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Washington State Legislature Joint Transportation Committee

Independent Review of Cascadia Ultra High Speed Ground Transportation System

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LIST OF ABBREVIATIONS

CAGR	Compound Average Growth Rate
CONNECT	CONceptual NEtwork Connections Tool
DB	Design-Build
DBB	Design-Bid-Build
DBOM	Design-Build-Operate-Maintain
EJ	Economic Justice
FRA	Federal Railroad Administration
GDP	Gross Domestic Product
HSR	High-Speed Rail
JTC	Joint Transportation Committee
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
OD	Origins and Destinations
SAAS	Software-as-a-Service
SP	Stated Preference
TREDIS	Transportation Economic Development Impact System
WSDOT	Washington State Department of Transportation

1.0 EXECUTIVE SUMMARY

Since 2016, the Washington State Department of Transportation (WSDOT), in partnership with the State of Oregon, the Province of British Columbia, and Microsoft Corporation, has been investigating the feasibility of an ultra-high-speed ground transportation system (UHSGT) to connect major metro areas in the region (Vancouver, BC; Seattle, WA; Portland, OR) and points in-between and beyond. During that time, several studies (see Table ES.1) have examined the economic, financial, technological, operational, governance, and delivery challenges as well as the impacts and benefits. The overarching conclusion of these efforts is that a UHSGT will improve travel times, enhance transportation system capacity, reduce congestion, and improve economic vitality, allowing the region to make progress toward shared mobility, accessibility, environmental, and economic goals.

TABLE ES.1: EXISTING UHSGT STUDIES & SUPPORTING ANALYSIS TOOLS

STUDY	OVERVIEW	ANALYSIS TOOLS
Feasibility Study (2018)	• High-level assessment of high-speed north-south connections between Vancouver, Seattle, Portland • Includes East-West branch from Seattle-Spokane; additional connection from Portland to CA HSR system	Ridership, revenue, and costs assessment using CONceptual NEtwork Connections Tool (CONNECT) developed by the Federal Railroad Administration (FRA)
Business Case Analysis (2019)	• More detailed assessment of UHSGT routes/service alternatives, ridership & economic benefits • Outlines potential governance models	• Discrete choice ridership & revenue model developed by Steer Group • Economic benefits assessment using Transportation Economic Development Impact System (TREDIS) developed by EBP, Inc.
Framework Study (2020)	• Identifies UHSGT governance, operating structures, funding/financing strategies • Proposed recommendations for the preliminary environmental, conceptual engineering, and phasing	None

As the Washington State Legislature, through the Joint Transportation Committee (JTC), considers progressing the UHSGT concept toward a more advanced project development phase, it is prudent to conduct an independent, unbiased review of the assumptions underlying the findings of these previous studies to help inform next steps. Our charge was to conduct such an assessment of the proposed Cascadia UHSGT concept. We focused on three key questions:

1. Were the previous studies done properly and reasonably?
2. What other factors need to be evaluated when considering next steps in UHSGT development?
3. What are the lessons learned from other high-speed ground transportation systems that should inform next steps in UHSGT development?

We structured our review—and our answers to these three key questions—through a three-phase approach:

- **Due diligence analysis**, which analyzed whether the core work completed as part of the previous UHSGT studies was done properly and reasonably. We paid particular attention to the reasonableness of the data sources and assumptions used as inputs; the reasonableness of the outputs; the strengths and limitations of tools, methods, and approaches; the appropriateness of the benchmarks & peer systems used as sources of comparison; and potential data or analysis gaps that should be filled when considering next steps for UHSGT development.
- **Trade-off analysis**, which identified the factors that need to be understood by the JTC when considering next steps on the Cascadia UHSGT project, particularly as they relate to changes in ridership, costs (both capital and O&M), and economic benefits (both direct and indirect). Our trade-off analysis focused on describing the market, cost, economic, environmental, technology, and implementation factors for three potential high-speed rail scenarios:
  - **Incremental high-speed rail (HSR) service,** which mainly utilizes existing rail corridors similar to the Acela service in the Northeast Corridor.
  - **State of the art HSR service,** similar to the 200 mph+ systems in Europe and Asia on mainly newly constructed corridors.
  - **Hybrid HSR service,** which utilizes new infrastructure in rural areas and existing infrastructure in urban areas similar to the California High-Speed Rail Project.
- **Governance & procurement analysis**, which identified and assessed the range of governance, procurement, and delivery methods that can help move the Cascadia UHSGT project from concept to operations. This assessment was drawn from appropriate peer systems, most notably the California High Speed Rail Project. We focused our analysis on factors that most significantly impact project development

timeframes, construction costs and impacts, public sector risk, and operational parameters.

1.1 OUR FINDINGS

Due Diligence Analysis

Overall, we found that the methods, assumptions, and analysis tools used to support existing UHSGT studies are consistent with industry standards, were appropriately built and applied, and generated reasonable results. However, there are features and assumptions that, while appropriate for the level of analysis required to support the three existing UHSGT studies, are insufficient for the types of investment grade analyses that are required to support advanced project development activities. Several elements, described below, should be addressed if and when a more detailed analysis is conducted on the proposed system:

- **Survey methods**. The Business Case analysis (2019) uses the results of a stated preference survey to estimate the coefficients of its mode choice model. However, the survey sample was not necessarily fully representative of the current corridor travelers and in particular was skewed by a large portion of the sample who were recruited through social media and outreach channels. These recruits had significantly more favorable views of high-speed ground transportation than would likely exist in the full travel market. Impacts were diluted as part of the overall ridership analysis, but respondents should have been segmented out during the estimation of model parameters.
- **Induced demand estimates**. The Business Case analysis (2019) included an estimate for induced demand,[1] which increased the total ridership forecast by 12-14 percent. This is on the high side of accepted practice in North America. While this is not a fatal flaw, it should be noted as an area for additional empirical work as part of any future investment grade analysis.
- **Level of service/travel time assumptions**. We found that frequency assumptions are in line with expectations for a system of this size. However, average speeds and travel times—which are key inputs to ridership and revenue estimates—are likely on the faster end of the realistic range when compared to existing systems. In fact, the assumed maximum speeds are higher than any system currently in existence.
- **Economic impact considerations**. The economic impact assessment tool to support economic benefit analysis is among the industry standards. However, because the Portland metropolitan area was not included in the model, the full economic impacts are likely underreported.

[1] Induced demand is the phenomenon whereby construction or expansion of transportation infrastructure leads to an increase in overall demand for travel.

- **Cost assumptions**. We find the previous estimate of capital costs to be unreasonably low in 2023 due to the following factors:
  - **Escalating overall construction costs**: There have been significant increases in construction costs for infrastructure projects in the past five years. From February 2018 through April 2023, the Saint Louis Federal Reserve's Producer Price Index for Non-Residential Construction has risen by over 50%.[2] ***This means that absent any other changes, the $24B-42B capital cost estimates presented in the 2018 study would now be equivalent to $36B-63B capital costs in 2023 dollars given the overall rise in construction prices.***
  - **Tunnel construction costs**: The estimate included in the Feasibility Study (2018) assumes that tunnels can be constructed for approximately $230M per mile for high-speed rail service. Recent tunnel construction projects both within and outside Washington suggest that number may be too low (notwithstanding general escalation in construction costs as noted in the first bullet). This is also exacerbated by the fact that many of the tunnels would be expected to be constructed in complex, highly urbanized areas. ***All these factors suggest that tunnels would be expected to cost closer to $450M per mile to construct***.
  - **Extent of tunneling**: While the previous studies estimate there is significant tunneling needed for a 200 mph+ high speed rail line, it is likely that even more extensive tunneling will be needed once detailed design is completed. This is due to the lack of current 200 mph+ rights of way in nearly all urban areas of the corridor from Vancouver to Portland. ***Tunnels are conservatively estimated to be needed for 200 mph+ operations in 80-90 miles of alignment for which current rights-of-way do not seem feasible for high-speed operations.*** There are less costly alternatives to much of this tunneling (described in more detail in Section 4.0), but they involve fewer stations or slower speeds, which have direct implications for travel time, ridership, and overall project benefits.

Trade-Off Analysis

Both a "state-of-the-art" high-speed rail system (new infrastructure, dedicated corridor) and "hybrid" (mix of existing & new corridors) would generate improved ridership and economic benefits as compared to an "incremental" scenario (existing infrastructure, shared corridor). But costs to achieve these benefits vary widely, driven primarily by the following:

- **Construction and operational complexity**. The amount of tunneling is a major cost driver, as noted previously. The state-of-the-art concept assumed a high percentage of tunnel through developed areas to avoid significant amounts of property acquisitions and community impacts. The hybrid concept replaced the tunnel sections in the state-of-the-

[2] https://fred.stlouisfed.org/series/WPU801

art scenario with improvements in the existing Amtrak Cascades corridor. These two concepts were meant to represent minimum and maximum amounts of tunneling. The actual route would likely include both tunnels and aerial structures in constrained areas. Operationally, sharing any amount of the existing corridor would require coordination during construction and operations to ensure that other operators are not impacted. There would also be a need for significant third-party coordination with corridor landowners, cities, and major utilities similar to other major infrastructure projects.

