterior:** 14 Days **Interior:** 30 Days
Train specifications • Vehicle and train configuration in terms of vehicle and train length	**S1 & S2:** 95ft cars, 4 cars per train
Train operations • Isolated fleet 5 line dedicated to specific OMF-I • Interchanging fleets operate across connected lines and OMFs at the remaining Link system	**Line isolated**
FTE ratios • Number of technicians working in parallel on one vehicle or component by type of maintenance work	**Inspection:** 1-2 FTE **Heavy Maint:** 2-3 FTE

Estimates by DB ECO
Author: Patrick Guette *Date: 11/25/25*

Maintenance Equipment needs - OMF-I

Scenario *Based on ConMaint LRV assumptions*

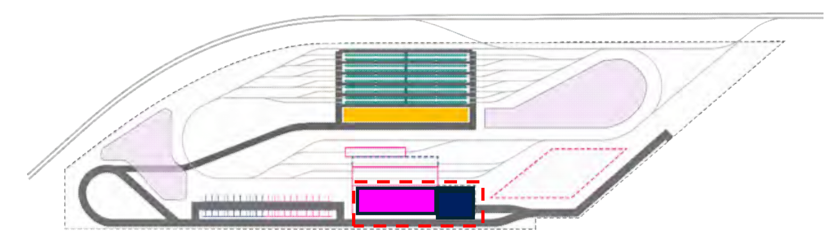
Part of	Item	Min. built-out	Full built-out	Notes
OMF	**Overhaul/Lifts**	0	1	*Only needed for heavy maintenance/Overhauls*
OMF	**S/I Pits**	2	3	*Full built-out with additional OEM/Commissioning/Project Pit*
OMF	**Wheel lathe**	0	1	*Locate next to flat-floor deep cleaning track and LRV lift*
OMF	**Deep Cleaning track**	1	1	*Extend track to full OMF length for Min. built out to use space for mobile LRV lift*
OMF	**Vehicle Wash**	1	1	*Separate building adjacent to Main OMF - 110ft Exterior Wash + Pre-wash track*
OMF	**Mobile LRV Lift**	1	0	*To exchange trucks; placed at extended deep cleaning track (2nd track)*
OMF	**Total track need within OMF**	2	3	*Each track accomodates two 95ft long equipments/items*

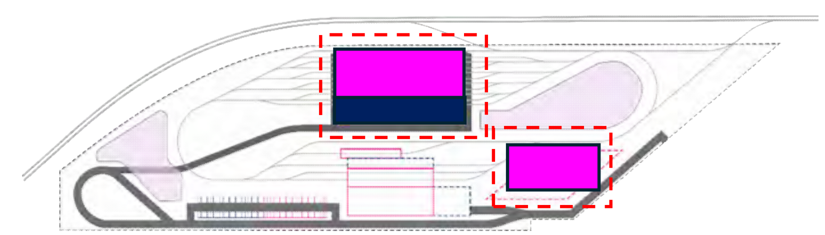


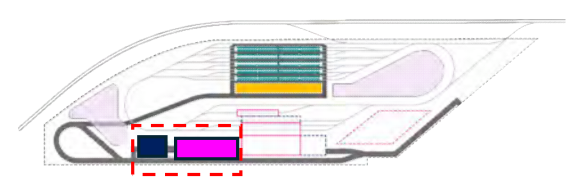
Size need of OMF-I in squarefoot

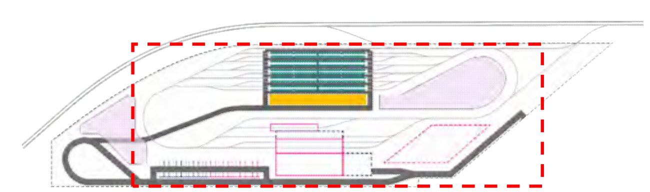
Scenario

Part of	Item	Min. built-out	Full built-out	Notes
OMF	**Maintenance Workshop (1st)**	20,700	33,200	*Everything placed on 1st floor; Equipment and Cranes to be included into space w/o HVAC/Pantograph area (750-1000sf) and 25% of Warehouse space (750 - 1500sf) - both placed on 2nd/Mezzanine level*
OMF	**Storage & Shops (1st)**	6,100	10,500	
OMF	**Admin & Offices (1st)**	2,900	5,700	*40% of total space need placed on 2nd floor; incl. space for Offices, meeting, training, break, tools, lockers, uniform*
OMF	*Storage, Mezzanie, Offices (2nd level)*	*3,400*	*6,100*	*Not relevant for facility footprint - assumed to be on 2nd/mezzanine level*
Yard	**LRV parking**	84,000	117,600	*Min. built-out for 40 LRVs with 10 tracks; full built-out estimated for 56 LRVs with 14 tracks*
Yard	**MoW lay-down yard**	40,000	40,000	*Storing large equipment and spares for MoW and equipment/NR-vehicles to ensure 15min response time at BLE*
Parking	**Staff/NRV Parking**	19,200	34,600	*Min. built-out estimated for 40 parking spots; Full built-out for 72 parking spots (covers one full shift + NRVs + 5-10 Visitor parking)*
	Total Estimated footprint in sf	**172,900**	**241,600**	*Without clearance, tracks and roads*
	in acre	4.0	5.5	*1 acre = 43,560 sf*
	Buffer (Clearance)	1.2	1.7	*+30% of estimated space need for clearance, pathways, landscaping*
	Tracks & Roads	2.0	2.8	*+50% of estimated space need for tracks and supporting roads*
	Total estimated footprint	**7.1**	**10.0**	









