FINAL REPORT

Steel Bridge Transit Improvements: Long-Term Concept Final Report

Prepared for

TriMet

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CH2M HILL, Inc.
Portland, Oregon

STEEL BRIDGE TRANSIT IMPROVEMENTS

Contents

Section Page

Acronyms and Abbreviations ..... **v**

1 Introduction **1-1**
- 1.1 Key Project Milestones and Deliverables 1-1
- 1.2 Modeling Tools 1-3
  - 1.2.1 Simplified Trips-on-Project Software (STOPS) 1-3
  - 1.2.2 Rail Traffic Controller (RTC) 1-3
  - 1.2.3 Travel Demand Analysis 1-3
- 1.3 Cost Estimates 1-4
- 1.4 Concept Analysis Approach 1-4

2 Existing and No-Build Conditions **2-1**

3 Concept Screening, Consolidation, and Refinement **3-1**
- 3.1 Screening and Consolidation 3-1
  - 3.1.1 Screening Criteria 3-2
  - 3.1.2 Screening and Consolidation Summary 3-2

4 Concept Assessment **4-1**
- 4.1 Existing Steel Bridge Concepts 4-2
  - 4.1.1 Description of Concept 4-2
  - 4.1.2 Cost of Concept 4-4
  - 4.1.3 Ridership, Travel Time, and System-Operations Considerations of Concept 4-4
  - 4.1.4 Seismic Resiliency of Concept 4-4
  - 4.1.5 Additional Structural Considerations 4-4
  - 4.1.6 Viability of Concept 4-5
- 4.2 New Bridge Concepts 4-6
  - 4.2.1 Description of Concept 4-6
  - 4.2.2 Cost of Concept 4-6
  - 4.2.3 Ridership, Travel Time, and System-Operations Considerations of Concept 4-6
  - 4.2.4 Seismic Resiliency of Concept 4-8
  - 4.2.5 Viability of Concept 4-8
- 4.3 Supplemental Bridge Concepts 4-8
  - 4.3.1 Description of Concept 4-8
  - 4.3.2 Cost of Concept 4-8
  - 4.3.3 Ridership, Travel Time, and System-Operations Considerations of Concept 4-8
  - 4.3.4 Seismic Resiliency of Concept 4-10
  - 4.3.5 Viability of Concept 4-10
- 4.4 Tunnel Concepts 4-10
  - 4.4.1 Description of Concept 4-10
  - 4.4.2 Cost of Concept 4-10
  - 4.4.3 Ridership, Travel Time, and System-Operations Considerations of Concept 4-12
  - 4.4.4 Seismic Resiliency of Concept 4-12
  - 4.4.5 Concept Variations 4-12
  - 4.4.6 Viability of Concept 4-12

5 References **5-1**

Appendixes

A Planning Framework
B Alternatives Workshop Matrix
C Rail Traffic Controller (RTC) Existing Conditions Model Summary Memo
D Long-Term Concept Refinement and Consolidation Memo and Concept Sketches
E Travel Demand – Existing Ridership Summary (SBTI), November 2016
F Long-Term Assessment Consolidation Rating Matrix
G Long-Term Concept Refinement and Simplified Trips-on-Project Software (STOPS) Model Summary Memo
H Rail Traffic Controller (RTC) Refinement and Sensitivity Analysis (Metro 2040 RTP) Model Summary Memo
I Steel Bridge Transit Improvements (SBTI) Rail Traffic Controller (RTC) Alternatives Assessment Blockage Input Generation for Bypass Tunnel RTC Model
Attachment 1 Summary of Additional Blockage Input Generation for Bypass Tunnel RTC Model
J Structural Assessment of 4-Tracking Steel Bridge
K Planning-Level Cost Estimates
L Long-Term Refinement and STOPS Model Summary, Updated 12/8/17
M Steel Bridge Transit Improvements Staff List
N Alternative Plan Profiles

Tables

1-1. Project Schedule and Process
3-1. Initial Concepts and Selected Representative Concepts[a]
4-1. Assessment of Concepts

Figures

2-1. Steel Bridge Delay Points
3-1. Process Flow Chart
3-2. Option C.1.A. Broadway Bridge Option (Orange/Yellow Lines Share Streetcar Tracks on Broadway Bridge [with Autos in Center Lane])
3-3. Option B.3.C. New Burnside Bridge at Oak/Stark Alignment Option (New Multimodal Bridge South of the Burnside Bridge [Oak/ Stark Alignment])
4-1. Existing Steel Bridge Concept
4-2. Steel Bridge Structural Assessment
4-3. New Bridge Concept
4-4. Supplemental 2-Track Bridge Concept
4-5. High-Speed Downtown Bypass Tunnel from Lloyd District to Goose Hollow Concept

Acronyms and Abbreviations

ADA	Americans with Disabilities Act
CH2M	CH2M HILL, Inc.
CSO	combined sewer overflow
ft	foot (feet)
I-5	Interstate 5
I-84	Interstate 84
I-405	Interstate 405
LRT	light rail transit
m	million(s)
Metro 2040 RTP	*Metro 2040 Financially Constrained Regional Transportation Plan*
mph	miles per hour
ODOT	Oregon Department of Transportation
OTP	on-time performance
Project	Steel Bridge Transit Improvements: Long-Term Concept Project
RTC	Rail Traffic Controller
SBTI	Steel Bridge Transit Improvements
Section 4(f)	Section 4(f) of the Department of Transportation Act of 1966
Section 106	Section 106 of the National Historic Preservation Act of 1966
STOPS	Simplified Trips-on-Project Software (Federal Transit Administration, 2013)
UPRR	Union Pacific Railroad

SECTION 1

Introduction

The Steel Bridge Transit Improvements (SBTI): Long-Term Concept Project (Project) identified potential long-term improvements to increase capacity and improve system performance near the Steel Bridge over and beyond the next 20 years. Given the anticipated growth in TriMet's light rail system demand over the next two decades, long-term analysis is necessary to maintain TriMet's goals to improve transit speed and reliability across the Steel Bridge. The analysis offered options for long-term improvements that could reduce light rail transit (LRT) network delay over a 30-year period of sustained transit demand growth. Long-term improvements could be implemented over the next 10 to 30 years, depending on funding and prioritization decisions.

The Steel Bridge is a critical link on the LRT system carrying 40 trains today in the peak hour.

Built in 1912, the Steel Bridge is one of the oldest lift bridges in service in the United States. The Steel Bridge is unique in that it is the only remaining truss double-decker vertical lift bridge with independent lifts (that is, the lower deck can retract into the upper deck without the upper deck moving) in the world. The Steel Bridge is a multimodal bridge. It carries single-occupancy vehicles (for example, autos and trucks), LRT, buses, pedestrian traffic, and bicyclists on the upper deck, and Amtrak trains, Union Pacific Railroad (UPRR) freight trains, pedestrians, and bicyclists on the lower deck.

Through this Project, TriMet staff and consultants developed improvement concepts (both on and off the Steel Bridge); grouped similar concepts; selected representative concepts from each grouping; and developed high-level analysis to compare the benefits, costs, and impacts related to improvement approaches. The process of identifying and analyzing representative concepts provides an information framework for future studies. Each representative concept includes many modifications that could be refined and considered.

This report summarizes key findings from the long-term analysis. The technical memorandums prepared for the Project are included as appendixes to this report.

1.1 Key Project Milestones and Deliverables

The Project team completed the SBTI Long-Term Concept analysis between March 2016 and October 2017. Table 1-1 lists the Project schedule and processes, with dates and development listed for each key milestone.

Table 1-1. Project Schedule and Process
SBTI: Long-Term Concept Final Report

Project Meeting or Milestone	Date	Project Development and Action	Key Deliverable
Project Coordination/ Kick-off meeting	March 2016	Developed input assumptions and model decisions	None
Site Visit and Planning Framework	March 2016	Site visit; developed long-term Project needs, goals, and evaluation criteria	Planning Framework, Appendix A

Table 1-1. Project Schedule and Process
SBTI: Long-Term Concept Final Report

Project Meeting or Milestone	Date	Project Development and Action	Key Deliverable
Alternatives Evaluation Workshop	March 2016	Developed 22 long-term concept alternatives	Alternatives Workshop Matrix, Appendix B
Rail Traffic Controller (RTC) Modeling Review Meeting	June 2016	Reviewed RTC modeling data and assumptions to inform development of existing conditions	Supported development of Rail Traffic Controller (RTC) Existing Conditions Model Summary Memo, Appendix C
Long-Term Concept Refinement Workshop	August 2016	Refined and screened long-term concept alternatives	Long-Term Concept Refinement and Consolidation Memo and Concept Sketches, Appendix D
2040 RTC Model Work Session	November 2016	Reported 2040 RTC model results and reviewed memo	Rail Traffic Controller (RTC) Existing Conditions Model Summary Memo, Appendix C
Travel Demand – Existing Ridership Summary (SBTI)	November 2016	Reviewed travel surveys and assessed transit originations, destinations, and patterns	Travel Demand – Existing Ridership Summary (SBTI), November 2016, Appendix E
Long-Term Concept Refinement and Consolidation	January 2017	Screened concepts and consolidated concepts into four representative concepts	Long-Term Assessment Consolidation Rating Matrix, Appendix F
Development of Concept Alternatives	April 2017	Developed and refined four representative concepts	Long-Term Concept Refinement and Simplified Trips-on-Project Software (STOPS) Model Summary Memo, Appendix G Rail Traffic Controller (RTC) Refinement and Sensitivity Analysis (Metro 2040 RTP) Model Summary Memo, Appendix H
STOPS Modeling Assumptions Meeting	April 2017	Developed STOPS Modeling Assumptions	
Long-Term Concept Refinement Workshop	May 2017	TriMet and consultant team selected two concepts to be modeled in STOPS	
SBTI RTC Alternatives Assessment	October 2017	Evaluated LRT operations of the new bridge and tunnel alternatives	Steel Bridge Transit Improvements (SBTI) Rail Traffic Controller (RTC) Alternatives Assessment, Appendix I
Structural Assessment of 4-Tracking Steel Bridge	October 2017	Evaluated structural feasibility and issues with 4-tracking the Steel Bridge	Structural Assessment of 4-Tracking Steel Bridge, Appendix J
Planning-Level Cost Estimates	October 2017	Developed preliminary cost estimates for three alternatives	Planning-Level Cost Estimates, Appendix K
Long-Term Refinement and STOPS Model Summary	December 2017	Developed STOPS Models to evaluate ridership changes of the new bridge and tunnel alternatives	Long-Term Refinement and STOPS Model Summary, Updated 12/8/17, Appendix L
Plan and profile drawings	December 2017	Developed plan and profile drawings for four concepts	Alternative Plan Profiles, Appendix N
Final report	December 2017	Review final report and Project conclusion	This *Steel Bridge Transit Improvements: Long-Term Concept Final Report*

RTC = Rail Traffic Controller

STOPS = Simplified Trips-on-Project Software (Federal Transit Administration, 2013)

This report also includes a list of SBTI staff members in Appendix M.