- **Environmental and community impacts**. Constructing an entirely dedicated corridor would require large amounts of property acquisitions and would likely result in significant community and environmental impacts. These impacts could be greatly reduced by using the existing corridor in more developed, urban areas, with the trade-off being a loss of speed.

Governance & Procurement Analysis

We found the governance analysis included in the Framework for the Future study (2020) to be sound. However, that the timeframes required to establish governance frameworks, secure financing, and deliver a mega-project are long, typically measured in decades (not years). This is particularly true for cross-border investments, which present unique challenges in governance, community mitigation requirements (US vis-à-vis Canada), and permitting.

Several procurement methods have been used to design, build, and operate similar systems, including traditional and alternative methods. Traditionally, public agencies have taken on the greatest risk and funding/financing responsibilities, but they are increasingly using alternative methods that transfer some of those risks and costs to the private sector, which bring opportunities for reduced cost, increased efficiency, and improved quality. The Gordie Howe International Bridge project serves as an excellent model of a multinational governance structure for a complex megaproject (see text box).

CASE STUDY

The Gordie Howe International Bridge project followed a two-step model, starting with an informal partnership agreement. A joint international authority, which established important provisions for design, construction, financing, operation and maintenance was then created by a formal project agreement. It took a decade-and-a-half of planning, environmental review, and permitting to finally reach the procurement stage (design-build-finance-operate-maintain), and the procurement process itself took another three years.

2.0 INTRODUCTION AND BACKGROUND

Since 2016, the Washington State Department of Transportation (WSDOT), in partnership with the State of Oregon, the Province of British Columbia, and Microsoft Corporation, has been investigating the feasibility of an ultra-high-speed ground transportation system (UHSGT) to connect major metro areas in the region (Vancouver, BC; Seattle, WA; Portland, OR) and points in-between and beyond. During that time, several studies (see text box) have examined the economic, financial, technological, operational, governance, and delivery challenges, impacts, and benefits. The overarching conclusion of these efforts is that a UHSGT will improve travel times, enhance transportation system capacity, reduce congestion, and improve economic vitality, allowing the region to make progress toward shared mobility, accessibility, environmental, and economic goals.

RECENT UHSGT STUDIES

- Ultra-High-Speed Ground Transportation Study - 2018
- Ultra-High-Speed Ground Transportation Business Case Analysis – 2019
- Cascadia Ultra-High-Speed Ground Transportation: Framework for the Future - 2020

But while the UHSGT concept enjoys some support from regional businesses, potential travelers, and other stakeholders, moving into a more advanced project development phase represents a significant investment. It is prudent for the Washington State Legislature, through the Joint Transportation Committee (JTC), to conduct an independent, unbiased review of the assumptions underlying the findings of these previous studies to help inform next steps.

Our charge was to conduct such an assessment of the proposed Cascadia UHSGT concept. We focused on three key questions:

- Were the previous studies done properly and reasonably?
- What other factors need to be evaluated when considering next steps in UHSGT development?
- What are the lessons learned from other high-speed ground transportation systems that should inform next steps in UHSGT development?

Subsequent sections describe our findings, as well as suggestions for the JTC to address when considering if and how to move forward on a UHSGT system in the Cascadia region.

Guiding Documents

We focused our review on the assumptions, tools, and methods utilized in the three UHSGT studies completed by WSDOT, each of which is summarized in Table 2 and described in detail below.

TABLE 2: EXISTING UHSGT STUDIES & SUPPORTING ANALYSIS TOOLS

STUDY	OVERVIEW	ANALYSIS TOOLS
Feasibility Study (2018)	• High level assessment of high-speed north-south connections between Vancouver, Seattle, Portland • Includes east-west branch from Seattle-Spokane; additional connection from Portland to CA HSR system	Ridership, revenue, and costs assessment using CONceptual NEtwork Connections Tool (CONNECT) developed by the Federal Railroad Administration (FRA)
Business Case Analysis (2019)	• More detailed assessment of UHSGT routes/service alternatives, ridership & economic benefits • Outlines potential governance models	• Discrete choice ridership & revenue model developed by Steer Group • Economic benefits assessment using Transportation Economic Development Impact System (TREDIS) developed by EBP, Inc.
Framework Study (2020)	• Identifies UHSGT governance, operating structures, funding/financing strategies • Proposed recommendations for the preliminary environmental, conceptual engineering, and phasing	None

UHSGT Study (2018)

The Ultra-High-Speed Ground Transportation Study (Feasibility Study) was led by CH2M-Hill (now Jacobs) and published in 2018. The Feasibility Study provides an initial, “sketch-level” assessment on the possibility of high-speed ground transportation between Portland, Seattle, and Vancouver. It examines the potential for development of UHSGT for five conceptual north-south corridors connecting Portland, Seattle, and Vancouver. It incorporates one possible east-west connecting corridor from Seattle to Spokane and also evaluates a conceptual high-speed rail extension from Portland to Sacramento that would connect to the California high-speed rail system.

The Feasibility Study uses a CONNECT[3] model to estimate ridership, revenue, and costs for a system serving the Vancouver to Portland corridor. The six sets of results involve two technologies- high speed rail (HSR) and maglev- separately considered for three scenarios, described in Table 3.

TABLE 3: UHSGT FEASIBILITY STUDY: CONCEPTUAL CORRIDORS

CORRIDOR CONCEPT	NEAREST STATION LOCATIONS	DEFINING CHARACTERISTICS
1A	• Vancouver International Airport – Vancouver, BC • Fairhaven Station – Bellingham, WA Everett Station – Everett, WA Stadium Station – Seattle, WA Tacoma Dome Station – Tacoma, WA Centennial Station – Lacey, WA • Rose Quarter Station – Portland, OR	• Combinations of urban core and periphery stations • Airport station in Vancouver, BC • All seven cities identified in legislation • 283 miles (455 km)
2	• Pacific Central Station – Vancouver, BC Stadium Station – Seattle, WA • Tacoma Dome Station – Tacoma, WA • Portland International Airport, Portland, OR	• Fewer potential stations • Major stations in 4 largest cities • Airport station in Portland, OR • 282 miles (454 km)
4	King George Station – Surrey, BC Tukwila Station – Tukwila, WA Expo Center Station – Portland, OR	• Fewest potential stations with 3 potential station locations • Station locations in urban periphery outside of 3 largest cities • Does not include airport station location • 270 miles (435 km)

Source: CH2M, 2017, Ultra High-Speed Ground Transportation: Corridor Concepts

[3] CONNECT was developed for FRA as a sketch planning tool to estimate the performance of passenger rail corridors and networks. It estimates order of magnitude ridership, revenue, and costs and is intended for use during the initial stages of the planning process

The hypothetical system would have 12 trains per day, with up to four of these trains considered express service (i.e., only stopping in Vancouver, Seattle and Portland). Assumed speeds range from 177-299 mph and estimated travel times range between 58-96 minutes for the full length of the corridor between Vancouver and Portland, depending on the respective scenario and technology.

To estimate economic impacts relating to construction, operation and maintenance (O&M), and agglomeration, the Feasibility Study uses the Transportation Economic Development Impact Study, referred to as TREDIS. TREDIS is among the industry standards for transportation economic evaluation. The tool is used to conduct economic impact analysis, benefit-cost analysis, and financial analysis for transportation projects and programs. The TREDIS model developed for the UHSGT Study considers the metropolitan areas of Vancouver, BC and Seattle, Washington and summarizes benefits in the number of jobs, labor income, business output and gross domestic product (GDP) based on construction and operations and maintenance of the project as well as the market access benefits due to faster travel times and better access.