APPENDIX D

Interlined Transit Rail Systems Case Study Memo

Interlined Transit Rail Systems Case Studies Memo

1. Introduction

Sound Transit's Link Light Rail system is entering a period of rapid expansion and transformation, driven by ambitious regional growth, increasing ridership, and the need for enhanced operational reliability. As the network extends and service frequencies rise, the limitations of existing infrastructure, particularly the Downtown Seattle Transit Tunnel and associated signaling systems have become increasingly apparent.

This report focuses on the Ballard Link Extension, a major upcoming project that will further expand the reach and capacity of the Link Light Rail network. The Ballard Link Extension presents both an opportunity and a challenge: it will serve new corridors and riders, but also requires careful consideration of system resiliency, capacity, and long-term sustainability.

To address these challenges and futureproof the system, Sound Transit is evaluating the adoption of Communications-Based Train Control (CBTC), a proven technology that enables higher capacity, shorter headways, improved safety, and faster recovery from service disruptions. The decision between continuing to operate a single tunnel with upgraded CBTC or investing in a new tunnel for the Ballard Link Extension is critical, with far-reaching implications for system performance, cost, and regional mobility.

This report synthesizes the findings of CBTC Feasibility Studies, peer agency lessons, and operational forecasts to provide Sound Transit decision-makers with a clear comparison of the pros and cons of each approach. It highlights the technical, regulatory, and organizational factors that must be considered to maximize the benefits of CBTC, ensure reliable service for future ridership, and support the region's mobility goals as the Ballard Link Extension moves forward.

Table 1 - System Comparison Table

#	Transit System	City	Country	Fully segregated sections	Semi-segregated sections	Mixed use sections	Max. number of lines interlining	Min. headway	(New) Train Control Technology	Interlining in tunnel	Remarks (Staging stations)	Grade of automation	Tunnel Vent. concepts
0	Sound Transit	Seattle	USA	X	X		3	170 sec	MicroCab	Possibly		GoA1	NFPA 130
1	Skytrain	Vancouver	Canada	X	-	-	2	75 sec	CBTC			GoA4	NFPA 130
2	ETS	Edmonton	Canada	X	X		2	15 mins	Wayside +ATP			GoA1	NFPA 130
3	BART	San Francisco	USA	X			4		CBTC				NFPA 130
4	GVB	Amsterdam	The Netherlands	X			3	3 min.	CBTC	YES	Dead-end terminal station in tunnel	GoA2	Safe Haven (Train cannot leave until next station is free)
5	RET	Rotterdam	The Netherlands	X	X		3	3 min.	PZB222 and ATP (cab signalling)	YES		GoA1	No restrictions
6	WMATA	Washington DC	USA	X			3		ATC + ATO + ATS	YES		GoA2	NFPA 130
7	B-Division	New York	USA	X			4		CBTC	YES			
8	Sub-surface lines	London	UK	X			3	90 sec	CBTC	YES			
9	SFMTA	San Francisco	USA	X	X	X	5		ATCS. TCUP: CBTC (2032)				NFPA 130
10	Green Line	Boston	USA	X	X	X	4 (branches)		AVI	YES			NFPA 130
11	U-Bahn	Frankfurt	Germany	X	X	X	4		DTCS (=CBTC + C-ITS)			GoA 2	BOStrab / EN45545
12	S-Bahn	Stuttgart	Germany	X	-	-	7	150 sec	Wayside/ new: ETCS L2 + ATO	YES		GoA 1 (wayside) GoA 2 (ETCS L2)	EBO / SRT / NFPA 130

#	Transit System	City	Country	Fully segregated sections	Semi-segregated sections	Mixed use sections	Max. number of lines interlining	Min. headway	(New) Train Control Technology	Interlining in tunnel	Remarks (Staging stations)	Grade of automation	Tunnel Vent. concepts
13	Line 3 and 4	Shanghai	China	X			2		CBTC				CDM (using NFPA 130 criteria)
14	S-Train	Copenhagen	Denmark	X	X		6		CBTC			GoA 2, GoA 4 (2033)	NFPA 130 / BOStrab
15	Metro Line 3 and 4	Copenhagen	Denmark	X			2		CBTC + ATS			GoA4	NFPA 130 / BOStrab