1.2 Modeling Tools

The SBTI: Long-Term Concept Project used the following tools to assess system operations, capacity, and ridership:

- Simplified Trips-on-Project Software (STOPS)
- Rail Traffic Controller (RTC)
- Travel Demand Analysis

1.2.1 Simplified Trips-on-Project Software (STOPS)

The STOPS (Federal Transit Administration, 2013) model predicts the number of rides that people would take on transit after building a major new investment. The STOPS model was calibrated for a 2016 base-year condition. TriMet developed travel-time data, existing vehicular data, and transit data for the STOPS model. The model was used to assess the ridership changes that could occur with a new bridge or tunnel compared to continued use of the existing Steel Bridge. Refer to Appendixes G and L for STOPS Model summaries.

1.2.2 Rail Traffic Controller (RTC)

RTC is a program that simulates the movement of trains through rail networks, using a variety of purposes. (These purposes range from tactically improving traffic flow to determining investments in capital infrastructure.) CH2M HILL, Inc. (CH2M) developed an existing conditions model and a future conditions model using projected headways as defined in the *Metro 2040 Financially Constrained Regional Transportation Plan* (Metro 2040 RTP; Metro). RTC provided information about expected performance of the LRT system in the Steel Bridge/Rose Quarter areas, which are pinch points on the existing system. It was also used to test the operational effects of increasing LRT speeds over the bridge and of changes to traffic signals at NE Multnomah Street and NE Interstate Avenue.

The study areas for the RTC model varied, as follows:

- The **existing conditions, future conditions, and new bridge models** evaluated LRT operations between Old Town (as defined by the Skidmore Fountain Station, NW 6th and NW Davis Station/NW 5th and NW Couch Station), to the Rose Quarter (defined by 7th/Holladay and Albina/Mississippi Stations). This study area extends one station beyond the long-term study area boundaries.
- The **tunnel model** evaluated conditions from Goose Hollow to the Hollywood Transit Center. This study area captures the entire area served by the tunnel concept.

The RTC model evaluated system operations in a future PM peak hour condition where 30 westbound trains and 34 eastbound trains cross the Steel Bridge. This assumption matches the Metro 2040 Travel Demand Model for the PM "peak of the peak" period.

1.2.3 Travel Demand Analysis

The travel demand component of the screening analysis was completed using the Metro Regional Travel Demand Model and 2015 on-board survey data that TriMet collected. The Metro model data were available from the most recent Regional Transportation Plan (Metro, 2014), with the existing condition represented by the base year 2010 and the future year condition represented by the Metro 2040 RTP. While the FTA STOPS model provides origins and destinations and transfers for trips boarding and alighting at specific stations, it does not have the ability to provide select line or segment data. Using on-board survey data for lines that pass through the Rose Quarter along with the available Metro model allowed TriMet to understand how riders with different origins and destinations might be affected by improvements at the Steel Bridge. See Appendix E, Travel Demand – Existing Ridership Summary (SBTI), November 2016, for details.

Metro completed select line assignment for both the base and future year and captured all trips that use the Steel Bridge on light rail and bus. These trips were saved out of the model and aggregated at a district level to provide overall travel movements by transit mode (bus vs. rail) for any trip that a project on the Steel Bridge would affect. In addition to the Metro model, TriMet provided on-board data from a spring 2015 survey of the Yellow Line. These data sources provided information about transfers at the Rose Quarter, as well as information about travel origins and destinations for trips on the Steel Bridge. Data from this exercise are provided in Appendix E.

1.3 Cost Estimates

CH2M prepared a planning-level cost estimate for three representative concepts. Based on the conceptual design, the estimates are expressed as a range representing minus 30% to plus 50% of the expected cost. The estimates itemize known items such as roadway modifications, systems, structures, trackway, and stations. Unit costs were based on experience and derived from bid results on previously bid transit and roadway projects. TriMet estimators concurred with the cost estimate approach and reviewed unit pricing. Lump-sum percentages were applied for items such as mobilization, design and construction engineering, and program support. Estimates do not include right-of-way or utility relocation. Each estimate includes a lump-sum assumption to account for anticipated city improvements.

Each estimate includes a contingency of 40 percent for unknowns and risks. Contingencies account for the general level of detail available upon which to complete the estimate and cover items not quantified or for which, currently, a cost cannot be determined. The contingency percentage covers unexpected changes to the project scope, higher than predicted inflation, unforeseen conditions, and any other such items that cannot be identified at this level of concept development. Costs should be considered a Class 5 estimate in accordance with *ASTM E2516 – Standard Classification for Cost Estimate Classification System*. These costs are suitable for project programming and for comparison of alternatives. Cost estimates are discussed in Section 4, with detail provided in Appendix K, Planning-Level Cost Estimates.

1.4 Concept Analysis Approach

The SBTI Long-Term Concept Project team selected representative concepts and set aside less promising concepts, which allowed the team to explore the range of solutions to the system constraint on the Steel Bridge. Before beginning Project design, TriMet and its partners would need to conduct a more comprehensive process to develop, analyze, and select alternatives.

Existing and No-Build Conditions

The Steel Bridge is 105 years old. UPRR owns the bridge and operates freight rail on its lower deck. The Oregon Department of Transportation (ODOT) leases the upper deck of the Steel Bridge. TriMet maintains and operates LRT on the inside lanes of the upper deck through a sublease agreement with ODOT. Currently, because of track-related issues, TriMet is restricted to operating at 10 miles per hour (mph) over the bridge. TriMet will complete trackway upgrades in 2019 that will increase train speed to 15 mph. However, this speed improvement will not address issues related to capacity.

In 2017, TriMet operates 40 LRT trains across the Steel Bridge in the a.m. and p.m. peak hours. This equates to one train every 90 seconds. In 20 years, the bridge, in its current configuration, would not be able to accommodate forecast demand of 64 trains in the peak hour. Even today, the bridge and interlockings at the approaches cause frequent reliability issues for TriMet; tight headways mean that even minor delays can cause long-lasting system impacts.

A traffic signal on the bridge's east side at Interstate Avenue affects access to the bridge. This signal is located at the same point as the track interlocking from the Yellow Line to the Red/Blue/Green Lines. This signal regulates conflicting train movements as well as vehicular traffic and pedestrian crossings resulting in delays for LRT. On the west side, the LRT interlockings to the Transit Mall on the Steel Bridge constrain LRTs. Figure 2-1 shows delay points.

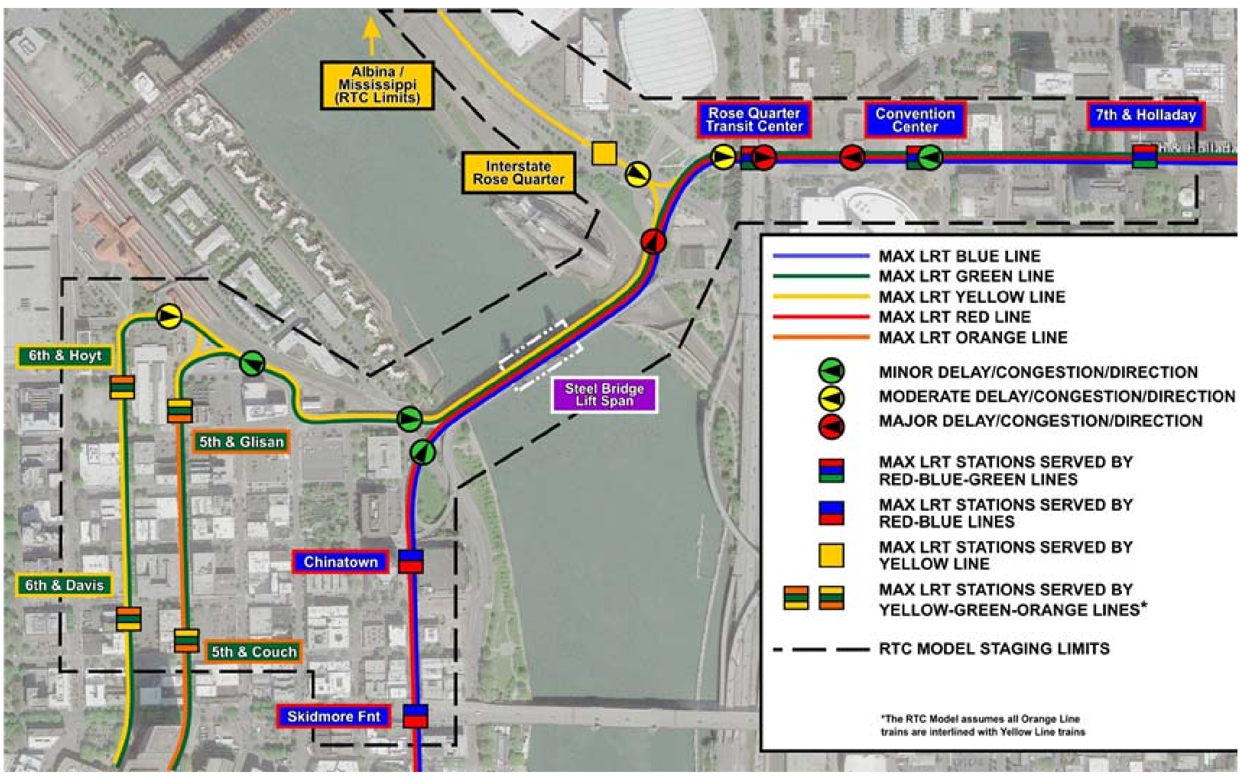

Figure 2-1. Steel Bridge Delay Points
SBTI: Long-Term Concept Final Report

The consultant team prepared an RTC Model to simulate existing conditions, evaluate operations during 2040 peak periods, and test the system's sensitivity to changes in speed and signal operations. The existing-conditions model verified that the model runs were consistent with actual field operations versus model operations and assumptions. Full results are included in Appendix C, Rail Traffic Controller

(RTC) Existing Conditions Model Summary Memo, and Appendix H, Rail Traffic Controller (RTC) Refinement and Sensitivity Analysis (Metro 2040 RTP) Model Summary Memo. Overall, the RTC model indicates that the current Steel Bridge alignment would not meet future demand and on-time performance (OTP) goals, even with changes to operating speeds, signalization, trackway improvements, and other operational improvements.