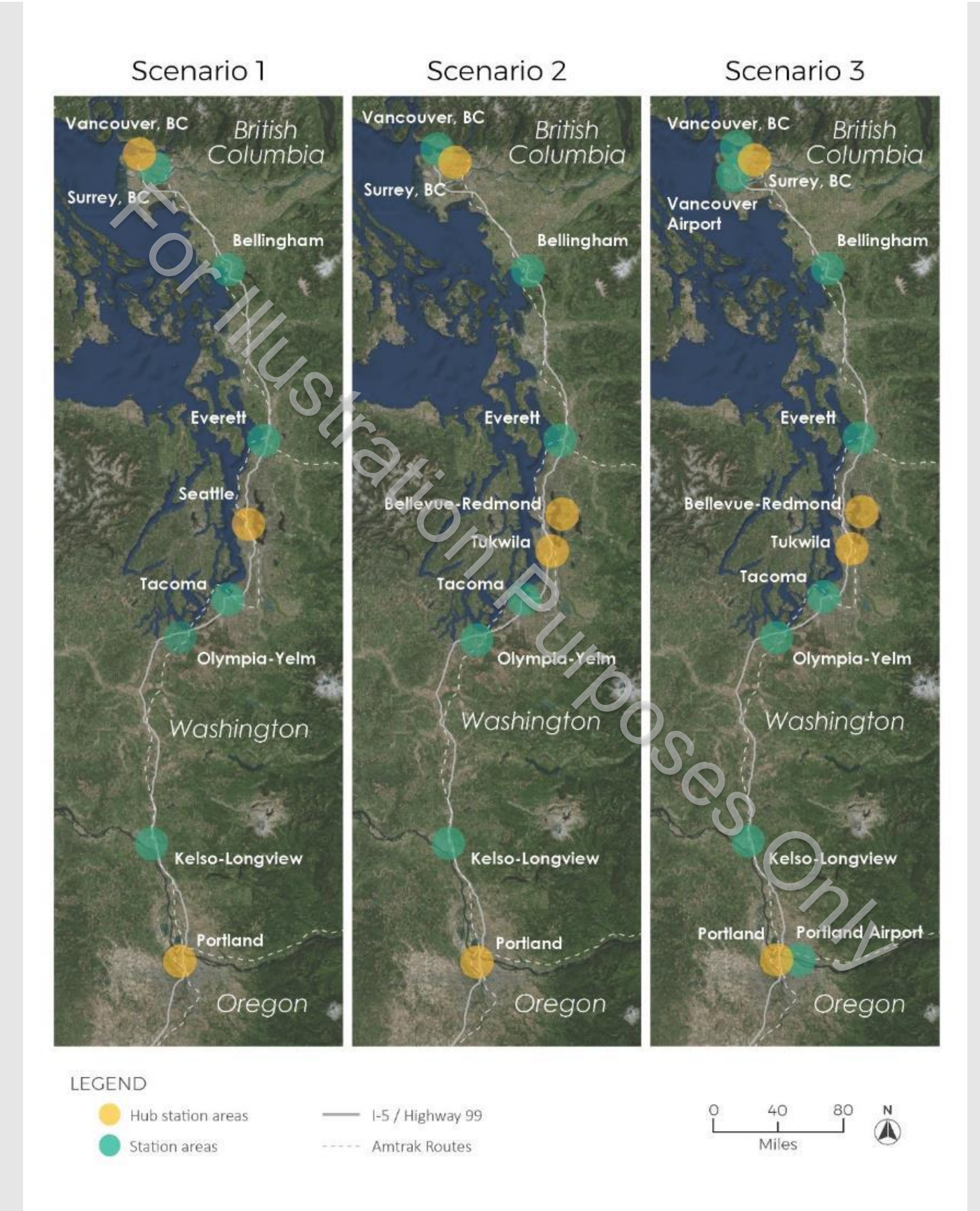
UHSGT Business Case Analysis (2019)

The Ultra-High-Speed Ground Transportation Business Case Analysis (Business Case) was prepared by WSP and published in 2019. The Business Case is significantly longer, broader, and deeper than the Feasibility Study. This Business Case analysis is informed by a series of technical reports that include:

- An economic benefit analysis that evaluates the monetizable user and social benefits associated with the project and broader economic benefits across the Cascadia megaregion;
- A planning analysis that lays out conceptual service attributes, hypothetical routes, and potential major and minor station locations;
- A funding and financing strategy; and
- A governance report that includes recommendations for potential multi-jurisdictional governance models structured to effectively deliver and manage the proposed system.

The Business Case uses a discrete choice model developed specifically for this corridor by the Steer Group to estimate ridership and the corresponding system revenue and costs. There are nine scenarios (as shown in Figure 1 and Table 4), with each having 21 trains per day and a varying number of stations (including Vancouver, BC, Bellingham, Seattle, Bellevue/Redmond, Tacoma, Olympia, and Kelso-Longview, WA, as well as Portland, Oregon). Between 9 and 21 of these trains will be considered express trains that only service Portland, Seattle, and Vancouver. Maximum speeds are estimated at up to 250 mph. Average expected speed ranges from 127 to 154 mph for base service and 143 to 184 mph for express service. Estimated travel times from Portland to Vancouver range from 116 to 150 minutes for base and 97 to 133 minutes for express service.

FIGURE 1: ILLUSTRATIVE UHSGT SCENARIOS WITH KEY STATION AREAS



Source: UHSGT Business Case

In total, nine scenario variations were developed for subsequent ridership modeling and were linked to market and socioeconomic factors as well as serving different potential station areas. Table 4 provides a summary of the stations served by each scenario variation.

TABLE 4: SUMMARY OF STATIONS SERVED BY SCENARIO VARIATION

STATION	1A	1B	1C	1D	1E	2A	2B	2C	3
Vancouver Airport, BC	–	–	–	–	–	–	–	–	●
Vancouver, BC	●	●	●	●	–	●	●	–	●
Surrey, BC	●	●	–	●	●	●	●	●	●
Bellingham, WA	●	●	–	●	●	●	●	–	●
Everett, WA	–	●	–	●	–	–	●	–	–
Bellevue/Redmond, WA	–	–	–	–	–	●	●	●	●
Seattle, WA	●	●	●	●	●	–	●	–	–
Tukwila, WA	–	–	–	–	–	●	●	–	●
Tacoma, WA	–	●	–	●	–	–	●	–	–
Olympia/Yelm, WA	●	–	–	–	●	●	–	–	●
Olympia, WA	–	●	–	●	–	–	●	–	–
Kelso/Longview, WA	●	●	–	●	●	●	●	–	●
Portland, OR	●	●	●	●	●	●	●	●	●
Portland Airport, OR	–	–	–	–	–	–	–	–	●

Source: UHSGT Business Case

Cascadia UHSGT Framework for the Future (2020)

The Cascadia Ultra High Speed Ground Transportation Framework for the Future (Framework Study) was prepared by WSP USA, IMG Rebel, Enviroissues, and DHM Research for the WSDOT at the end of 2020. This effort identified UHSGT governance, operating structures, funding/financing strategies, and proposed recommendations for the preliminary environmental, conceptual engineering, and phasing activities required in the next stage of UHSGT development.

Our Approach

We structured our review -- and our answers to the three key questions described earlier -- through a three phased approach, consisting of the following elements and described in more detail below:

- Due diligence analysis.
- Trade-off analysis.
- Potential governance & procurement approaches.

Due Diligence Analysis

Was work done reasonably?

The objective of our due diligence analysis is to ensure that the core work completed as part of the previous UHSGT Studies was done properly and reasonably. We **paid particular attention to the reasonableness of the data sources and assumptions used as inputs; the reasonableness of the outputs; the strengths and limitations of tools, methods, and approaches; the appropriateness of the benchmarks & peer systems used as sources of comparison; and potential data or analysis gaps that should be filled when considering next steps for UHSGT development.**

Trade-Off Analysis

What factors should be considered?

The objective of our trade off analysis was to identify the factors that need to be understood by the JTC when considering next steps on the Cascadia UHSGT Project, particularly as they relate to changes in ridership, costs (both capital and O&M), and economic benefits (both direct and indirect).

Our trade-off analysis focused on describing the market, cost, economic, environmental, technology, and implementation factors for three potential scenarios:

- **Incremental high-speed rail (HSR) service,** which mainly utilizes existing rail corridors similar to the Acela service in the Northeast Corridor (Boston-Washington DC).
- **State of the art HSR service** equivalent to the latest 200 mph+ systems in Europe and Asia on mainly newly constructed corridors. The speeds and levels of service assumed within the 'state of the art' scenario most closely align with the UHSGT system evaluated in previous studies.
- **Hybrid HSR service,** which utilizes new infrastructure in rural areas and existing infrastructure in urban areas similar to the California High-Speed Rail Project.

A NOTE ON METHODS

The three existing UHSGT studies were "technology agnostic," and considered a range of technologies that could meet the objective of one hour travel times between major city pairs (Vancouver, Seattle, and Portland). However, because our assessment indicates that only high-speed rail (HSR) technologies are sufficiently mature to be reasonably viable, we focused our trade-off analysis on HSR services.

Our analysis relied on the existing UHSGT studies to the extent possible, while also integrating best practices from around the world and new sketch-level analysis for the corridor as needed.

Potential Governance & Procurement Approaches

What are the lessons learned from others?

Finally, we identified and assessed the range of governance, procurement, delivery methods (e.g., traditional, design-build, construction manager at risk), and finance methods (e.g., public, PPP, private), that can help move the Cascadia UHSGT project from concept to operations. This assessment was drawn from appropriate peer systems, most notably the California High Speed Rail Project. We focused our analysis on factors that most significantly impact project development timeframes, construction costs and impacts, public sector risk, and operational parameters.

The following sections describe our findings in each one of these analysis elements.

3.0 DUE DILIGENCE ANALYSIS

The objective of our due diligence analysis is to ensure that the core work completed as part of the previous UHSGT Studies was conducted properly and reasonably. We focused our analysis on the topics and assumptions shown in Table 5 below, paying particular attention to the reasonableness of the data sources and assumptions used as inputs; the reasonableness of the outputs; the strengths and limitations of tools, methods, and approaches; the appropriateness of the benchmarks & peer systems used as sources of comparison; and potential data or analysis gaps that should be filled.