2. Case Study Systems

The authors contacted a selection of peer transit agencies including San Francisco Muni, New York City Transit, London Underground, and Stuttgart to ask a series of targeted operational questions. These agencies were chosen because they represent a diverse range of urban rail environments, have direct experience with interlining, tunnel operations, and CBTC implementation, and face challenges like those anticipated for the Ballard Link Extension. The insights gathered from these agencies provide valuable real-world perspectives on the operational impacts of interlining, the benefits and challenges of adding a second tunnel, and the practical effects of advanced train control systems.

This report synthesizes the findings from these peer agency interviews to provide Sound Transit decision-makers with a clear comparison of the pros and cons of each approach. It highlights the technical, regulatory, and organizational factors that must be considered to maximize the benefits of CBTC, ensure reliable service for future ridership, and support the region's mobility goals as the Ballard Link Extension moves forward.

2.1 Case Study 1: Vancouver's SkyTrain

2.1.1 Context and Summary

Vancouver's SkyTrain is a high-capacity, automated rapid transit system serving the Metro Vancouver, British Columbia region. This system is a backbone of public transportation in the area, characterized by advanced train control technologies and frequent service. It is two separate systems, The Canada Line is operated and maintained by a private consortium. The other lines are operated and maintained by BCRTC, owned by TransLink, and consists of primarily a trunk line system, with some parallel high-capacity transit corridors and integration points with other regional transit modes.

While parts of the system are legacy (especially the loop based antennas), much of the infrastructure and technology have been modernized or constructed in recent decades. Unique constraints include the integration of legacy moving block train signaling with modern systems, as well as specific operational enhancements such as axle counters and advanced CBTC deployment.

2.1.2 Ventilation and Electrical Systems

- Vent Zones: Ventilation is managed to ensure safe separation between trains, especially in underground sections, supporting operational safety and reliability.
- Electrical Capacity and Redundancy: The electrical system is designed to support frequent, high-capacity service, with built-in redundancy to minimize disruptions and ensure continuous operations.

2.1.3 Train Signaling & Line Capacity

- Signal System Technology: SkyTrain uses Communications-Based Train Control (CBTC) on all lines and in depots, enabling short headways (as low as 75 seconds) and high service frequency. There is no secondary detection. Axle counters are currently considered for secondary detection. The systems doesn't use platform screen doors.
- Capacity and Modernization: The base headway is typically around 2 minutes, though service patterns may adjust this to 4 or 6 minutes. There are ongoing plans and considerations for further train control modernization and possible network expansion, such as new parallel lines or tunnels.

2.1.4 Service Delivery & Operations

- Service Plan and Network Layout: The SkyTrain's service plan is built around frequent, reliable service on dedicated tracks, with design elements supporting rapid egress and station access. The network includes redundancy through parallel transit routes and integration with other transportation systems.
- Station Operations: Stations are designed for efficient passenger flow, with attention to access, egress, and safety.
- Contingencies: Operational plans include contingencies for service disruptions, leveraging network integration with a robust local bus system to maintain reliability.

2.1.5 Key Takeaways

Feature	Description
System Design	• High-capacity, automated rapid transit backbone for Metro Vancouver, with a trunk line structure and parallel high-capacity corridors. Integration points exist with other local or

Feature	Description
	regional transit modes, notably at interlined segments between the Expo and Millennium Lines.
Train Signaling	• Advanced Communications-Based Train Control (CBTC) technology deployed on most lines, supporting short headways (as low as 75 seconds). • Some sections operate with legacy axle counters, highlighting integration challenges between old and new signaling systems.
Track Infrastructure	• Dedicated tracks for frequent, reliable service; trunk line configuration with parallel transit routes provides redundancy and supports rapid egress and station access.
Electrical & Ventilation	• Electrical system designed for high-capacity, frequent service, incorporating redundancy to minimize disruptions. Ventilation zones ensure safe train separation and operational reliability, especially in underground segments.
Station Design	• Stations prioritize efficient passenger flow, with design elements for easy access, egress, and safety. Operational plans include contingencies for disruptions, leveraging network integration with local bus services
Regional Integration	• Strong integration with other transportation systems, including robust connections to local bus networks and other regional transit. Interlined service between Expo and Millennium Lines provides operational flexibility and redundancy.
Lessons for Ballard Link Extension	• Modern train control technologies like CBTC enable high-frequency service but high degree of

Feature	Description
	automation allows for maximum flexibility. • Redundant infrastructure and strong regional integration enhance reliability and operational resilience.