Key findings from the RTC Model include the following.

- Trains crossing the Steel Bridge in the Metro 2040 RTP would increase by 60 percent from Existing Conditions during the peak hour of the peak period, resulting in an overall OTP[1] drop from 87.6 percent in the Existing Conditions model to 55.1 percent in the Metro 2040 RTP Model.
- With tight headways across the Steel Bridge of approximately 2 minutes during peak periods, minor delays could escalate and result in the "bunching" of trains and inefficiencies where there were conflicting movements at junctions. This would affect all operations within the study area, as referenced in Figure 2-1.
- Maintaining the status quo in terms of facilities and operations would not provide reliable and efficient operations of trains crossing the Steel Bridge in the future. Long-term capacity improvements should be developed and implemented, potentially in interim phases, before the year 2040. (By then, the number of LRT vehicles required to meet demand would be at or above the current capacity.)
- Model runs with speeds of 10 mph, 15 mph, and 20 mph over the existing Steel Bridge did not yield significant improvements to OTP or running times between stations. Upgrading the trackway and increasing operating speeds would not increase future capacity and address OTP.
- Automobile and pedestrian signals appear to have a relatively significant effect on LRT operations in the RTC Model. Generally, these impacts result from trains waiting at locations for pedestrian signal cycles to complete before the trains can enter pre-emption cycle phases.
- If the needs are not addressed, long-term capacity would exceed overall system performance and provide poor OTP. Even with TriMet's plans to upgrade the traffic controller at the Interstate Avenue intersection to accommodate non-conflicting train movements, the RTC model indicates that the long-term capacity needs would not be addressed.

[1] On-time performance (OTP) measures the percentage of time trains are within 1 minute early to 5 minutes late of their scheduled times.

Concept Screening, Consolidation, and Refinement

3.1 Screening and Consolidation

The Project team,[2] including TriMet staff from operations, planning, maintenance-of-way, systems and capital projects, began the long-term analysis process by enumerating needs, goals, and evaluation criteria. The team developed 22 long-term concept alternatives and grouped those concepts under the following themes: existing bridge, new bridge, Broadway bridge, and other (including tunnel, eastside connector and mixed routing options). Appendix D provides graphics illustrating these concepts. The team identified seven representative long-term concepts to study further. Subsequently, the Project team narrowed the seven concepts to four representative concepts for additional design and modeling.

At the same time, CH2M developed an Existing Conditions RTC Model to improve understanding of system capacity and operations through the Rose Quarter and on the Steel Bridge. CH2M used both the RTC and STOPS Models to evaluate two representative concepts each, with variations that allowed the Project team to improve their grasp of the factors affecting system reliability, operations, and ridership.

The flow chart in Figure 3-1 illustrates the process for identifying and studying projects to improve long-term system capacity.

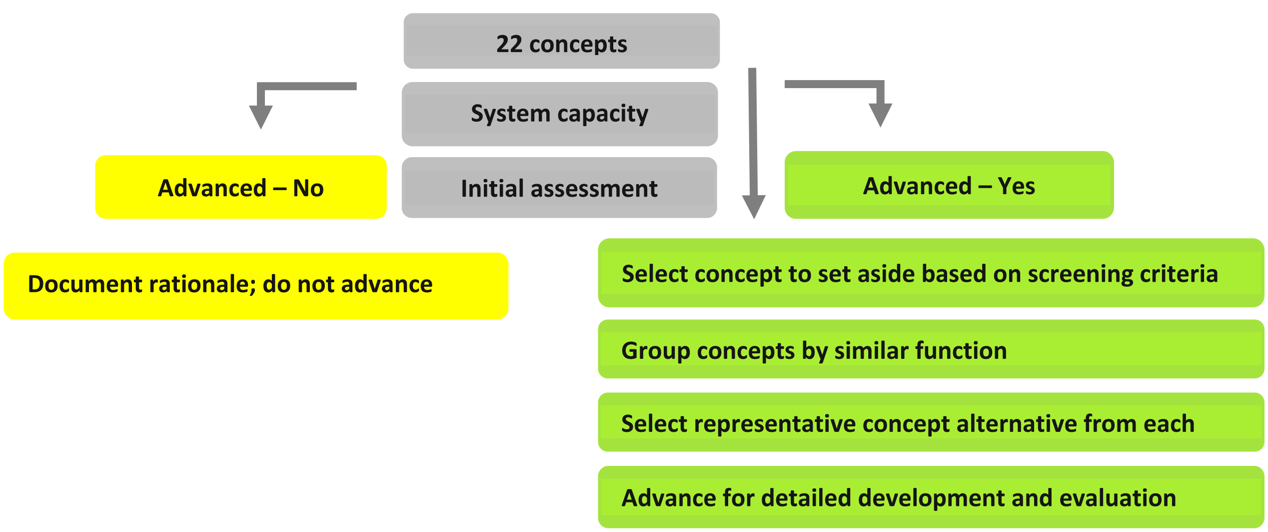

Figure 3-1. Process Flow Chart
SBTI: Long-Term Concept Final Report

[2] Appendix L includes a list of TriMet and consultant staff members who contributed to the long-term analysis.

3.1.1 Screening Criteria

The process for long-term concept refinement applied initial screening criteria to guide recommendations to advance or not to advance a concept for further study. The screening process relied on the following questions:

1. Does the concept increase system capacity over the Willamette River?
2. Does the concept significantly improve service for riders in a reasonable way?
   a. Does it allow people to make convenient and reasonable transfers?
   b. Does it serve known ridership patterns?
3. Is the concept generally feasible to construct?
   a. Could it be permitted? Does it impact a U.S. Department of Transportation Act Section 4(f) resource?[3]
   b. Does it require acquisition of a high-value building?

The subsequent consolidation process included these additional screening criteria:

- Improve system redundancy and reliability
- Support convenient transfers among rail and bus lines at Rose Quarter and understand travel demand for trips crossing the Willamette River
- Accommodate demand growth (rail vehicle) beyond 20 years
- Be consistent with long-term land use plans in the Rose Quarter
- Avoid impacts to Section 4(f) and Section 106 of the National Historic Preservation Act of 1966[4] resources and park lands[5]
- Minimize life-cycle costs by balancing operating, maintenance, and capital costs
- Provide seismic resiliency

3.1.2 Screening and Consolidation Summary

The Project team used the following process to select the representative concepts:

- Identified 22 concepts and consolidated the initial concepts into 7 representative concepts
- Refined and consolidated these 7 concepts into the final 4 representative concepts for further analysis

3.1.2.1 Initial Screening and Consolidation (22 concepts to 7 concepts)

Table 3-1 shows the initial 22 concepts. The following seven concepts were initially advanced for further assessment:

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[3] Section 4(f) of the Department of Transportation Act of 1966 stipulates that U.S. Department of Transportation agencies cannot approve the use of land from publicly owned parks, recreational areas, wildlife and waterfowl refuges, or public and private historical sites unless the following conditions apply:

- There is no feasible and prudent avoidance alternative to the use of land; and the action includes all possible planning to minimize harm to the property resulting from such use;

OR

- The Administration determines that the use of the property will have a de minimis impact.

[4] Section 106 of the National Historic Preservation Act of 1966 requires that federal agencies take into account the effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment.

[5] Environmental resources such as impacts to environmental justice communities, noise-sensitive receptors, navigable waterways, and so forth were not studied in detail. A full environmental analysis would need to be completed in subsequent studies.

- A.2.B – Grade Separated Interstate Avenue (Rail Over)
- A.3.B – 4-track Steel Bridge Without Autos
- B.2.C – New multimodal bridge for all rail lines (no autos)
- B.3.C – New Burnside Bridge at Oak/Stark Alignment Option (New Multimodal Bridge South of the Burnside Bridge [Oak/Stark Alignment])
- C.1.A – Broadway Bridge Option (Orange/Yellow Lines Share Streetcar Tracks on Broadway Bridge [with Autos in Center Lane])
- D.1.B – High-speed downtown bypass tunnel from Lloyd District to Goose Hollow
- D.3.A – Route Some LRT to New Burnside Bridge

The two concepts advanced as variations (Options A.2.C and D.4.A) were not evaluated separately.

Appendix D, Long-Term Concept Refinement and Consolidation Memo and Concept Sketches, provides a full assessment of these concepts and the screening and consolidation process.

Table 3-1. Initial Concepts and Selected Representative Concepts[a]
SBTI: Long-Term Concept Final Report

Family	Concept	Option	Alternative description	Reason for Action	Action
A. Existing Steel Bridge	1. Rose Quarter street reconfiguration	A.1.A. Rose Quarter square about	Creates new traffic circulation pattern in Rose Quarter to create new developable parcels.	Does not address capacity issues; grade separation seems more promising	Not advanced
	2. Interstate Avenue grade separation	A.2.A. Grade separate Interstate Avenue southbound	SB Interstate Avenue (heaviest traffic movement) crosses under remaining traffic and LRT tracks.	A.2.B/A.2.C advanced as representative concepts; only grade separating southbound Interstate Avenue would provide less system benefit than separating both movements	Not advanced
		A.2.B. Grade separate Interstate Avenue northbound/southbound (rail over)	Interstate Avenue crosses under LRT. Includes elevated station with pedestrian bridge to Rose Quarter.		**Advanced**
		A.2.C. Grade separate Interstate Avenue northbound/southbound (rail under)	Interstate Avenue crosses over LRT.		**Advanced** as a variation of A.2.B
	3. 4-track Steel Bridge	A.3.A. 4-track Steel Bridge with autos (outside lanes)	Blue/Red Lines use south lanes; Yellow/Orange Lines use north lanes. Green Line uses south lanes on east end and north lanes on west end. Outside lanes shared with autos.	A.3.B selected to represent 4-track Steel Bridge options due to operational benefits from dedicated trackway;	Not advanced (initially advanced; subsequently, A.3.B was selected as a representative concept)

Table 3-1. Initial Concepts and Selected Representative Concepts[a]
SBTI: Long-Term Concept Final Report