TABLE 5: SUMMARY OF DUE DILIGENCE ANALYSIS AREAS

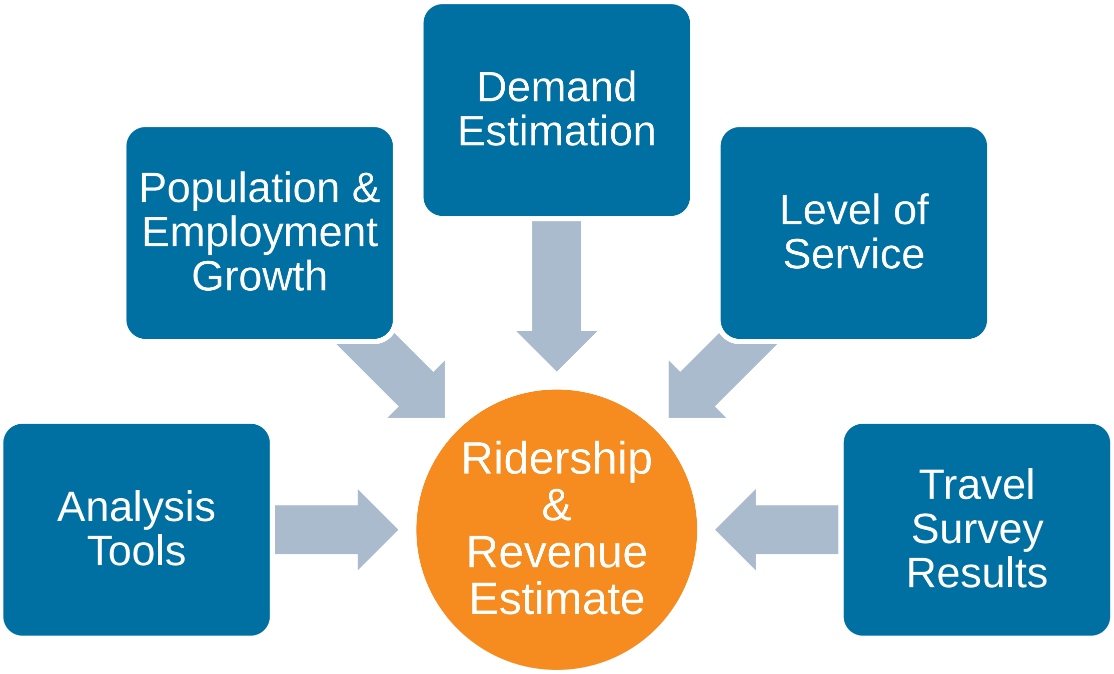
TOPIC AREA	ANALYSIS ELEMENTS
Ridership & Revenue Analysis	• Analysis tools • Population & employment forecasts • Demand estimation • Level of service assumptions • Travel survey process/results • Ridership, mode share, & revenue results
Cost Analysis	• Capital costs • Operations & maintenance costs • O&M cost recovery ratio
Economic Impact Analysis	• Analysis tools • Construction impacts • O&M impacts • Market access impacts • Operational Impacts

Finally, we provide some additional context for our analysis and review by discussing impacts of the COVID-19 pandemic on travel demand forecasting and current travel trends in the Cascadia region.

3.1 RIDERSHIP AND REVENUE ANALYSIS

Ridership and revenue estimates are derived from a series of inputs, as shown in Figure 2.

FIGURE 2: KEY INPUTS TO RIDERSHIP & REVENUE



Overall, we found ridership and revenue estimates to be reasonable. However, we did discover issues and limitations within several of the input elements, as described in the sections below.

Analysis Tools

***Key Finding**: We found that the analysis tools used to support the existing UHSGT studies, which are generally considered to be within the industry standards, were appropriately built and applied and generated reasonable results. However, while appropriate for high level ridership estimation, there are features and assumptions embedded within these tools that combine to limit their appropriateness for investment grade analysis. Any future analysis of these results should take this into consideration.*

As described earlier, two analysis tools were used to develop ridership and revenue estimates: the FRA CONNECT model (Feasibility Study) and a discrete choice model developed by Steer Group specifically for this corridor (Business Case). We found that these tools, which are generally considered to be within the industry standards, were appropriately built and applied and generated reasonable results. However, while appropriate for high level ridership estimation, there are features and assumptions embedded within these tools that combine to limit their effectiveness for investment grade analysis. Any future analysis of these results should take this into consideration.

This section describes and annotates the two different ridership and revenue analysis tools. Subsequent sections will assess the reasonableness of the inputs for each tool.

CONNECT Model

The Federal Railroad Administration's (FRA) Conceptual Network Connections Tool (CONNECT) is a high-level intercity passenger rail sketch planning tool that estimates overall performance of user-defined corridors and networks. It is intended for early-stage planning processes to compare corridors and enables a user to describe a potential high-performance rail network at a coarse level, estimate the financial and operational performance of the network, develop high-level service plans, and generate operational data.

The CONNECT tool was used to generate the ridership and revenue forecasts published in the Feasibility Study and helped to estimate the identified rail corridors and network performance for public benefits. The Feasibility Study evaluated high-speed (steel-wheel) rail, maglev, and hyperloop technology. Within this study, ultra-high-speed is defined as a maximum operating speed of >250 miles per hour (mph) (402 km/h).

CONNECT supplies corridor analysis outputs for three high-performance intercity passenger rail service tiers:[4]

- **Core Express** occurs in the densest and most populous regions of the US, with frequent trains ranging from 125 to 250+ mph (201 to 402+ km/h).
- **Regional** runs between mid-sized and large cities, with speeds ranging from 90 to 125 mph (145 to 201 km/h).
- **Emerging** connects communities to passenger rail networks and provides a foundation for future corridor development, with speeds up to 90 mph (145 km/h).

Because the CONNECT tool is a high-level sketch forecasting model, its results are appropriate for the level of planning completed in the Feasibility Study but would not be acceptable for an investment grade forecast. Primary limitations of the CONNECT tool include:

- **Lack of detailed population and employment data**. CONNECT tool ridership and revenue forecasts are primarily based on base year population and population growth forecasts. The model provides "default values" for many of these inputs to arrive at high level estimates of demand, revenue, and operating costs of a proposed sketch level system. Employment is not used as an input to the CONNECT model.

[4] The Feasibility Study only focused on the primary, north-south corridors as well as the connecting corridor from Portland to Sacramento, which are considered "Core Express" by CONNECT.

- **Generalized parameters**. Similarly, operating parameters such as service frequency and assumed rail speeds are based on general assumptions that are not necessarily specific to the corridor being analyzed.
- **Unconstrained analysis**. Finally, travel times, speeds, and station locations do not have any environmental or geographical limitations. This can result in unrealistic expectations on the ultimate costs associated with specific alignments, attainable speeds, and levels of service.

Application of CONNECT in the Feasibility Study

As discussed previously, ***we assess that the use of the CONNECT tool was appropriate to support the Feasibility Study and its application and assumptions were reasonable and in line with existing practice***.

The parameters in the CONNECT models prepared for the Feasibility Study do not deviate from the default parameters related to ridership estimation. While this was likely appropriate for the level of detail needed at the time, any future analysis of these results should take this into consideration. The CONNECT model does allow the user flexibility to create a fairly detailed cost estimate and many of the cost-related parameters were adjusted from the default parameters in the Feasibility Study to reflect local conditions and costs.

Steer Discrete Choice Model

The Business Case includes a discrete choice model-based ridership and revenue forecast developed by Steer specifically for a Cascadia high-speed rail network. The Steer forecast is based on a discrete choice model that calculates mode shares with model coefficients estimated from a stated preference survey that was performed specifically for the Cascadia corridor market.

Estimates for base demand and projected growth in demand for auto, air, rail, and bus modes were developed for the model using demographic data, estimates of current travel demand for air, rail, and auto modes, and outputs from other current travel demand models. Base travel demand was aggregated into 53 geographic zones each with their own travel demand and population growth properties as well as travel time estimates for each available travel mode. This allows for access time to high-speed rail and air modes to be considered based on travel times to the nearest rail station or airport and allows for competing drive times to be more representative of actual origin-destination drive times.

The discrete choice model predicts the share of trips that would switch to the new high-speed rail based on its service characteristics as well as those of a traveler’s current mode (auto, air, current rail or bus). The models include coefficients for travel time, cost, access time and rail frequency and are segmented by business and non-business trip purposes.

In addition to estimating new high speed rail trips that are shifted away from current travel modes, the Steer forecast includes an additional amount of induced demand which is then added to the results of the discrete choice model to create the final forecast.

Application of the Steer Discrete Choice Model in the Business Case

The Steer Discrete Choice Model provides more detailed results than the CONNECT model, which is appropriate for use in the Business Case analysis. As discussed previously, ***we assess that the use of the Steer Discrete Choice model was appropriate to support the Business Case and its application and assumptions were generally reasonable and in line with existing practice.*** And while such a model could be used to support higher level analyses, including investment grade studies, it would require more detailed population and employment inputs and address some other limitations, including:

- **Binary choice approach**. The model was developed using a binary mode choice approach, i.e., the model assumes that users are only choosing between the travel mode that they currently use and the future HSR mode. In addition, the coefficients of models for current bus and conventional rail riders were asserted based on studies conducted in other regions rather than based on Cascadia corridor travelers. This contrasts with the more commonly used multinomial (or “nested”) mode choice models that assume that travelers can shift among any of the available modes in response to changes in travel conditions. If the service levels of existing modes (i.e., auto, air, bus) change in the future, the use of simple binary mode choice models could result in inaccurate estimates of the use of the future HSR service.
- **Competing mode performance remains unchanged**. The Steer model includes an assumption that “journey times, frequencies, etc. are assumed to be unchanged from current/base year conditions, and prices and fares are constant in real terms.[5]” Because it is highly likely that air and bus fares and service levels, fuel prices and highway travel times will change in the future (but are unchanged in the model), this assumption could result in unrealistic forecasts of future mode shares.
- **Survey process**. The Steer work uses the results of a stated preference survey to estimate the coefficients of its mode choice model. As discussed later in this report, the survey sample was not necessarily fully representative of the current corridor travelers and in particular was skewed by a large portion of the sample who were recruited through social media and outreach channels.
- **Skewed constants**. The discrete choice models base their calculations of mode shares in part on the relative travel times, service frequencies and costs of competing travel

[5] Ultra-High-Speed Ground Transportation Business Case Analysis Appendix D. Assumptions Log. Page 72

modes (HSR vs. auto, air or bus). However, the models also include “mode-specific constants” as is common in most such models to represent factors beyond those measurable service levels that could affect mode choices. The mode-specific constants used in the binary choice models for the competing air, auto and bus modes are generally very favorable to HSR. This means that even with service levels just equal to those of the competing modes, HSR is being modeled as more attractive than those current modes. Since the estimates of the mode-specific constants are based directly on the survey responses, the more positive values are likely a result of the survey sample that appears to be skewed toward travelers with a predisposition to favor HSR.