2.2 Case Study 2: San Francisco's BART System

2.2.1 Context and Summary

San Francisco's Bay Area Rapid Transit (BART) system is a legacy, high-capacity rapid transit network serving the San Francisco Bay Area, including major cities such as Oakland, San Francisco, and Daly City. BART operates primarily as a 2-track trunk line system, featuring extensive multi-track sections and flying junctions at MacArthur, Downtown Oakland (Oakland Wye), Bay Fair and San Bruno that enable efficient management of high passenger volumes and complex service patterns. The system's backbone is a two-track tunnel extending from Downtown Oakland from the point of under the bay to Daly City via San Francisco, flanked by strategic segments with three- and four-track platforms to facilitate transfers, turnbacks, and operational flexibility.

While much of BART's infrastructure dates to its initial construction in the late 1960s and early 1970s, the system employs Automatic Train Operation (ATO) and has continuously upgraded components to maintain reliability and capacity. An example of these continuous upgrades includes the addition new signal blocks c. 1990 between Concord and Daly City known as the STEP Project that increased capacity to 2-minute headways.

Unique operational features include legacy train control systems integrated with periodic modernization efforts, as well as strategically placed multi-track layouts and platform configurations were designed to maximize throughput and service resilience through an interlined tunnel through West Oakland and Downtown San Francisco.

BART mentioned that in their peer groups ISBERG and COMET that Madrid, Munich, Sydney, and Brisbane are building new tunnels to supplement their constrained 2-track tunnels. These are the regional rail rapid transit systems but key insights can be gathered from these systems.

2.2.2 Ventilation and Electrical Systems

BART's ventilation system is structured to ensure safe air quality and effective smoke management, particularly in the transbay tunnel and other underground segments. Vent zones are coordinated with train separation requirements, supporting both operational safety and emergency response capabilities.

BART has different occupancy rules for the Berkeley Hills Tunnel (ventilation) where 2-minute headways or scheduled 4-minute headways do not pose issues, no more than 2 trains per bore per direction. Transbay Tube at 2 minutes headways is not ventilation based but evacuation based and does not run into issues.

Figure 1 - New electrical infrastructure being installed through street access point in San Francisco.

BART's electrical infrastructure supports high-capacity service with extensive redundancy to reduce interruptions. Reliable power distribution enables frequent ATO operations, especially in core segments. The system includes multiple power feeds from public utilities and parallel AC transmission cables (left and right 34.5 kV power transmission cables). BART has expanded substation capacity, particularly in Downtown San Francisco. Design criteria now includes 8-minute headways (12-minutes prior) through Oakland Wye as shown in Figure 1 in order to support higher train densities and CBTC as envisioned as part of the Transbay Core Capacity Project. BART capacity will still be designed to support 30 trains per hour peak direction through the Transbay Tube and interlined 2-track alignment.

2.2.3 Train Signaling & Line Capacity

BART utilizes legacy automatic train control and ATO technology across most of its network, enabling short headways and high-frequency service. Strategic use of multi-track sections and flying junctions in Oakland and Daly City allows for efficient management of merging/diverging services, turnbacks, and service recovery during disruptions (e.g., bi-directional CX or 3rd track in Downtown Oakland).

Figure 2 below shows the unique, multi-track arrangement that lies adjacent to the Transbay Tube which allows for the BART OCC to mitigate train delays and manage train flows through the Oakland Wye in advance of the more constrained 2-track Transbay Tube and line through San Francisco.

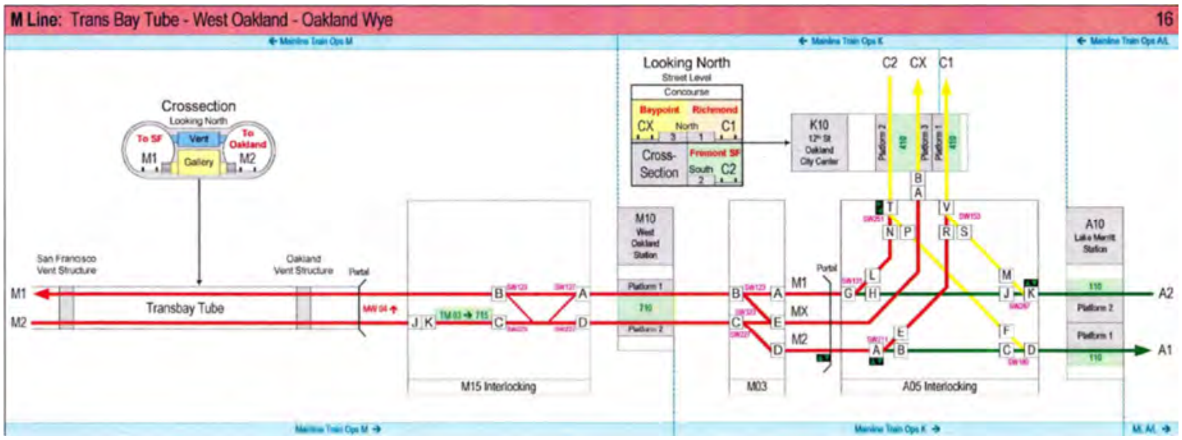


Figure 2 - BART Oakland Wye and Transbay Tube (Source: BART SCOA, 2013).