Family	Concept	Option	Alternative description	Reason for Action	Action
		A.3.B. 4-track Steel Bridge without autos	Blue/Red Lines use south lanes; Yellow/Orange Lines use north lanes. Green Line uses south lanes on east end and north lanes on west end. Maintains bus operations on the outer lanes of the Steel Bridge.	configurations with and without autos would likely need to be assessed in future studies to balance tradeoffs for transit and vehicular performance	**Advanced**
		A.3.C. 4-track the Steel Bridge single vehicular travel lane during peak periods	4-track the Steel Bridge but make center lanes reversible to provide additional peak hour capacity; maintains auto traffic.		Not advanced
B. New Bridge	1. Supplemen-tal bridge	B.1.A. New rail bridge for all rail	New bridge north of Steel Bridge for all rail; buses stay on Steel Bridge.	Supplemental Bridge between Steel and Burnside developed as a representative concept (see variation of D.3.A)	Not advanced
		B.1.B. New rail bridge for Orange/Yellow Lines	New bridge north of Steel Bridge for Orange/Yellow Lines; Red/Blue/Green Lines and buses stay on Steel Bridge.		Not advanced
	2. New multimodal bridge north of Steel Bridge	B.2.A. New multimodal bridge with all rail on new bridge (includes all modes)	New multimodal bridge north of Steel Bridge; all rail on new bridge.	B.2.C advanced as a representative new bridge concept	Not advanced
		B.2.B. New multimodal bridge with Orange/Yellow Lines on new bridge (north)	New multimodal bridge north of Steel Bridge; Orange/Yellow Lines on new bridge.		Not advanced
	NEW OPTION	**B.2.C. New multimodal bridge for all rail lines (no autos)**	New multimodal bridge for all LRT lines adjacent to Steel Bridge.		**Advanced**
	3. New bridge south of Steel Bridge	B.3.A. New multimodal bridge for all rail lines (south) and autos	New multimodal bridge south of Steel Bridge; all rail lines and autos use new bridge.	B.2.C advanced as a representative new bridge concept	Not advanced
		B.3.B. New multimodal bridge for all rail lines, autos and UPRR (south)	New multimodal bridge south of Steel Bridge; all rail lines, autos and UPRR use new bridge.		Not advanced

Table 3-1. Initial Concepts and Selected Representative Concepts[a]
SBTI: Long-Term Concept Final Report

Family	Concept	Option	Alternative description	Reason for Action	Action
		B.3.C. New multimodal bridge south of the Burnside Bridge (Oak/Stark alignment/new Burnside Bridge)	New multimodal bridge south of Morrison Bridge; all rail lines use new bridge.	Required clearances on either side of the river may render it infeasible	Not advanced after subsequent analysis
C. Broadway Bridge	1. Orange/ Yellow Lines on Broadway Bridge	**C.1.A. Orange/Yellow Lines share streetcar tracks on Broadway Bridge (with autos in center lane)**	Yellow Line uses Larrabee Avenue to access Broadway Bridge. Would require bridge strengthening and relocation of existing streetcar tracks to avoid LRT dynamic envelope conflicts. On the west side, trains would pass near Union Station to the Mall.	Broadway Bridge options not advanced because they do not increase system capacity compared to other alternatives; removing autos might not be feasible	Not advanced after subsequent analysis
		C.1.B. Orange/Yellow Lines share streetcar tracks on Broadway Bridge (without autos in center lane)	Yellow Line uses Larrabee to access Broadway Bridge. Would require bridge strengthening and relocation of existing streetcar tracks to avoid LRT dynamic envelope conflicts. On the west side, trains would pass near Union Station to the Mall. Exclusive transit lane on bridge.		Not advanced
D. Other	1. Tunnel	D.1.A. Short tunnel from Lloyd District to downtown	Red/blue Line tunnel under the Willamette River. New underground stations at Lloyd District, Rose Quarter, and Union Station.	Short-tunnel option not advanced because it would provide similar service improvements to new bridge but at a higher cost; a high-speed bypass tunnel provides more benefit	Not advanced
		D.1.B. High-speed downtown bypass tunnel from Lloyd District to Goose Hollow	High speed alternative for Red and/or Blue Lines. New underground stations at Rose Quarter and Pioneer Square. Maintains existing Red/Blue Lines and stations.		**Advanced**
	2. Eastside Connector	D.2.A. Eastside Connector for Orange/Yellow trains	Orange and Yellow Lines stay on the east side. Transfers at Rose Quarter to access downtown.	Concept does not improve service or provide reasonable transfers	Not advanced

Table 3-1. Initial Concepts and Selected Representative Concepts[a]
SBTI: Long-Term Concept Final Report

Family	Concept	Option	Alternative description	Reason for Action	Action
	3. Burnside Bridge	**D.3.A Route some LRT to new Burnside Bridge**	Red and Blue Lines realign to new Burnside Bridge and reconnect to the Banfield at the Rose Quarter station or streetcar alignment on Martin Luther King and Grand.	Combining with new Burnside Bridge may not be feasible due to geometric constraints at approaches	**Advanced** as a supplemental bridge option
	4. Supplemental Downtown Connections	**D.4.A. Supplemental Connections between Blue/ Yellow/Orange and Red/Green Lines at Yamhill/Morrison**	Adds switch tracks between the Blue/Yellow/Orange and Red/Green Lines. These could be beneficial and add flexibility if the Steel Bridge is out of service.	Provides significant operational flexibility but no additional capacity	**Advanced** as an enhancement to B.2.C

[a] The items with bold highlighting were advanced as representative concepts for additional analysis.

The team performed subsequent analysis and set aside two more options – C.1.A and B.3.C.

Option C.1.A, Broadway Bridge Option

Option, C.1.A, Broadway Bridge Option (Orange/Yellow Lines Share Streetcar Tracks on Broadway Bridge [with Autos in Center Lane]) (Figure 3-2), was set aside because operating light rail across the Broadway Bridge would require reconstructing the streetcar track. (Tracks today are too close together to accommodate the dynamic envelope of light rail vehicles.) This option would:

- Have a significant cost, disrupt streetcar operations, and have additional traffic impacts to the system.
- Not address seismic resiliency or reduce maintenance costs associated with operating light rail on aging lift bridges. (The Broadway Bridge, similar to the Steel Bridge, is an aging lift bridge.)
- Be less desirable to operate.

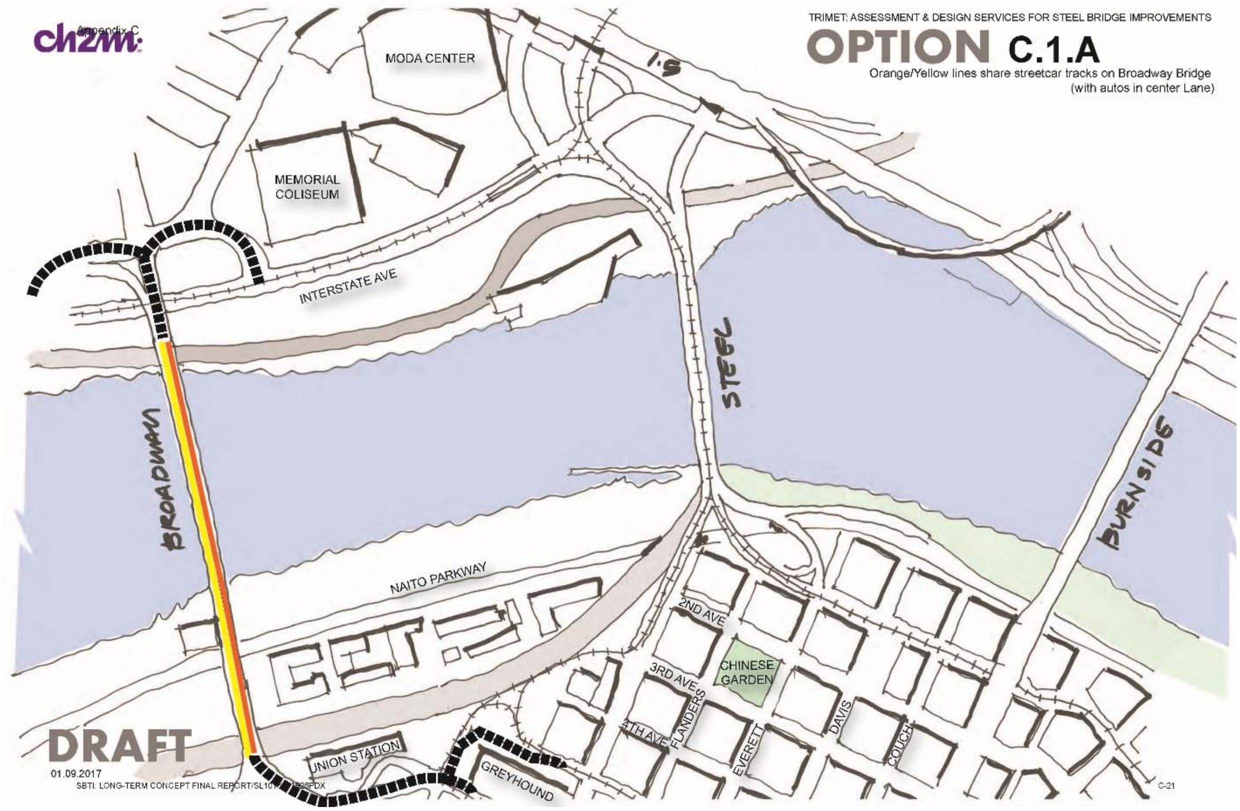

Figure 3-2. Option C.1.A. Broadway Bridge Option
(Orange/Yellow Lines Share Streetcar Tracks on Broadway Bridge [with Autos in Center Lane])
SBTI: Long-Term Concept Final Report

Option B.3.C, New Burnside Bridge at Oak/Stark Alignment Option

Option B.3.C, New Burnside Bridge at Oak/Stark Alignment Option (New Multimodal Bridge South of the Burnside Bridge [Oak/Stark Alignment]) (Figure 3-3) was set aside because the clearances required may render it infeasible. This option would:

- Need to pass over Naito Parkway and Waterfront Park before landing west of the Willamette River. Given the height of the bridge, it would likely take two blocks to land in downtown Portland. This would impact several downtown blocks, which might include historic properties.
- Not connect to the transit mall.

The new transit bridge south of the Steel Bridge option (Option B.2.C) and the option that would add light rail to a replacement Burnside Bridge (Option D.3.A) are better, similar representative concepts.