Population and Employment Forecasts

***Key Finding**: We found the population and employment forecasts to be reasonable. We compared these population forecasts to several other available forecasts and found that the population and employment forecasts generally follow the forecasted consensus. This leads to a reasonable estimated base demand estimate.*

Demographic data, specifically population and employment data, are key inputs to the estimation of ridership demand. Typically, travel demand models use population and employment forecasts to estimate future travel demand. Different population and employment projections were used as inputs to the CONNECT model (Feasibility Study) and the Steer Discrete Choice model (Business Case). In addition, the forecast years also differed between the two studies: while both studies used a 2015 base year, the Feasibility Study used a 2055 forecast year while the Business Case forecast to 2040 (although extrapolations were provided to 2055). Despite these differences, ***we found the population and employment forecasts to be reasonable***, as described in the sections below.

Population

The population forecasts used as inputs to the CONNECT model to support the Feasibility Study are shown in Table 6, and the population forecasts used as inputs to the Steer Discrete Choice model (Business Case) are shown in Table 7. The two models use population forecasts a little bit differently – CONNECT uses population directly as an input to the model, while the Steer model uses population as one input to their base (no-build) demand profile.

Although the forecast years differ, the total calculated compound average growth rate (“CAGR”) for the entire Cascadia region is generally consistent between the two forecasts.

TABLE 6: POPULATION INPUTS IN THE CONNECT MODEL (FEASIBILITY STUDY)

METRO AREA	2015 (BASE YEAR) IN MILLIONS	2055 IN MILLIONS	CAGR (2015-2055)
Portland, OR	2.29	3.77	1.25%
Seattle, WA	3.56	5.54	1.11%
Vancouver, BC	2.50	3.47	0.82%
Total	**8.35**	**12.79**	**1.07%**

Source: UHSGT Feasibility Study

TABLE 7: POPULATION INPUTS IN THE STEER MODEL (BUSINESS CASE)

METRO AREA	2015 (BASE YEAR) IN MILLIONS	2040 IN MILLIONS	CAGR (2015-2040)
Portland	2.40	3.00	0.90%
Seattle	4.00	5.00	0.90%
Vancouver, BC	2.40	3.40	1.40%
Total	**8.80**	**11.40**	**1.04%**

Source: UHSGT Business Case

Comparison to Consensus Population Forecasts

We compared these population forecasts to other existing, official population forecasts in the region. Prior population forecasts described in Table 8 were obtained from various sources. Note that these existing sources only forecast as far as 2040:

- **Portland's population estimate** is derived from Oregon Metro's *2018 Growth Management Decision Urban Growth Report*. This forecast involves a low-end, a high-end, and a medium estimate and uses a 2038 forecast year.
- **Two Seattle forecasts were used in our comparison**. The first Seattle forecast listed, "PSRC", comes from Puget Sound Regional Council's *Vision 2040*, published at the end of 2009 and updated in 2022. An additional Seattle forecast, the 2017 State of Washington Office of Financial Management's *County Growth Management Population Projections by Age and Sex: 2010-2040*, includes a low-end, a high-end, and a medium estimate.
- The **Vancouver, BC forecast** originates from population projections within the 2021 Metro Vancouver *Growth Projection Tables*.

TABLE 8: PREVIOUS POPULATION FORECASTS (MILLIONS)

AREA	PSRC	LOW ESTIMATE	HIGH ESTIMATE	MEDIUM ESTIMATE	BUSINESS CASE[5]
Portland (2038)[1]	–	2.78	3.18	3.01	3.00
Seattle (2040)[2,3]	4.99	4.53	6.01	5.16	5.00
Vancouver (2040)[4]	–	–	–	3.56	3.40
Total	**–**	**–**	**–**	**11.73**	**11.40**

[1] Oregon Metro 2018 Growth Management Decision Urban Growth Report (https://www.oregonmetro.gov/sites/default/files/2018/12/03/2018_UGR-summary-11282018_v2pdf.pdf)
[2] Puget Sound Regional Council Vision 2040 (https://www.psrc.org/sites/default/files/2022-07/v2040.pdf)
[3] State of WA OFM County Growth Management Population Projections by Age and Sex: 2010–40 (https://ofm.wa.gov/sites/default/files/public/dataresearch/pop/GMA/projections17/GMA_2017_county_pop_projections.pdf)
[4] Metro Vancouver Growth Projection Tables (http://www.metrovancouver.org/services/regional-planning/data-statistics/data-projections/Pages/default.aspx)
[5] Business Case Analysis

Because official forecasts use 2040 as the forecast year, we could not directly compare existing population forecasts to those utilized in the Feasibility Study. However, we find that the population projections used in that study as well as the Business Case are reasonable and generally follow consensus forecasts in the Cascadia region. It should be noted, however, that regional forecasts like these can suffer from optimism and strategic bias because they serve in part as a basis for allocating transportation improvements and other infrastructure funds. In any future investment-grade ridership forecasting effort, will be useful to compare these consensus regional forecasts with forecasts available from Moody’s Analytics or other sources.

Employment

The employment forecasts used as inputs to the Steer Discrete Choice model (Business Case) are shown in Table 9. As discussed previously, employment is not used as an input to the CONNECT model, which uses population as its only market size input.

TABLE 9: BUSINESS CASE EMPLOYMENT (MILLIONS)

METRO AREA	BASE YEAR (2015)	2040	CAGR (2015-2040)
Portland	1.1	1.4	0.97%
Seattle	2.2	3.1	1.38%
Vancouver, BC	1.2	1.8	1.64%
Total	**4.5**	**6.3**	**1.35%**

Source: UHSGT Business Case Analysis

Comparison to Consensus Employment Forecasts

Again, we compared these employment forecasts to other existing, official forecasts in the region. Prior employment forecasts described in Table 10 were obtained from various sources:

- **Oregon Metro Growth Report**, which provides employment forecasts (to 2038) for the Portland metropolitan region;
- **PSRC Vision 2040**, which provides employment forecasts for the Seattle metropolitan region; and
- **Metro Vancouver Growth Projection Tables**, which provide forecasts for Vancouver, BC.

TABLE 10: PREVIOUS EMPLOYMENT FORECASTS (MILLIONS)

AREA	PSRC	LOW ESTIMATE	HIGH ESTIMATE	MEDIUM ESTIMATE	BUSINESS CASE[4]
Portland (2038)[1]	–	1.24	1.55	1.40	1.40
Seattle (2040)[2]	3.11	–	–	–	3.10
Vancouver (2040)[3]	–	–	–	1.78	1.80
Total	**–**	**–**	**–**	**–**	**6.30**

[1] Oregon Metro Urban Growth Report (https://www.oregonmetro.gov/sites/default/files/2018/12/03/2018_UGR-summary-11282018_v2pdf.pdf)
[2] Puget Sound Regional Council Vision 2040 (https://www.psrc.org/sites/default/files/2022-07/v2040.pdf)
[3] Metro Vancouver Growth Projection Tables (http://www.metrovancouver.org/services/regional-planning/data-statistics/data-projections/Pages/default.aspx)
[4] Business Case Analysis

We found that the employment projections used in the Business Case are reasonable and generally follow consensus forecasts in the Cascadia region.

Demand Estimation

***Key Finding**: We found the demand estimate process and results to be generally reasonable for both the Feasibility Study and Business Case analysis. The Business Case analysis also included an estimate for induced demand and we found that the Steer Discrete Choice model may slightly overestimate this factor. While this is not a fatal flaw, it should be noted as an area for additional empirical work if and when a more detailed, investment grade analysis is conducted on the proposed system.*

The population and employment projections discussed in the previous section are used to develop demand estimates. The Feasibility Study and Business Case analysis develop these demand estimates in two different ways, which is related to the analysis tools used to support each effort:

- CONNECT, which is used in the Feasibility Study, includes a direct input for population and simply calculates expected demand by applying standard default assumptions on the relationship between market size and ridership.
- The Steer Discrete Choice mode used in the Business Case does not use population and employment directly but uses them as an input to create a base travel demand table which represents the intercity travel on the corridor under current or “no-build” conditions. This base demand table was then grown to create a base demand table for future years. The Steer model also incorporates an estimate of “induced demand,” which represents new trips that would not be made without a new service (in this case UHSGT) but that occur as a result of the improved set of overall travel options provided by the proposed service. Total base travel demand for 2017 and 2040 from the Business Case (Steer Model) is show in Table 11 and Table 12.