BART's overall system capacity depends on its legacy Automatic Train Operation (ATO) system and highly precise scheduling. Instead of relying on flexible, headway-based service like Link Light Rail, interlined train routes are assigned to specific scheduled time slots and sequences: this approach ensures maximum capacity in the core segments and enables smooth transfers between different lines.

In BART's core segments where multiple routes overlap, trains typically run every 2.5 to 4.0 minutes. Historically, the base service operated with 15-minute intervals, but this shifted to 20-minute intervals following the pandemic. During peak periods, the Yellow Line receives additional interlined service, which previously allowed trains to run every 5.0 minutes on that line between North Concord/Pleasant Hill and Daly City. Interlined service on four routes through the Transbay Tube and San Francisco would operate a combined headway of 2.5 to 3.0 minutes in the peak hour/direction with select trains turning back in opposing traffic at 24th/Mission or Montgomery Street Stations in the peak shoulders.

Ongoing modernization efforts target signaling upgrades with CBTC are underway and additional network expansion is in the planning stage, with consideration given to new tunnels, platform enhancements, maintenance resiliency, and integration with standard gauge regional rail transit systems such as Capitol Corridor and Caltrain. With 8-minute base headway design, 8-minute headways or combined frequency of 28 trains per hour peak direction through the Transbay Tube with an FTA funding commitment or goal of 30 trains per hour long-term peak direction.

2.1.4 Service Delivery & Operations

BART's service plan centers on frequent, reliable service along dedicated tracks, with strategic multi-track sections and flying junctions supporting efficient merging, operational flexibility, and fixed transfers that serve as "build points" for the entire schedule which requires a significant level of management by the Operations Control Center and precision.

Stations are designed to handle substantial passenger volumes, featuring wide, center platforms, and clear access/egress points to facilitate safe and efficient passenger movement. The exceptions are the three-track and platform station at Daly City and Colma plus the two-track side platform aerial station at West Oakland.

Operational plans incorporate contingencies for service disruptions, leveraging network integration and multi-track layouts to maintain reliability and manage incidents with minimal impact on service. Additional mitigation strategies such as roaming or standby vehicle technicians and paramedics are used to ensure major delay issues in the 2-track interlined tunnel and resolved quickly. The BART system includes redundancy through parallel transit routes and strong integration with regional bus and rail services but this can be imperfect since 10-car BART trains can carry upwards of 1,500 passengers at crush load.

2.1.5 Key Takeaways

Feature	Description
System Design	• Built for high passenger volumes and 24 trains per hour per direction; reliable 70-80 mph rapid transit infrastructure with flying junctions at all line merging and diversion points.
Train Signaling	• ATO utilized across all lines since the 1970s; enables short headways, variable speeds, scheduled station dwells, and precise scheduling that reinforces a high degree of operational resilience and discipline.
Track Infrastructure	• Strategic 3-4 track sections in Oakland and Daly City enhance operational flexibility at junction areas flanking the 2-track interlined tunnel through San Francsico.
Electrical & Ventilation	• Robust systems ensure reliability, especially in tunnels; train density limited but throughput unaffected. • Ventilation is not a limiting factor; instead, train density in the Berkeley Hills Tunnel and Transbay Tube drive operational constraints which are not a factor for new CBTC installation that is underway.

Feature	Description
Station Design	• Wide center platforms, clear access points; network redundancy maintains frequent service during disruptions.
Regional Integration	• Connected to a diverse number of parallel regional and local systems (Transbay buses, ferries, Muni Metro light rail, and Caltrain) for added capacity and redundancy. • Despite this redundancy, capacity of parallel systems can be insufficient during major service disruptions in the interlined Transbay Corridor since BART design capacity is high.
Lessons for Ballard Link Extension	• **Innovative signaling, strategically placed multi-track layouts, and flying junctions offer planning insights.** • **Lack of sufficient crossovers or pocket tracks in 2-track interlined segment through San Francisco creates ongoing resilience issues.** • **Major delays in interlined tunnel mitigated by robust parallel regional services and high degree of Operations Control Center contingency strategies.** • **Plans for supplemental regional rail tunnel are under development as part of Link21 program to address resiliency and regional growth needs.**

• Case Study 3: NYC

1...1. Context and Summary

- Overview of key systems and operational considerations
- How is this system situated in the regional system
  - o Is this a regional or trunk line system or is it flanked by other parallel high-capacity transit systems?
  - o Is it a legacy system or was it constructed relatively recently?
- Are there any unique systems constraints or enhancements to note?