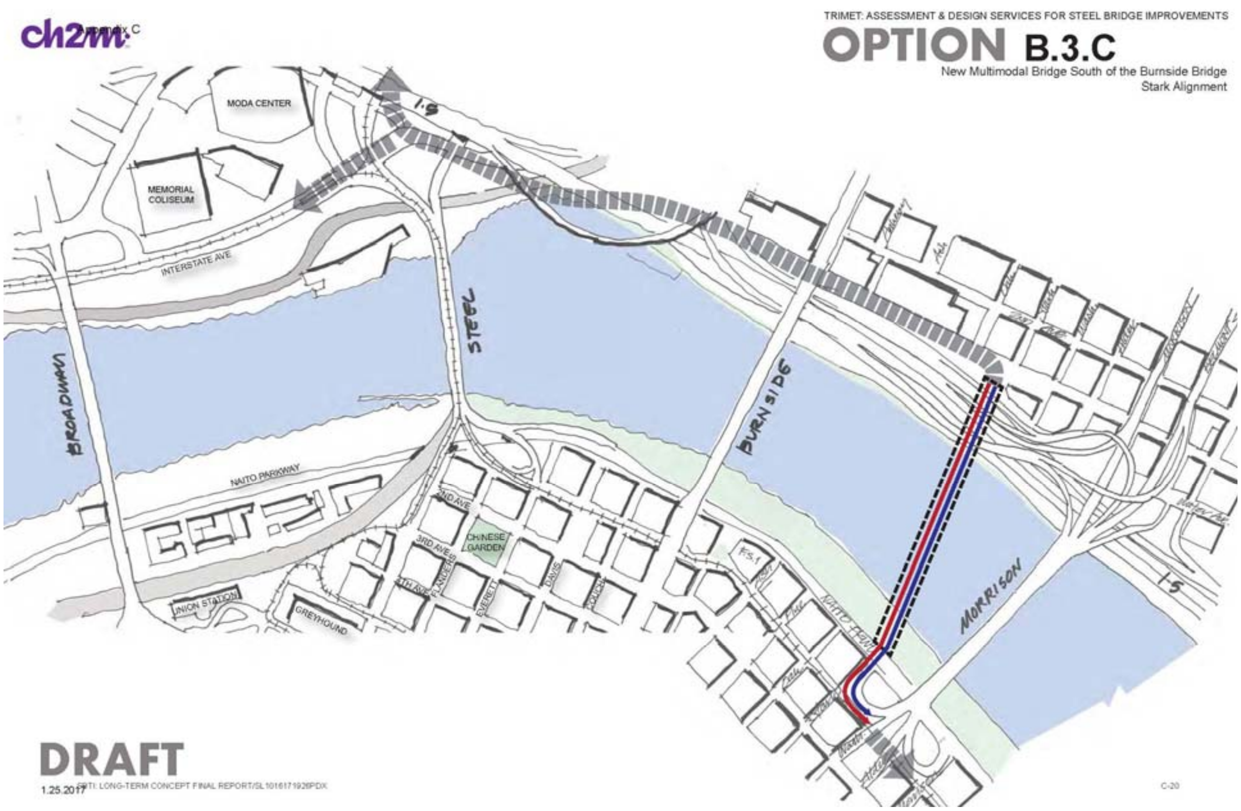

Figure 3-3. Option B.3.C. New Burnside Bridge at Oak/Stark Alignment Option (New Multimodal Bridge South of the Burnside Bridge [Oak/ Stark Alignment])
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3.1.2.2 Refinement and Consolidation

The Project team consolidated the remaining five concepts into the following four representative concepts for more detailed conceptual design, planning-level cost estimates, and technical evaluation:

- Existing Steel Bridge (4-track/east grade separation)
  - 4-track Steel Bridge with grade-separation at Interstate Avenue (option would not include autos on Steel Bridge for this phase of the study)
- New Bridge (immediately south of Steel Bridge)
  - New 4-track transit bridge south of Steel Bridge (assumes buses and LRT on the new bridge; assumes fixed bridge with bikes and pedestrians on the Steel Bridge)
- Supplemental Bridge (midway between the Steel and Burnside Bridges)
  - Blue and Red Lines on supplemental bridge; Green/Yellow Lines on Steel Bridge
- Tunnel (Supplemental high-speed downtown bypass)
  - High-speed downtown bypass tunnel from Lloyd District to Goose Hollow (maintains surface alignment to serve all existing stations)

Concept Assessment

The Project team conducted further analysis on the four remaining representative concepts (Table 4-1). This included conceptual design with vertical and horizontal alignment, planning-level cost estimates, and ridership forecasting.

The concepts each provide a different set of benefits and drawbacks.

- The Tunnel Concepts provide the most benefits in terms of travel-time savings (15 minutes between Goose Hollow and Lloyd Center Stations), increased system ridership, and improved system on-time performance (97 percent for all lines within the study area), but come at the highest cost.
- The New Bridge Concepts remove all LRT from the Steel Bridge, reducing TriMet's reliance on the aging structure; provide some travel-time reduction; have a moderate OTP (86 percent for all lines within the study area); and deliver some system ridership benefit.
- The Existing Steel Bridge Concepts do not address redundancy and continue reliance on the Steel Bridge. With 4 tracks, the Steel Bridge could accommodate 2040 peak demand, but OTP would not meet TriMet's 90 percent target.
- The Supplemental Bridge Concept is likely not viable because of navigational clearance issues and difficulty for large ships to dock at the harbor wall.

Discussion of ridership and system operations differences among the representative concepts can be found in Appendix L, Long-Term Refinement and STOPS Model Summary, Updated 12/8/17, and Appendix I, SBTI RTC Alternatives Assessment.

Table 4-1. Assessment of Concepts
SBTI: Long-Term Concept Final Report

Assessment	Existing Steel Bridge Concepts	New Bridge Concepts	Supplemental Bridge Concept	Tunnel Concepts
Description	4-track Steel Bridge with grade-separation at Interstate Avenue (with autos) includes needed structural improvements and seismic upgrades	New 4-track transit bridge south of Steel Bridge	Blue and Red Lines on a bridge between the Steel and Burnside Bridges; Green and Yellow Lines remain on the existing Steel Bridge.	High-speed downtown bypass tunnel from Lloyd District to Goose Hollow (maintains surface alignment to serve all existing stations)
Cost ($2017) without right-of-way and utility relocations[1]	$220m to $470m (includes seismic upgrades)	$300m to $650m	Not estimated	$900m to $1,940m
Ridership considerations	3,000 new system riders[2]	3,000 new system riders	3,000 new system riders[2]	7,500-15,200 new system riders
Travel-time considerations	Minor decrease in travel time[3]	Decreases travel time an average of approximately 2 minutes	Minor decrease in travel time[3]	Major reduction in travel time – Approximately 15 minutes[5] between Goose Hollow and Lloyd Center Stations

Table 4-1. Assessment of Concepts
SBTI: Long-Term Concept Final Report

Assessment	Existing Steel Bridge Concepts	New Bridge Concepts	Supplemental Bridge Concept	Tunnel Concepts
System-operations considerations	Improves system operations, but does not address redundancy[4]	Addresses redundancy and improves operations	Addresses redundancy and improves operations, but still relies on Steel Bridge	Addresses redundancy and improves operations, but still relies on Steel Bridge
Seismic Resiliency	Steel Bridge and west approaches currently vulnerable; Seismic retrofit included in concept	Would be constructed to be current seismic standards	Would be constructed to seismic standards; Steel Bridge would remain vulnerable unless retrofitted	Would be constructed to seismic standards; Steel Bridge would remain vulnerable unless retrofitted
Viability of Concept	**Low:** Anticipated uplift from operating fully loaded trains in the outside lanes; could accelerate fatigue; UPRR expects to renegotiate lease at higher cost; service life less than new bridge; cost to strengthen bridge to rehabilitate corrosion and fatigue issues and moveable components is nearly as much as a new bridge	**High:** Provides operational and capacity benefit; eliminates reliance on Steel Bridge	**Low:** Likely not viable due to navigational clearance and difficulty for large ships to dock at the harbor wall; requires construction of a new bridge and maintenance of trackway on Steel Bridge	**High:** Provides operational and capacity benefits to the overall system, but has high cost

m = million

[1] Cost estimates represent a minus 30% to plus 50% range and are based on unit costs; include design, construction, and program costs; do not include right-of-way or utility relocations.

[2] Supplemental Bridge and 4-Track Steel Bridge concepts not tested in STOPS modeling. Ridership is likely to be similar to a new 4-track bridge.

[3] Supplemental Bridge and 4-Track Steel Bridge concepts not evaluated in RTC. Travel times are anticipated to be similar to a new 4-track bridge.

[4] Redundancy is a system design that provides multiple trackways to serve a line providing an alternative route if the primary route is not serviceable.

[5] Travel time savings calculated by TriMet in comparison with 2017 travel times.

4.1 Existing Steel Bridge Concepts

4.1.1 Description of Concept

The representative Existing Steel Bridge Concept is a 4-track Steel Bridge (without autos in either lane) and grade-separation at Interstate Avenue (Figure 4-1). This alternative includes installing two additional sets of tracks on the outside lanes of the Steel Bridge and grade-separating LRT over N Interstate Avenue. Autos would be restricted from using the bridge, but buses could be accommodated in a shared trackway in the outside lanes. The Interstate Station would be elevated in its current location. To accommodate LRT on the outer lanes of the Steel Bridge, the steel stringers, floor beams, deck, counterweights, span locks, and, likely, the trusses, lift-span mechanisms, and cables would need to be