TABLE 11: DEMAND BY MSA PAIR

	2017 (MILLIONS OF ONE WAY TRIPS)	2040 (MILLIONS OF ONE WAY TRIPS)
Portland–Seattle	3.8	5.4
Portland–Vancouver, BC	0.9	1.2
Seattle–Vancouver, BC	3.2	4.3
Other	2.8	3.8
Total	**10.7**	**14.7**

TABLE 12: DEMAND BY CURRENT MODE

	2017 (MILLIONS OF ONE WAY TRIPS)	2040 (MILLIONS OF ONE WAY TRIPS)
Auto	6.8	9.4
Air	2.1	2.9
Air (OD)	0.4	0.6
Air (connecting)	1.7	2.3
Rail	0.6	0.8
Bus	1.2	1.6
Total	**10.7**	**14.7**

Demand Growth Comparison

The Steer Discrete Choice model used various metropolitan planning organization (MPO) travel demand models to grow the base year (2017) travel demand to a projected future year (2040). Steer estimated growth between key origins and destinations (ODs) by averaging population and employment growth rates for the origin and destination zones then averaging the two average rates. Table 13 shows the combined annual growth rates for each OD pair and mode that are implied by the Steer model demand base demand tables.

TABLE 13: STEER MODEL BASE DEMAND CAGRS

CAGR	2017–2040	2040–2055	2017–2055
Portland–Seattle	1.54%	1.14%	1.38%
Portland–Vancouver, BC	1.26%	1.03%	1.17%
Seattle–Vancouver, BC	1.29%	1.14%	1.23%
Other	1.34%	1.28%	1.31%
Auto	1.42%	1.17%	1.32%
Air	1.41%	1.07%	1.28%
Air (OD)	1.78%	1.03%	1.48%
Air (connecting)	1.32%	1.32%	1.32%
Rail	1.26%	1.50%	1.35%
Bus	1.26%	1.15%	1.22%
Total	**1.39%**	**1.21%**	**1.32%**

Source: Business Case

Table 14 shows the combined annual growth rates in base (no-build) travel demand used in the Steer model for each major OD pair, compared with the combined population and employment growth for that pair. ***This shows that the trip table growth assumed by the Steer model is reasonable because the base travel demand growth rate is consistent with the population and employment growth rates***. One small exception seems to be the Portland – Seattle OD pair where the base demand CAGR is higher than both population and employment CAGRs, but this is close enough that it could be explained by other factors, including higher population growth in parts of the region with better access to high-speed rail or projected changes in the mix of trip purposes.

TABLE 14: STEER MODEL CAGRS, 2017–2040

OD PAIR	BASE DEMAND	POPULATION	EMPLOYMENT
Portland–Seattle	1.54%	0.90%	1.25%
Portland–Vancouver, BC	1.26%	1.16%	1.33%
Seattle–Vancouver, BC	1.29%	1.09%	1.47%
Other	1.34%	1.04%	1.35%

Source: Business Case

Induced Demand Estimation

The Steer Discrete Choice model incorporates estimates of additional travel demand that could be induced by new HSR service (CONNECT does not estimate induced demand). The Steer demand forecast thus has two components: the results of the demand estimation (described above), which account for any travelers switching from their current mode to a UHSGT system; and an estimate of induced demand, which represents new intercity trips that would not be made without a new service (in this case UHSGT) but that occur as a result of the improved set of overall travel options provided by the proposed service. The induced demand is then added to the forecast of diverted UHSGT trips to produce the total UHSGT ridership forecast.

Steer uses a formula for calculating induced demand based on a Volpe Commercial Feasibility Study, which itself is based on an induced demand formula developed in 1995.[6] RSG has used similar approaches to the one used by Steer, but the general practice used in earlier US high-speed rail proposals was not to rely on any levels of induced demand above approximately 10 percent, particularly for investment grade forecasts. As with most induced demand forecasts, this is based on professional judgement rather than hard empirical evidence.

The Steer method increases the total forecast by 12-14 percent due to induced demand impacts. This is certainly on the high side of accepted practice in North America, particularly for a piece of the forecast that is not backed by any empirical evidence, but it is not so high as to be considered implausible.

Estimates of induced demand from about a dozen studies of completed HSR projects in Europe and Asia show a wide range of outcomes with induced demand representing between 6% and 36% of actual HSR ridership.[7,8] However, it is important to note that the auto mode shares in all of the corridors studied in Europe and Asia prior to the introduction of HSR were considerably lower than what exists in the Cascadia corridor. And, correspondingly, the level of induced demand tends to be lower in corridors with high auto shares. So while the potential overestimate of induced demand in the Steer study is not a fatal flaw, it should be noted if and when an investment grade analysis is conducted.

Level-of-Service Assumptions

***Key Finding**: We found that frequency assumptions are in line with expectations for a system of this size. However, average speeds and travel times- which are key inputs to ridership and revenue estimates- are likely on the faster end of the realistic range when compared to existing systems. While suitable for this level of analysis, updating travel times will be an important element of any future investment grade analysis.*

The primary level of service attributes important for ridership and revenue forecasting are service frequency, travel time, and stations served, as described below.

[6] Charles River Associates as documented in Revised Induced Demand Formula, Memorandum CRA No. 434-01 to VNTSC, Charles River Associates, April 28, 1995.
[7] Givoni, M. and Dobruszkes, F. “A review of ex-post evidence for mode substitution and induced demand following the introduction of high-speed rail,” *Transport Reviews, 33 (6)*, 720–742, 2013.
[8] Excludes anomalously high estimates from two HSR projects in China.

Frequency

Frequency is a common metric for determining the level of service of a public transportation system and is defined as the number of vehicles that run over a certain period of time (for example, 4 buses per hour, or 6 flights per day). The inverse of frequency, “headway,” is sometimes also discussed and is defined as the average time between vehicle arrivals. Frequency has a direct impact on attractiveness of a service with increases in frequency correlating with increases in ridership. A more frequent service allows potential riders greater flexibility – allowing them to choose to make the trip closer to the time of day most ideal for their purposes. With only one or two trains per day, flexibility is low and potential riders may be more likely to choose other modes. When the number of trains in an intercity service approaches one per hour, potential riders have many more options and the system will be much more competitive with other intercity travel modes.

Travel Time

Station-to-station travel time is another key metric of level of service. Faster travel time makes a transit service more competitive with other modes and therefore more likely to be chosen by potential riders. Many high-speed rail proposals, or any rail proposal, will use maximum speed to communicate level-of-service. While maximum speed does have an impact on station-to-station travel times, other factors also impact time including acceleration and deceleration, amount of the route where the train is actually able to operate at maximum speed, and time spent on intervening stops. For these reasons, it is important to consider both average speed as well as maximum speed as a point of comparison. For this reason, the following sections also reference average speed which is particularly helpful in comparing OD pairs that are not exactly the same distance apart.

Stations Served

The number of stations on a system has direct impacts on ridership and level of service. In general, adding a stop in an additional location will increase ridership, but in practice this comes with trade-offs on travel time and frequency. Every station added between two stations will increase the travel time between those stations due to time stopping at the new station, and time lost for acceleration and deceleration. Serving more stations while holding the operations budget constant would likely also require reductions in frequency on the network.

Both the CONNECT model (Feasibility Study) and Steer model (Business Case) report results for a number of different level of service scenarios, as described below.

Level of Service Assumptions—Feasibility Study

The scenarios developed for the Feasibility Study, using the CONNECT model, include high-speed rail and maglev systems with stations in Vancouver, BC, Seattle, WA and Portland, OR. Certain scenarios included secondary stations at intermediate locations including Bellingham, Everett, Tacoma, Lacey and Tukwila, depending on the scenario. In general, the CONNECT model scenarios include frequencies of 12 trains per day between major stations or one train every 1-2 hours, as shown in Table 15.

TABLE 15: FEASIBILITY STUDY LEVEL OF SERVICE ASSUMPTION, VANCOUVER, BC TO PORTLAND, OR

SCENARIO	FREQUENCY, BASE	FREQUENCY, EXPRESS	TRAVEL TIME (MIN)	STATIONS
1A HSR	8	4	96	Main 3 + Bellingham, Everett, Tacoma, & Lacey, WA
1A Maglev	8	4	69	Main 3 + Bellingham, Everett, Tacoma, & Lacey, WA
2 HSR	8	4	85	Main 3 + Tacoma, WA
2 Maglev	8	4	60	Main 3 + Tacoma, WA
4 HSR	12	0	83	Surrey, BC, Tukwila, WA, & Portland, OR
4 Maglev	12	0	58	Surrey, BC, Tukwila, WA, & Portland, OR

Source: Feasibility Study

Travel times, route miles, average speeds, and maximum speeds for the CONNECT model scenarios are shown in Table 16.