1...2. Ventilation and Electrical Systems

- Focus on vent zones and train separation constraints
- Electrical system capacity and redundancy

1...3. Train Signaling & Line Capacity

- Overview of signal system technology and capacity
- Plans for CBTC or train control modernization, new rail capacity such as a new parallel line or tunnel?

1...4. Service Delivery & Operations

- Service plan and network/track layout overview
- Redundancy and integration with parallel systems and contingencies
- Station operations, egress, and access

1...5. Key Takeaways

- Summary of findings relative to ST's proposal
- Focus like laser on context

• Case Study 4: London

London Underground currently operates a mix of legacy fixed-block signaling and modern Communications-Based Train Control (CBTC) systems. Traditional signaling limits train frequency due to fixed block sections, while CBTC enables real-time train location monitoring, reducing headways and increasing line capacity. Upgrades on lines such as the Jubilee, Northern, and Victoria have demonstrated significant improvements in reliability and throughput.

The Circle, District, Hammersmith & City, and Metropolitan lines form the London Underground's sub-surface network, operating with significant interlining across shared tracks and junctions. This interconnected layout enables flexible routing and service patterns but also introduces operational complexity. The sub-surface lines have interlining on all four lines creating overlapping service patterns.
Interlining provides flexibility for passenger distribution and network resilience but can constrain capacity due to shared track occupancy. Delays on one line often

propagate across others, requiring advanced traffic management and robust signaling systems.

The Four Lines Modernisation (4LM) program introduces CBTC signaling across the sub-surface lines, reducing headways and improving reliability despite interlining complexity. The upgrade would allow for better coordination of train movements, minimizing conflicts at junctions and increasing overall throughput.

The rollout of CBTC is being executed in 14 different migration areas, each representing a segment of the network where CBTC is commissioned. Each migration area undergoes rigorous testing and staged commissioning to minimize disruption. The phased approach is needed to ensure compatibility between legacy and CBTC systems during transition.

To meet growing passenger demand, TfL is exploring additional capacity through infrastructure projects such as new parallel tunnels and line extensions. Concepts under review include a potential Bakerloo Line extension and additional cross-city connections to relieve congestion on central corridors. These projects aim to complement signaling upgrades by providing both operational efficiency and physical capacity enhancements.

• Case Study 4: Stuttgart S-Bahn

1…1. Context and Summary

- Overview of key systems and operational considerations
- How is this system situated in the regional system
  - o Is this a regional or trunk line system or is it flanked by other parallel high-capacity transit systems?
    The S-Bahn system consists of 7 lines coming together in the S-Bahn tunnel under the city, where 4 lines end underground and turn around with a balloon track underground to keep up short headways.
  - o Is it a legacy system or was it constructed relatively recently?
- Are there any unique systems constraints or enhancements to note?

1…2. Ventilation and Electrical Systems

- Focus on vent zones and train separation constraints
- Electrical system capacity and redundancy

1…3. Train Signaling & Line Capacity

- Overview of signal system technology and capacity
  The current system is equipped with wayside signalling and Automatic Train Protection and allows a headway of
- Plans for CBTC or train control modernization, new rail capacity such as a new parallel line or tunnel?
  Currently the system is transferred

1…4. Service Delivery & Operations

- Service plan and network/track layout overview
- Redundancy and integration with parallel systems and contingencies
- Station operations, egress, and access

1…5. Key Takeaways

- Summary of findings relative to ST's proposal
- Focus like laser on context

2. Conclusion

Key Findings and Lessons Learned from Peer Agencies

Agency	Key Finding/Lessons Learned
Vancouver SkyTrain	• CBTC enables short headways, high-frequency service, and robust redundancy. • Integration with parallel transit routes enhances reliability. • CBTC on all lines; headways as low as 75 seconds. • Redundancy: Parallel transit routes and robust integration with local bus systems. • Key Lesson: Modern train control and automation enable high-frequency, resilient service. Redundant infrastructure is crucial for reliability
San Francisco BART	• Legacy ATO with ongoing CBTC upgrades. • Operational Flexibility: Multi-track sections and flying junctions (Oakland Wye) mitigate delays and support resilience. • Ventilation/Electrical: Not a limiting factor for headways; redundancy in power and ventilation. • Key Lesson: Strategic infrastructure (multi-track layouts, crossovers) and robust contingency planning are essential. Lack of sufficient crossovers in interlined tunnels creates resilience issues. Plans for supplemental tunnels are underway
London Underground	• Mixed legacy and CBTC signaling; interlining increases operational complexity. • Interlining: Sub-surface lines share tracks, increasing