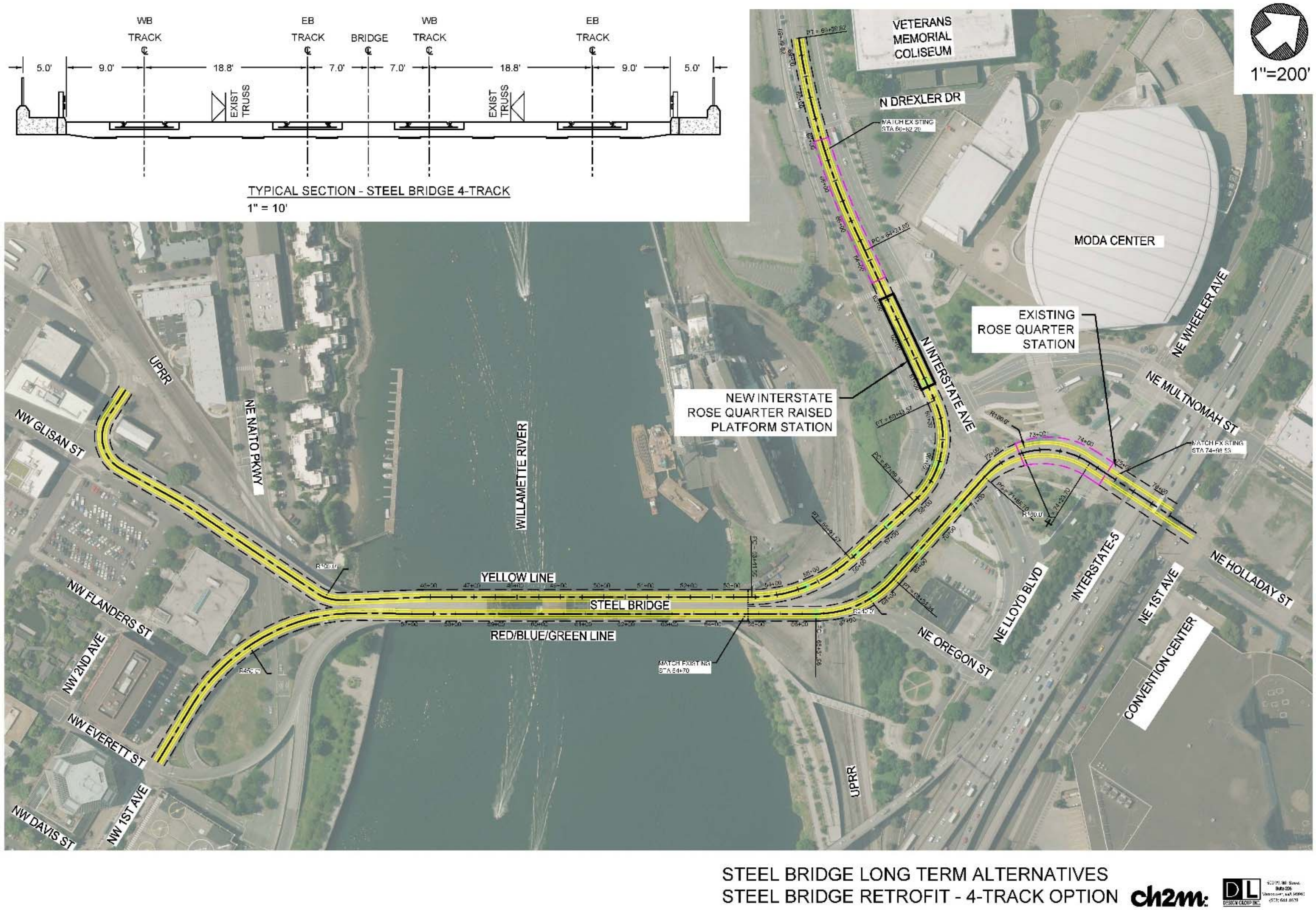

Figure 4-1. Existing Steel Bridge Concept
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strengthened and retrofitted. The Steel Bridge, built in 1912, does not meet current criteria for seismic design and construction. To be eligible for federal funding, TriMet would need to include seismic upgrades to the bridge in the Project. In this option, Blue/Red Lines would use the southern lanes; Yellow/Orange Lines would use the northern lanes. Track crossovers for the Green Line could occur on the fixed river spans.

Variations of this option could include sharing outside lanes with vehicular traffic or grade-separating Interstate Avenue by having LRT pass under Interstate Avenue.

4.1.2 Cost of Concept

This Existing Steel Bridge concept would cost between $220 million (m) and $470m including painting, rehabilitation of damaged and fatigued sensitive members, and strengthening and seismic retrofit of the superstructure and foundations.

4.1.3 Ridership, Travel Time, and System-Operations Considerations of Concept

This Existing Steel Bridge Concept might result in a minor decrease in travel time due to the grade separation at Interstate Avenue and removal of autos. Systemwide boardings might increase by around 3,000 per day, similar to those with the New Bridge Concepts. STOPS modeling was not performed for this option. Because it relies on a single crossing, it does not provide system redundancy for any line.

This Existing Steel Bridge Concept would improve system operations by increasing LRT capacity across the Willamette River and by removing conflicts with autos at Interstate Avenue and SW 3rd Avenue and Glisan Street. It would maintain convenient bus transfers at Rose Quarter. It would also maintain all stations on the current system.

4.1.4 Seismic Resiliency of Concept

Seismic resiliency, durability, and constructability are factors that must be considered in continuing to use the Steel Bridge as the main route for the overall TriMet system. The bridge, including the west approach, would have to be seismically retrofitted (the east approach would be reconstructed to achieve grade separation). Seismic upgrades would impact the aesthetics of the bridge which would need to be documented and analyzed under Section 106 of the National Historic Preservation Act of 1966 because the Steel Bridge is a historic structure. Further, little is known about the existing foundations, resulting in the potential for increased risk and cost in final design and construction.

4.1.5 Additional Structural Considerations

Strengthening the structure to resist additional LRT loading is feasible, as described in Appendix J, Structural Assessment of 4-Tracking Steel Bridge. However, strengthening does not address fatigue of the existing steel members. Fatigue cracks have been observed in secondary members. When cracks appear in primary truss members, the bridge might be closed to traffic. While member strengthening is feasible, the concept would increase fatigue and durability issues.

Fully loaded trains operating in the exterior lanes of the bridge could cause uplift at the lift-span live-load bearings. This uplift could damage the existing span locks and rail locks holding the lift span in position and be a significant safety concern for oncoming trains, vehicles, pedestrians, and bicycles. Uplift would also cause excessive wear on the live-load bearings and on the rail joints. It would also increase dynamic forces throughout the truss, which would exacerbate existing fatigue vulnerabilities.

A full summary of the structural assessment can be found in Appendix J, Structural Assessment of 4-Tracking Steel Bridge.

Figure 4-2 illustrates the uplift at the lift-span.

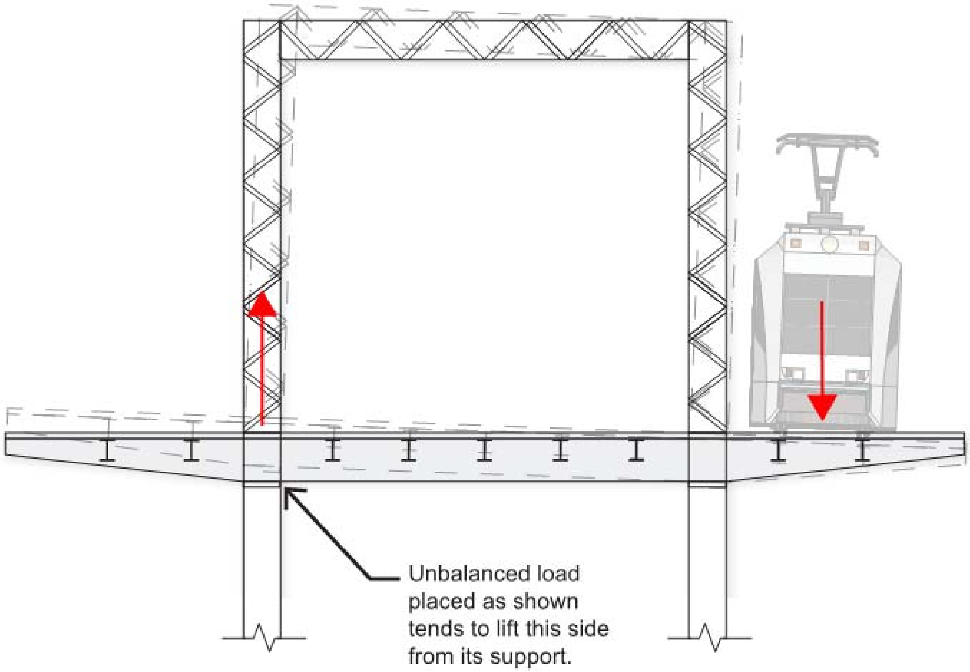

Figure 4-2. Steel Bridge Structural Assessment
SBTI: Long-Term Concept Final Report

Auto use and circulation would be affected for a dedicated transit facility. Ownership and/or lease of the bridge would need to be renegotiated with UPRR and ODOT, which would likely increase costs and risks to TriMet. As modeling was not conducted, vehicular, pedestrian, and bicycle traffic impacts would need to be further analyzed.

4.1.6 Viability of Concept

The Existing Steel Bridge Concepts are feasible, but involve risks to TriMet. These risks include the following items.

- Continued reliance on the structural adequacy of the 105-year old Steel Bridge for all LRT lines
- Increased fatigue and maintenance issues associated with higher bridge loads and LRT frequency
- Costs and risks associated with seismic retrofit, and residual seismic vulnerability of the retrofitted structure
- Cost of a new bridge lease, as TriMet would assume ODOT's share and UPRR would likely renegotiate the terms
- Need for UPRR approvals to address additional weight, rehabilitation of movable systems, seismic vulnerabilities, and structural issues
- Uplift at lift-span bearings with fully loaded trains in outside lanes that could pose significant safety risks to users, damage existing span-locks, and accelerate fatigue issues

4.2 New Bridge Concepts

4.2.1 Description of Concept

The representative New Bridge Concept is a new 4-track bridge for all LRT lines approximately 130 feet (ft) south of the Steel Bridge (Figure 4-3). Buses would continue to operate on the Steel Bridge. Given the grades, the representative New Bridge Concept would not meet requirements for an Americans with Disabilities Act (ADA)-compliant pedestrian path. ADA access would be provided via the existing bike/ pedestrian path on the lower deck of the Steel Bridge or the sidewalks on the upper deck. Bike and pedestrian access on a transit bridge would be explored during design.

The representative New Bridge Concept reflects a minimum navigational vertical clearance of 114 ft, with approximately 118 ft at the center of the channel and a movable span in the center of the river to accommodate primarily U.S. Navy vessels. It includes approach grades of up to 6.2 percent, with critical touchdown points at Interstate 5 (I-5) on the east side and 1st Avenue/Burnside Street on the west side (tie in at Burnside Street). The design also provides a minimum of 17 ft vertical clearance over existing streets and Steel Bridge ramps, except over NE Multnomah Street, which would have a 16-ft vertical clearance.

On the east side, the existing Rose Quarter and Interstate/Rose Quarter Stations would be consolidated and relocated to a new elevated station. This would provide an opportunity to reconfigure traffic circulation around the Rose Quarter. Refinements to the roadway geometry and potential redevelopment could improve the LRT geometry. On the west side, constraints would include the existing ODOT building, historic structures, and the street system. The Old Town/Chinatown Station would be eliminated because the track would not return to grade until Burnside Street. Couch Street would be closed at 1st Avenue, where the new tracks would be on retained fill.

The bridge, as designed, would be both high and long (to reduce effects on LRT during construction and allow for navigational clearance to the nearby Steel Bridge). It would have a movable span (to accommodate U.S. Navy ships). This footprint is not ideal. A lower replacement bridge, combined with UPRR freight rail, warrants future development. In addition, with Coast Guard concurrence, TriMet could evaluate bridge designs that do not accommodate some U.S. Navy ships. The movable span provides 38 feet more vertical clearance than the top deck of the existing Steel Bridge, so bridge lifts for ships are expected to be infrequent.

4.2.2 Cost of Concept

The representative New Bridge Concept would cost between $300m and $650m.