TABLE 16: FEASIBILITY STUDY TRAVEL TIME & SPEED ASSUMPTIONS, VANCOUVER, BC TO PORTLAND, OR

SCENARIO	ROUTE MILES	TRAVEL TIME (MIN)	AVG SPEED (MPH)	MAX SPEED (MPH)
1A HSR	283	96	177	250
1A Maglev	283	69	246	375
2 HSR	282	85	199	250
2 Maglev	282	60	282	375
4 HSR	289	83	209	250
4 Maglev	289	58	299	375

Source: Feasibility Study

Level-of-Service Assumptions—Business Case

The scenarios developed for the Business Case analysis, using the Steer model, include high-speed rail systems with key stations in Vancouver, BC, Seattle, WA, and Portland, OR. As with the CONNECT model, certain scenarios included secondary stations at intermediate locations. For the most part, the reported results include scenarios with 21 trips per day, with a mixture of express service and regular service depending on the scenario, as shown in Table 17.

TABLE 17: BUSINESS CASE LEVEL OF SERVICE FROM VANCOUVER, BC TO PORTLAND, OR

SCENARIO	FREQUENCY, BASE	FREQUENCY, EXPRESS	TRAVEL TIME, BASE (MIN)	TRAVEL TIME, EXP (MIN)	STATIONS
1A	12	9	132	105	Main 3 + Surrey, BC, Bellingham, Olympia-Yelm, Longview, WA, & Portland, OR
1B	12	9	119	105	1A + Downtown Olympia, Tacoma, & Everett
1C	–	21	–	106	Main 3
1D	12	9	133	105	1A + Tacoma, Everett, & Downtown Olympia
1E	12	9	116	97	1A without Vancouver, BC
2A	12	9	126	109	Vancouver, Surrey, BC, Bellingham, Bellevue, Tukwila, Olympia-Yelm, Longview, WA, & Portland, OR
2B	12	9	121	104	2A + Seattle, Downtown Olympia, Tacoma, & Everett
2C	–	21	–	104	Surrey, BC, Bellevue, WA, & Portland, OR
3	12	9	150	133	2A + YVR & PDX airports

Source: Business Case

Travel times, route miles, average speeds, and maximum speeds for the Steer model scenarios are shown in Table 18.

TABLE 18: BUSINESS CASE TRAVEL TIME & SPEED ASSUMPTIONS, VANCOUVER, BC TO PORTLAND, OR

SCENARIO	ROUTE MILES (ESTIMATED)	TRAVEL TIME, BASE (MIN)	TRAVEL TIME, EXP (MIN)	AVG SPEED, BASE (MPH)	AVG SPEED, EXP (MPH)	MAX SPEED (MPH)
1A	306	132	105	139	175	220
1B	306	119	105	154	175	220
1C	306	–	106	–	173	220
1D	322	133	105	145	184	220
1E	292	116	97	151	181	220
2A	300	126	109	143	165	220
2B	300	121	104	149	173	220
2C	286	–	104	–	165	220
3	318	150	133	127	143	220

Source: Business Case

Comparison with Peer Systems

Table 19 shows how the average speeds that are implied by the various Cascadia corridor forecasts compare among other high speed rail origin-destination city pairs. The comparison includes both existing and proposed systems in the United States, Europe and Asia. The existing city pairs were chosen to represent some of the most used and most recognizable high speed rail pairs in the world (Tokyo-Kyoto and Paris-Lyon) as well as city pairs touting the fastest average and maximum speeds on the France and Japanese networks (Paris-Strasbourg, Tokyo-Morioka). In addition, the table includes the fastest average speed for a long-distance high-speed train in China (Beijing-Nanjing). For comparisons in the United States, Acela represents the only existing high speed rail line, and the proposed California High Speed rail represents an important point of comparison in the Pacific Northwest.

The average speeds implied in both the CONNECT and Steer forecasts are on the high end of the range with the CONNECT model speeds being faster than any system in existence. The Steer model average speeds tend to be faster than most of the standard city pairs in France and Japan. The average speeds are in line with what is projected on the California High Speed rail and are much higher than those ultimately attained by the Acela, which suffers from not being able to travel at its highest speed for most of the route.

TABLE 19: COMPARISONS OF FORECASTED AVERAGES SPEEDS WITH EXISTING AND PROPOSED SYSTEMS

ROUTE	EXISTING / PROPOSED	CITY PAIR	ROUTE MILES	TRAVEL TIME (MIN)	AVERAGE SPEED (MPH)	MAX SPEED (MPH)
Cascadia Maglev CONNECT (Scenario 4)	**Proposed**	**Vancouver, BC - Portland, OR**	**289**	**58**	**299**	**375**
Cascadia HSR CONNECT (Scenario 4)	**Proposed**	**Vancouver, BC - Portland, OR**	**289**	**83**	**209**	**250**
China	Existing	Beijing - Nanjing (Fastest Trains)	639	193	199	217
Cascadia Express Steer (1A)	**Proposed**	**Portland, OR - Seattle, WA**	**174**	**58**	**180**	**220**
California HSR	Proposed	San Francisco - Los Angeles	472	160	177	220
Cascadia Express Steer (1A)	**Proposed**	**Vancouver, BC - Portland, OR**	**306**	**105**	**175**	**220**
France TGV	Existing	Paris - Strasbourg	306	107	171	200
Cascadia Express Steer (1A)	**Proposed**	**Seattle, WA - Vancouver, BC**	**132**	**47**	**169**	**220**
Thalys	Existing	Paris - Brussels	203	82	148	186
China	Existing	Beijing - Nanjing (Most Trains)	639	260	147	217
France TGV	Existing	Paris - Lyon	291	120	146	186
Japan Tohoku Shinkansen	Existing	Tokyo - Morioka	310	132	141	200
Japan Tokaido Shinkansen	Existing	Tokyo - Kyoto (South)	298	129	139	168
Japan Tohoku Shinkansen	Existing	Tokyo - Shin-Aomori (North)	422	197	128	200
Northeast corridor Acela	Existing	New York, NY - Washington, DC	226	177	77	150
Northeast corridor Acela	Existing	New York, NY - Boston, MA	231	230	60	150

Source: RSG Analysis

Travel Survey Process/Results

***Key Finding**: We found the travel survey recruitment process to be biased toward respondents that had favorable opinions about HSR. While it appears that the impacts of these flaws were diluted as part of the overall ridership analysis, survey and model estimation methods should be improved if/when investment grade ridership studies are undertaken.*

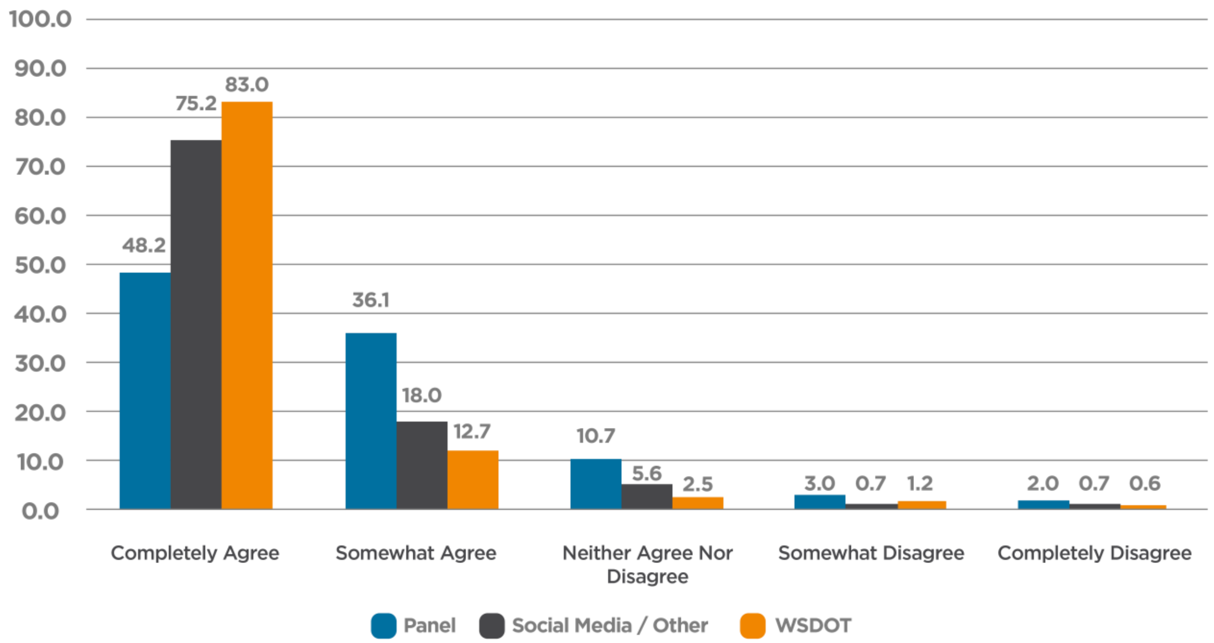
Travel surveys are important tools used in estimating ridership for various modes of transportation, including HSR. These surveys gather data directly from travelers about their travel behavior, preferences, and characteristics. The collected information is then used to inform the development of models and estimate ridership levels. The Steer Discrete Choice model used in the Business Case analysis utilized travel surveys conducted with samples of Cascadia corridor travelers while CONNECT does not use such surveys directly.

Steer conducted a behavioral and stated preference (SP) survey of residents in the region between October 2018 and January 2019 in order to:

- Collect trip pattern information to gain insight on the profiles of travelers;
- Develop a qualitative and quantitative understanding of how people make choices between using their car, or flying between cities based on attitudinal questions; and
- Collect willingness to pay for travel time savings information based on stated preference scenarios.