Agency	Key Finding/Lessons Learned
	operational complexity and risk of delay propagation. • Modernization: The Four Lines Modernization (4LM) program is reducing headways and improving reliability. • Key Lesson: CBTC upgrades improve throughput and reliability, but interlining complexity requires advanced traffic management and robust signaling. Additional tunnels/extensions are being considered to relieve congestion
Stuttgart S-Bahn	• Seven lines interlined in a central tunnel; balloon track for turnarounds. • Signaling: Wayside signaling and ATP; plans for CBTC modernization. • Key Lesson: Centralized interlining can achieve short headways but requires advanced signaling and operational planning

- **Key Similarities:** All systems face challenges with interlining, capacity constraints, and the need for modernization.
- **Key Differences:** Degree of automation, redundancy, and regional integration vary. Some systems (e.g., Vancouver, London) have strong parallel networks, while others (BART) rely heavily on a single corridor.
- **Key Takeaway**: Systems with robust redundancy and advanced signaling (CBTC) achieve higher resiliency. However, single-tunnel configurations remain vulnerable to disruptions. Peer agencies moving toward supplemental tunnels and CBTC upgrades highlight the importance of both physical and technological redundancy.

SWOT Analysis of CBTC/Tunnel Configurations

CBTC + 1 single tunnel

Strength	**Weakness**
• Shorter headways / increased capacity • More regular operations / efficiency • Faster recovery from incident • Enhanced safety	• Single point of failure in tunnel • High initial cost for CBTC • Implementation challenges
Opportunities	**Threats**
• Lower system life cycle cost • System expansion easier to implement • Lower maintenance cost	• Skilled staff availability

2 tunnels + current signaling

Strength	**Weakness**
• Skilled staff availability for systems • Known system to implement	• Less system reliability • Less system availability • Longer headways • No automatic train regulation
Opportunities	**Threats**
• Operational resiliency with 2nd tunnel	• Cost for tunnel • Constructability • System obsolescence

2 tunnels + CBTC

Strength	Weakness
• Shorter headways / increased capacity • More regular operations / efficiency • Faster recovery from incident • Enhanced safety	• High initial cost • Implementation challenges
Opportunities	**Threats**
• Operational resiliency with 2nd tunnel • Lower system life cycle cost • System expansion easier to implement • Lower maintenance cost	• Cost/funding for 2nd tunnel • Constructability of tunnel • Skilled staff availability

1 tunnel + current signaling

Strength	Weakness
• Skilled staff availability for systems • Known system to implement	• High system maintenance cost • Less system reliability • Less system availability • Longer headways • No automatic train regulation
Opportunities	**Threats**
• Operational resiliency with 2nd tunnel	• No possibility to expand system • No possibility to increase traffic

Decision Matrix: Single Tunnel vs. New Tunnel (with CBTC)

Criteria	Single Tunnel (CBTC)	New Tunnel (CBTC)
Capital Cost	Lower	Higher
Implementation Complexity	Lower	Higher
Operational Resiliency	Low (single point of failure)	High (redundancy, backup available)
Capacity & Growth	Moderate	High (supports future ridership growth)
Disruption Recovery	Slow (all service affected)	Fast (service can continue in other tunnel)
Maintenance Flexibility	Limited	High
Regulatory Constraints	May limit CBTC benefits unless addressed	Can be designed to meet future standards
Staffing/Training Needs	Moderate (CBTC migration)	High (CBTC + new tunnel operations)
Futureproofing	Limited	Excellent
Urban/Constructability Risks	Low to moderate	High

Key Insights & Takeaways

- **Single Tunnel (CBTC):**
  - Suitable for short-term cost savings and operational simplicity.
  - Risks major service disruptions and may not meet long-term growth or resiliency needs.
  - CBTC benefits are limited by existing tunnel constraints unless significant upgrades are made.
- **New Tunnel (CBTC):**
  - Provides robust redundancy, future capacity, and operational flexibility.
  - Enables full realization of CBTC's benefits, including higher throughput and reliability.
  - Requires significant investment, planning, and organizational change.

- **A new tunnel allows for design solutions** that eliminate current regulatory and physical constraints, maximizing CBTC's operational potential.
- **Maintenance and reliability:** CBTC reduces maintenance costs and improves safety, but a single tunnel remains vulnerable to disruptions. A new tunnel with CBTC offers system-wide resiliency and operational flexibility
- **CBTC (Communications-Based Train Control)** enables shorter headways, higher capacity, improved safety, and faster recovery from disruptions. It is most

effective when physical and regulatory constraints (e.g., tunnel ventilation, speed restrictions) are addressed.