4.2.3 Ridership, Travel Time, and System-Operations Considerations of Concept

The New Bridge Concept addresses redundancy, eliminates rail to vehicle/pedestrian conflicts, and improves operations. The concept would increase systemwide boardings by approximately 3,000 per day. Travel times would be reduced primarily by eliminating the Old Town/Chinatown Station. OTP is expected to remain approximately 86 percent, just shy of TriMet's 90-percent target through 2040.[6] Some train congestion and delay would be anticipated because of the slow curves at the east end of the new bridge, the new station platform at Rose Quarter, and Green Line crossovers between the Banfield and Mall alignments.

6 OTP includes all lines operating between the Skidmore Fountain Station, NW 5th/Davis Station, NW 6th/Couch Station, and Hollywood Transit Center.

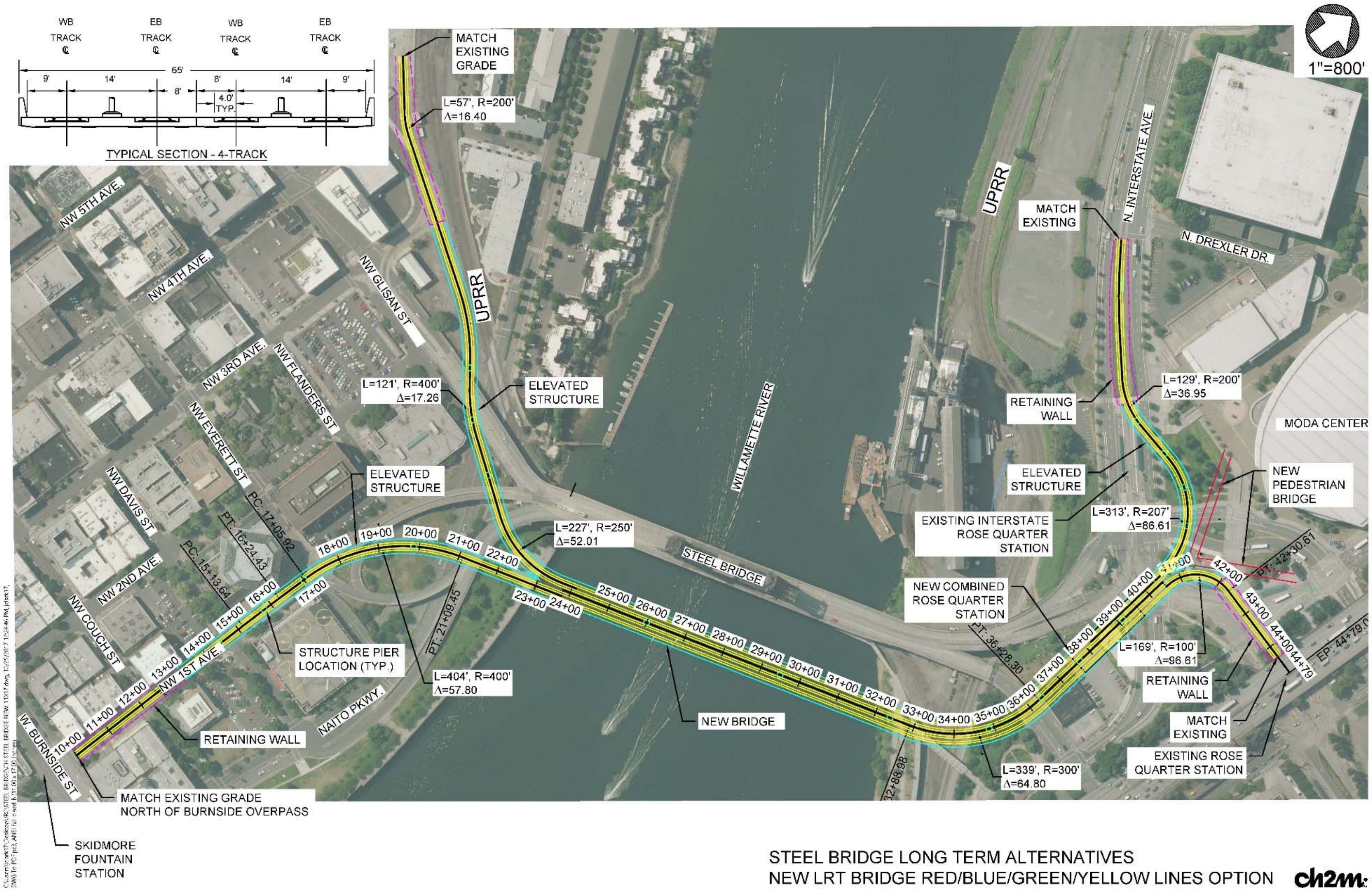

Figure 4-3. New Bridge Concept

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4.2.4 Seismic Resiliency of Concept

A new bridge would be constructed to current seismic standards and is the only alternative that would eliminate TriMet's dependence on the Steel Bridge.

4.2.5 Viability of Concept

The New Bridge Concept is viable. It provides operational and capacity benefits and reduces reliance on the existing Steel Bridge. It appears that an alignment between the Steel Bridge and Burnside Bridge is most promising due to land use constraints on east and west of the Willamette River. Navigational issues including the lift span would need to be considered. Potential variations (including replacing the Steel Bridge with a new lower bridge for all modes) could be considered in partnership with UPRR and other agencies. This concept maintains the surface alignment, serves most existing LRT stations, and maintains current transfer points.

4.3 Supplemental Bridge Concepts

4.3.1 Description of Concept

The representative Supplemental Bridge Concept is a 2-track bridge with vertical clearance similar to that of the upper deck of the Steel Bridge. It would cross the river diagonally between Peace Memorial Park on the east side and NW Davis Street on the west side (Figure 4-4). The supplemental bridge would serve Blue/Red Lines only, while the Yellow/Green Lines would continue to operate on the Steel Bridge. The concept could also include a seismic retrofit of the Steel Bridge because the Yellow/Green lines would continue to operate on the Steel Bridge. The supplemental bridge would include a lift span to accommodate large ships. However, lifts and interruptions to LRT services would be infrequent.

The Old Town/ Chinatown Station would be eliminated because the track would not return to grade until Burnside Street. Couch Street would be closed at 1st Avenue.

A potential variation of this Supplemental Bridge Concept would be to install Blue/Red Lines on a replacement Burnside Bridge. The design team considered potential options for this, but determined that the connections to the existing alignment on both ends of the bridge might be geometrically infeasible without the removal of existing buildings.

With this Supplemental Bridge Concept, the horizontal and vertical clearances at the Harbor Wall would be insufficient for U.S. Navy ships and would limit anchoring opportunities along the wall. These navigational restrictions would represent disadvantages related to this alternative.

4.3.2 Cost of Concept

A cost analysis was not prepared because it is likely that the Supplemental Bridge Concept is not viable.

4.3.3 Ridership, Travel Time, and System-Operations Considerations of Concept

This Supplemental Bridge Concept would improve reliability at the Rose Quarter and would reduce congestion, reduce conflicts, and improve signal timing.

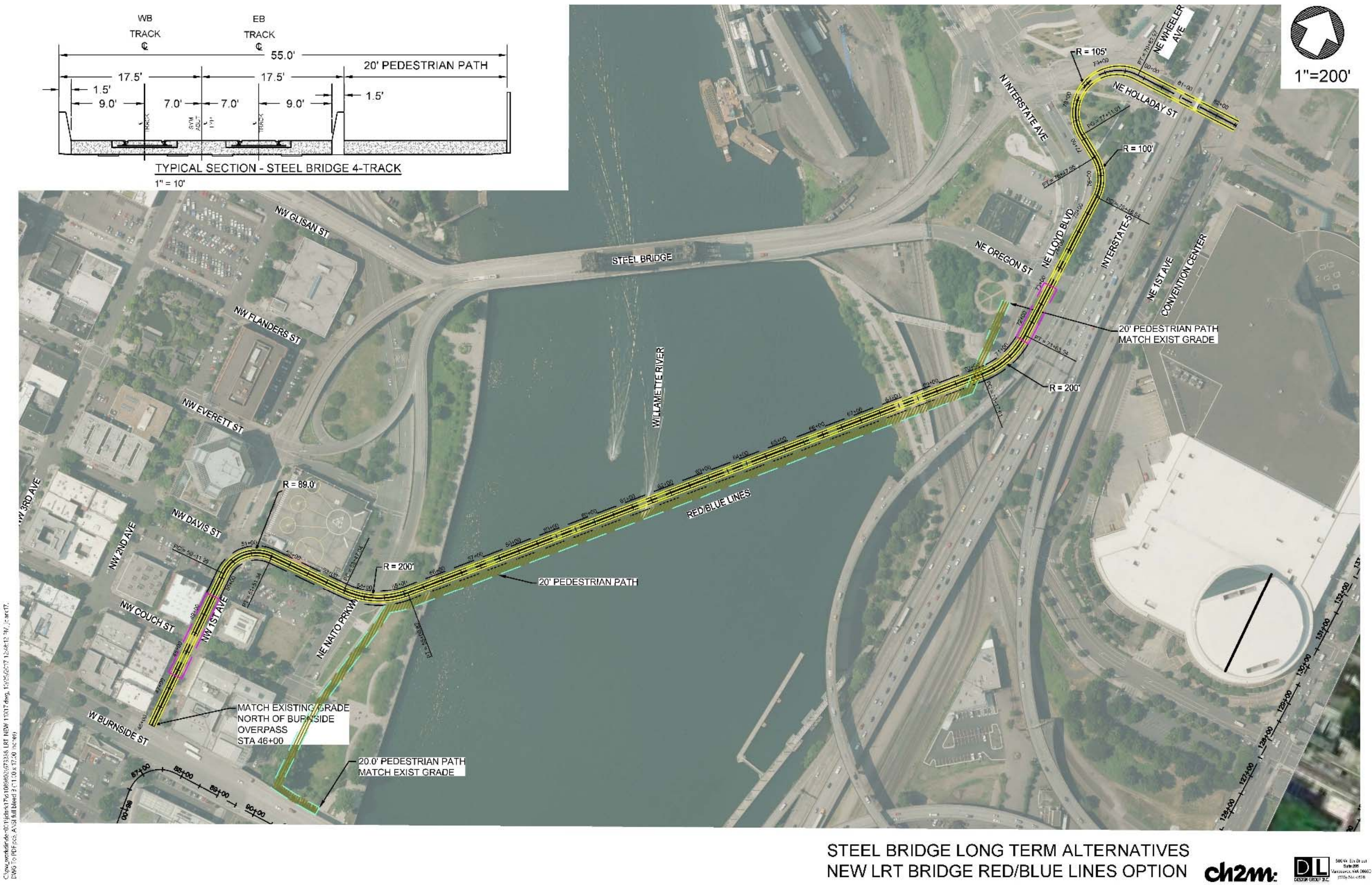

Figure 4-4. Supplemental 2-Track Bridge Concept
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4.3.4 Seismic Resiliency of Concept

This supplemental Bridge Concept addresses redundancy. However, TriMet would still depend on the Steel Bridge to maintain LRT service. Conditions would be subject to the Steel Bridge's seismic resiliency, structural feasibility, and constructability because of its age (105 years), similar to the Existing Steel Bridge Concept conditions. With an additional bridge, operations and maintenance would be required on two bridges. TriMet would likely need to address seismic upgrades of the Steel Bridge in addition to construction of a new bridge.

4.3.5 Viability of Concept

The Supplemental Bridge Concept is not a viable concept due to navigational clearance and the restricted ability for vessels to anchor at the harbor wall. The concept also requires continued use of the Steel Bridge, creating additional maintenance and operations costs.

4.4 Tunnel Concepts

4.4.1 Description of Concept

This representative Tunnel Concept consists of a high-speed tunnel from Lloyd District to Goose Hollow that would bypass most downtown stations (Figure 4-5). Either Red or Blue, or Red and Blue Lines would use the twin-bored tunnels. It would have a west portal on Jefferson Street near SW 16th Avenue (the alignment would go under Interstate 405 [I-405]) and an east portal near NE Holladay Street and NE 16th Drive.

The tunnel would cross above the eastside combined sewer overflow (CSO) pipe and under the westside CSO pipe (18-ft-6-inch inner diameter) with a portal at Holladay Street. The representative Tunnel Concept assumes a 100-ft-by-100-ft area for station construction access, requiring both in-street and off-street space. To maintain LRT service during construction, TriMet would construct temporary tracks on Lloyd Boulevard between NE 7th Avenue and NE 13th Avenue.

The representative Tunnel Concept includes new underground stations at Lloyd Center, Rose Quarter, Union Station, Pioneer Square, and the Park Blocks. [7] These stations were designed to accommodate 4-car trains. The remaining lines (Orange, Green, Yellow, and, possibly, Blue or Red) would use existing surface alignments and serve existing stations. Ridership modeling assumes about a 2-minute access time to tunnel stations.

Because it would remove trains and train-to-train conflicts from the surface network, the Tunnel Concept would provide high-speed service for the lines in the tunnel and would increase the overall system capacity. The tunnel would also provide a redundant east/west connection to cross the river if the Steel Bridge or portions of the downtown trackway were closed.

4.4.2 Cost of Concept

Based on the cost of similar rail tunnels, the estimated cost of the proposed twin-bore tunnel concept would be between $900m and $1,940m. This estimate includes the 2017 cost of design and construction, allocations for city street improvements at the portals, and ground improvements. The cost of retrofitting existing stations to accommodate 4-car trains outside of the tunnel was not included in these estimates.

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[7] These underground station locations were developed with input from TriMet and City of Portland.

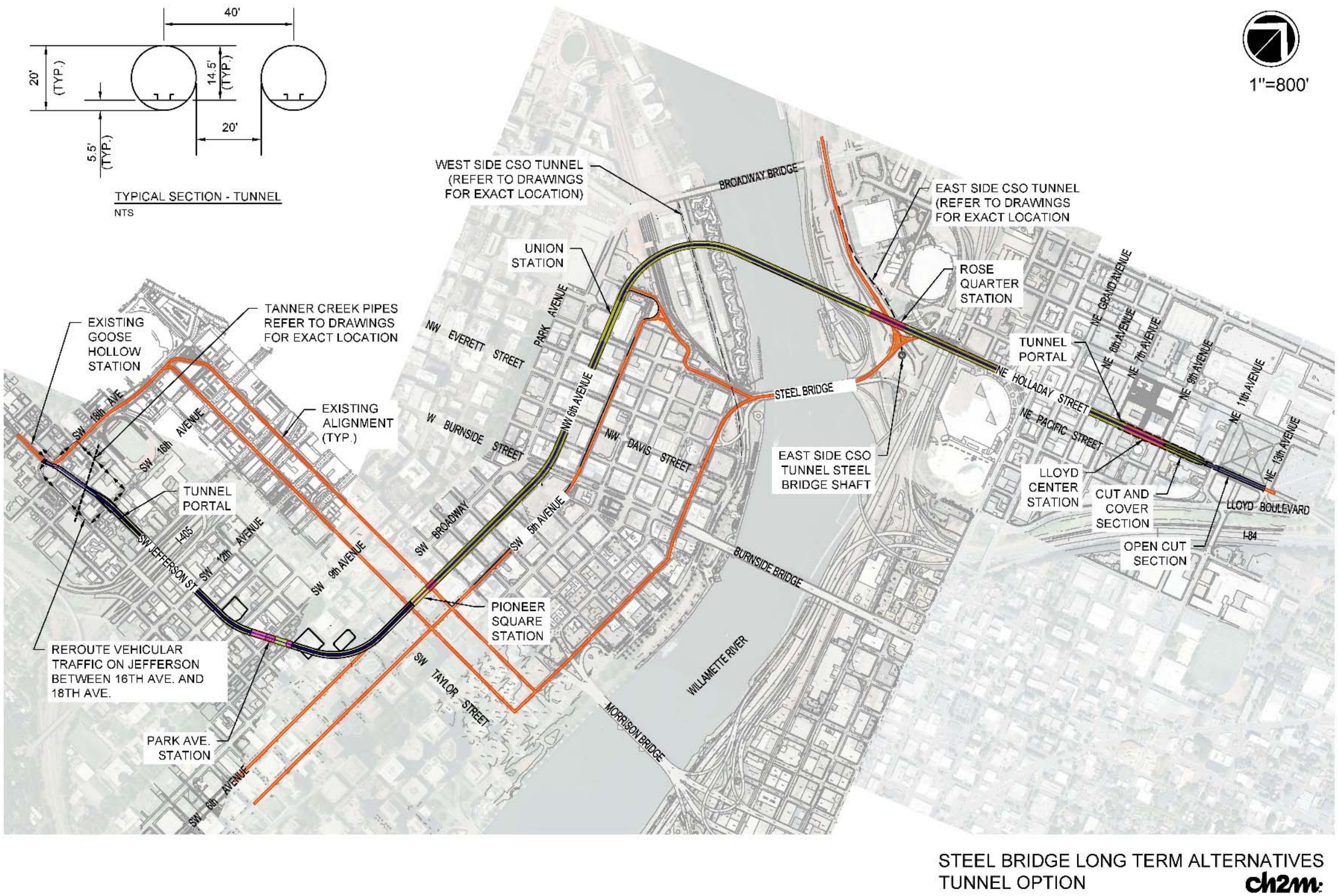

Figure 4-5. High-Speed Downtown Bypass Tunnel from Lloyd District to Goose Hollow Concept
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4.4.3 Ridership, Travel Time, and System-Operations Considerations of Concept

This Tunnel Concept would benefit trips traveling from the east side to the west side and to the central business district. This concept would save about 15 minutes of travel time for riders using the tunnel. The Tunnel Concept could increase ridership between 7,600 and 15,200 boardings, depending on the lines routed through the tunnel. Additional analysis of ridership would be required to determine if stations outside of the tunnel would need to be modified to accommodate 4-car trains.

Results of the RTC Model with the Blue Line in the tunnel indicate that OTP would reach 97 percent for all lines (tunnel and surface) within the study area by reducing conflicts. The Blue Line has the highest ridership of any line, so routing the Blue Line through the tunnel would remove the most trains from the surface alignment, improving performance for the remaining lines.

Refer to Appendix L, Long-Term Refinement and STOPS Model Summary, Updated 12/8/17, and Appendix I, Steel Bridge Transit Improvements (SBTI) Rail Traffic Controller (RTC) Alternatives Assessment for trip data and OTP.

4.4.4 Seismic Resiliency of Concept

Tunnels generally behave extremely well in seismic events because they move with the ground. Risks associated with tunnels include constructability adjacent to or under the river or building foundations. Common risks for tunneling projects require identification and mitigation throughout the design and construction phases. Portal security must also be considered and monitored during operations.

This concept maintains surface operations and use of the Steel Bridge for the Yellow and Green Lines. As such, a seismic retrofit of the existing bridge might be considered to provide a more resilient system.

4.4.5 Concept Variations

The representative Tunnel Concept could be modified in many ways. At the east portal, the feasibility of a temporary shoefly onto NE Lloyd Boulevard could be one way to maintain service during construction. The Tunnel Concept makes assumptions about the number and location of stations; these assumptions would need to be examined in more detail. Future design developments should consider several variations to reduce conflicts at the portals and to optimize system performance, including the following:

- **Eastside portal.** Shift portal east of NE 13th Avenue and construct a new 2-track LRT bridge over NE 16th Avenue and the UPRR tracks. This option would require reconstructing the Interstate 84 (I-84) off-ramp and structure to shift it south.
- **Westside portal.** Grade-separate LRT from vehicles and bikes at the SW 18th Avenue roundabout. Given the steep grades on SW Jefferson Street to the west, a potential solution could include realigning the intersection for autos and active modes over LRT.

4.4.6 Viability of Concept

The Tunnel Concept is viable. It would require additional study of alignment, portal locations, and station locations to determine the optimal design.

SECTION 5

References

ASTM International. 2011. *ASTM E2516 – Standard Classification for Cost Estimate Classification System.*

Federal Transit Administration. 2013. *Simplified Trips-on-Project Software (STOPS)*.

Metro. 2014. *2014 Regional Transportation Plan*. Adopted September 11, 2014.

Appendixes

- Appendix A, Planning Framework
- Appendix B, Alternatives Workshop Matrix
- Appendix C, Rail Traffic Controller (RTC) Existing Conditions Model Summary Memo
- Appendix D, Long-Term Concept Refinement and Consolidation Memo and Concept Sketches
- Appendix E, Travel Demand – Existing Ridership Summary (SBTI), November 2016
- Appendix F, Long-Term Assessment Consolidation Rating Matrix
- Appendix G, Long-Term Concept Refinement and Simplified Trips-on-Project Software (STOPS) Model Summary Memo
- Appendix H, Rail Traffic Controller (RTC) Refinement and Sensitivity Analysis (Metro 2040 RTP) Model Summary Memo
- Appendix I, Steel Bridge Transit Improvements (SBTI) Rail Traffic Controller (RTC) Alternatives Assessment
- Appendix J, Structural Assessment of 4-Tracking Steel Bridge
- Appendix K, Planning-Level Cost Estimates
- Appendix L, Long-Term Refinement and STOPS Model Summary, Updated 12/8/17
- Appendix M, Steel Bridge Transit Improvements Staff List
- Appendix N, Alternative Plan Profiles