- **Existing tunnel infrastructure** (Downtown Seattle Transit Tunnel, University/Northgate Link) imposes limits on train throughput due to fire codes, ventilation, and speed restrictions. These must be resolved to fully realize CBTC's benefits.
- **Tunnel ventilation and speed restrictions** (e.g., University of Washington segment) are major bottlenecks; without addressing these, CBTC's full benefits cannot be realized in a single tunnel.
- **Redundancy and resiliency** are critical: While CBTC in a single tunnel improves efficiency, it does not eliminate the risk of total service disruption in case of failure, hence a single tunnel remains a single point of failure, while a new tunnel provides operational flexibility and future proofing

Summary & Recommendation:

A single tunnel with CBTC offers substantial improvements in efficiency and capacity but remains vulnerable to single-point failures and may not meet long-term growth needs. Building a new tunnel provides critical redundancy, operational resiliency, and future capacity, but at a much higher cost and complexity. The decision should balance immediate needs, long-term growth, risk tolerance, and available funding.

The decision to add a second tunnel should weigh the operational resiliency benefits (redundancy, flexibility, capacity) against cost and constructability challenges. If long-term reliability, resiliency, and capacity are priorities and funding is available, a new tunnel with CBTC is the superior choice. If immediate cost and simplicity are paramount, a single tunnel with CBTC offers improvements but with notable risks and limitations.

APPENDIX E

Cost Details

Alternative 1A – Third Ave DSTT Tie-in (at-grade)

Interline Construction Cost

SCC	DESCRIPTION	Markup %	Cost	Allocated Contingency % Markup	Allocated Contingency	Total W/ Contingency
20.03	UNDERGROUND STATION		130,368,028			
	SUBTOTAL DIRECT COST		130,368,028			
	CONSTRUCTION INDRECT	55%	71,702,415			
	TOTAL DIRECT COST		202,070,443	50%	101,035,221	303,105,664
80.03	Agency Administration	5.0%	10,103,522			
80.01	Preliminary Engineering	3.0%	6,062,113			
80.02	Final Design & DSDC	7.5%	15,155,283			
80.06	Third Parties	1.5%	3,031,057			
80.06	Permitting	0.5%	1,010,352			
80.08	Startup	0.5%	1,010,352			
80.04	Construction Management	7.0%	14,144,931			
	SUBTOTAL	25%	50,517,611	20%	10,103,522	60,621,133
90	UNALLOCATED CONTINGENCY	15%	30,310,566	0%	-	30,310,566
	TOTAL ORDER OF MAGNITUDE PROJECT COST					$ 394,037,363
	Additional construction cost risk	50%				197,018,682

Alternative 1B – Third Ave DSTT Tie-in (grade-separated)

Interline Construction Cost

SCC	DESCRIPTION	Markup %	Cost	Allocated Contingency % Markup	Allocated Contingency	Total W/ Contingency
20.03	UNDERGROUND STATION		246,834,095			
	SUBTOTAL DIRECT COST		246,834,095			
	CONSTRUCTION INDRECT	55%	135,758,752			
	TOTAL DIRECT COST		382,592,847	50%	191,296,423	573,889,270
80.03	Agency Administration	5.0%	10,103,522			
80.01	Preliminary Engineering	3.0%	6,062,113			
80.02	Final Design & DSDC	7.5%	15,155,283			
80.06	Third Parties	1.5%	3,031,057			
80.06	Permitting	0.5%	1,010,352			
80.08	Startup	0.5%	1,010,352			
80.04	Construction Management	7.0%	14,144,931			
	SUBTOTAL	25%	50,517,611	20%	10,103,522	60,621,133
90	UNALLOCATED CONTINGENCY	15%	57,388,927	0%	-	57,388,927
	TOTAL ORDER OF MAGNITUDE PROJECT COST					$ 691,899,330
	Additional construction cost risk	50%				345,949,665

Alternative 2 – Westlake Station Terminus for BLE tunnel

OMF Construction Cost

SCC	DESCRIPTION	Markup %	Cost	Allocated Contingency % Markup	Allocated Contingency	Total W/ Contingency
	OMF Construction Cost		399,584,661	50%	199,792,331	599,376,992
80.03	Agency Administration	5.0%	19,979,233			
80.01	Preliminary Engineering	3.0%	11,987,540			
80.02	Final Design & DSDC	7.5%	29,968,850			
80.06	Third Parties	1.5%	5,993,770			
80.06	Permitting	0.5%	1,997,923			
80.08	Startup	0.5%	1,997,923			
80.04	Construction Management	7.0%	27,970,926			
	SUBTOTAL	25%	99,896,165	20%	19,979,233	119,875,398
90	UNALLOCATED CONTINGENCY	15%	59,937,699	0%	-	59,937,699
	TOTAL ORDER OF MAGNITUDE PROJECT COST					**$ 779,190,089**
	Additional construction cost risk	50%				389,595,044