More than 3,000 surveys were completed and 2,430 were analyzed: 970 from a panel of corridor residents, 300 from a social media campaign, and 1,160 from Washington State DOT outreach efforts. This type of survey sampling does not result in a fully population-representative survey sample. For example, while the sample from the survey panel had approximately equal numbers of males and females, females constituted less than one-third of the social media and outreach samples. More directly concerning is the fact that the social media and outreach recruits is made up of respondents with significantly more favorable views of HSR than would likely exist in the full travel market. This is reflected in their much higher stated likelihood to try HSR, as shown in Figure 3.

FIGURE 3: DISTRIBUTION OF BUSINESS CASE RESPONSES TO "I WOULD DEFINITELY TRY UHSGT"



Source: Business Case Analysis, Figure B.98.

While it appears that the impacts of the skewed recruitment were diluted as part of the overall ridership analysis, the respondents should have been segmented out during the model estimation process to arrive at more representative estimates of the model parameters.

Overall Ridership, Mode Share, and Revenue Results

***Key Finding**: Overall, we found the overall ridership, mode share, and revenue forecasts to be in line with a reasonable expectation for a quality intercity rail service in the United States.*

In addition to the individual elements that make up the ridership, mode share, and revenue estimates, we assessed the reasonableness of the results described in both the Feasibility Study and the Business Case.

Ridership

The ridership forecasts from the Feasibility Study (using the CONNECT model) are shown in Table 20, while the ridership forecasts resulting from the Business Case (using the Steer model) are shown in Table 21. Depending on service and network characteristics, the CONNECT model forecasts primary corridor ridership between 1.7 to 2 million riders in 2035 and 2.6 to 3.2 million riders in 2055. Depending on service and network characteristics, the Steer model forecasts between 1.6 to 2.8 million riders annually in 2035 and 2.5 to 3.7 million riders annually in 2055.

TABLE 20: CONNECT PRIMARY CORRIDOR RIDERSHIP BY SCENARIO AND YEAR (MILLIONS)

SCENARIO	2035 RIDERSHIP (ANNUAL PASSENGERS)	2055 RIDERSHIP (ANNUAL PASSENGERS)
1A HSR	1.9	3
1A Maglev	2	3.2
2 HSR	1.8	2.9
2 Maglev	1.9	3
4 HSR	1.7	2.6
4 Maglev	1.7	2.8

TABLE 21: STEER MODEL RIDERSHIP BY SCENARIO AND YEAR (MILLIONS)

SCENARIO	2035 RIDERSHIP (ANNUAL PASSENGERS)	2055 RIDERSHIP (ANNUAL PASSENGERS)
1A	2.3	3.0
1B	2.5	3.3
1C	1.8	2.3
1D	2.8	3.7
1E	1.9	2.5
2A	2.4	3.1
2B	2.6	3.4
2C	1.6	2.1
3	2.4	3.1

Mode Share

Feasibility Study (CONNECT Forecast)

A range of mode shares for the HSR CONNECT Forecasts are shown in Table 22 for 2035 and Table 23 for 2055. For 2035, the HSR rail mode share ranges from 13.1% to 16.8%, with a medium estimate of 15.3%. The HSR 2055 rail mode share varies from 12.8% to 15.6%, with a medium estimate of 14.0%.

TABLE 22: CONNECT MODEL HSR MODE SHARE, 2035

MODE	LOW (SCENARIO 1A)	MEDIUM (SCENARIO 4)	HIGH (SCENARIO 2)
Rail	13.1%	15.3%	16.8%
Auto	81.9%	81.3%	79.7%
Local Air	0.4%	0.3%	0.3%
Bus	4.7%	3.1%	3.2%

Source: Feasibility Study

TABLE 23: CONNECT MODEL HSR MODE SHARE, 2055

MODE	LOW (SCENARIO 1A)	MEDIUM (SCENARIO 4)	HIGH (SCENARIO 2)
Rail	12.8%	14.0%	15.6%
Auto	82.5%	82.6%	80.8%
Local Air	0.2%	0.2%	0.2%
Bus	4.5%	3.2%	3.4%

Source: Feasibility Study

The mode shares for the Maglev CONNECT Forecasts are listed in Table 24 for 2035 and Table 25 for 2055. The 2035 Maglev rail mode share spans from 13.7% to 17.5%, with a medium estimate of 15.2%. The 2055 Maglev rail mode share ranges from 13.4% to 16.6%, with a medium estimate of 14.6%.

TABLE 24: CONNECT MODEL MAGLEV MODE SHARE, 2035

MODE	LOW (SCENARIO 1A)	MEDIUM (SCENARIO 4)	HIGH (SCENARIO 2)
Rail	13.7%	15.2%	17.5%
Auto	81.5%	81.3%	79.2%
Local Air	0.3%	0.3%	0.3%
Bus	4.5%	3.1%	3.1%

Source: Feasibility Study

TABLE 25: CONNECT MODEL MAGLEV MODE SHARE, 2055

MODE	LOW (SCENARIO 1A)	MEDIUM (SCENARIO 4)	HIGH (SCENARIO 2)
Rail	13.4%	14.6%	16.6%
Auto	81.9%	81.9%	80.2%
Local Air	0.2%	0.2%	0.2%
Bus	4.5%	3.3%	3.0%

Source: Feasibility Study

Business Case Analysis (Steer Forecast)

The range of mode shares for the Steer Forecasts are shown in Table 26 for the year 2040.The UHSGT mode share ranges from 12.0% and 19.8%, with a medium estimate of 17.8%.

TABLE 26: STEER FORECAST MODE SHARE, 2040

MODE	LOW (SCENARIO 2C)	MEDIUM (SCENARIO 2A)	HIGH (SCENARIO 2B)
UHSGT	12.0%	17.8%	19.8%
Auto	56.8%	53.0%	52.1%
Air	0.7%	0.3%	0.3%
Connect Air	15.8%	15.7%	15.7%
Rail	4.0%	3.1%	2.6%
Bus	10.6%	10.1%	9.6%

Source: Business Case

Table 27 shows the mode shares implied by the Steer forecast for the major city origin-destination pairs on the corridor. The Portland – Seattle pair has the highest mode share of any city pair ranging from 16% to 23% depending on the forecast year and scenario.

TABLE 27: STEER FORECAST MODE SHARE BY MSA PAIR

MSA PAIR (BOTH DIRECTIONS)	SCENARIO 2C - 2017	SCENARIO 1D - 2017	SCENARIO 2C - 2040	SCENARIO 1D - 2040
Portland – Seattle	16%	22%	19%	23%
Portland – Vancouver, BC	13%	16%	15%	17%
Seattle – Vancouver, BC	7%	17%	8%	16%
Other	–	12%	–	12%
Total	**9%**	**17%**	**10%**	**18%**

Source: Business Case

Comparison to Other Systems

Table 28 shows the mode share among Northeast corridor cities – the only region in the US where a high-speed rail system is operational. The city pairs with the highest rail shares in the Northeast Corridor are Philadelphia-New York City and Greater Baltimore/DC-New York City. The rail totals here are a combination of the high-speed service Acela and a slower, less-expensive regional service. In general, where both services are offered, 2/3 of the rail market travels with the regional service. While the high-speed rail option (Acela) doesn't travel as fast as true high speed rail systems around the world, a high rail share is still attained in this corridor due to high levels on auto congestion and unreliability, parking availability and parking costs in the major cities. **The projected mode shares in the Cascadia corridor fall within the range of major OD pairs on the northeast corridor, indicating that the forecasts are in line with a reasonable expectation for a quality intercity rail service in the United States**.

TABLE 28: MODE SHARE AMONG NORTHEAST CORRIDOR MARKETS WHERE HIGH SPEED RAIL IS COMPETITIVE[9]

SUBMARKET PAIR	AUTO SHARE	RAIL SHARE (ACELA + NEC REGIONAL)	AIR SHARE	BUS SHARE
Philadelphia area - New York City	62%	29%	0%	9%
New York City - Greater Boston/Providence	65%	15%	8%	13%
Greater Baltimore/DC - New York City	43%	27%	6%	24%
Greater Baltimore/DC - Philadelphia area	75%	19%	0%	5%
Greater Baltimore/DC - Greater Boston/Providence	80%	2%	17%	1%
Philadelphia area - Greater Boston/Providence	89%	5%	6%	1%

Source: RSG Analysis of Amtrak Data

Table 29 shows the high-speed rail forecast by California High Speed rail. Although this is a forecast and not a real-life comparison, it still is a worthwhile benchmark to consider. The forecast indicates a mode share of 25% between the San Francisco area and the Los Angeles area by 2033 when Phase 1 is complete and lower shares of 15% between San Diego and San Francisco and 12% between Los Angeles and the San Joaquin Valley. ***Again***, ***the Cascadia forecasted mode shares fall within the range of shares in the California High Speed rail forecast***.

TABLE 29: CALIFORNIA HIGH SPEED RAIL FORECASTED MODE SHARE BETWEEN KEY MARKETS[10]

MARKET PAIR	2029 MODE SHARE	2033 MODE SHARE	2040 MODE SHARE
San Diego - San Francisco	4.4%	15.4%	15.6%
San Diego - San Joaquin Valley	3.5%	10.3%	10.2%
San Francisco - Los Angeles	10.0%	25.2%	25.9%
San Francisco - San Joaquin Valley	8.6%	8.7%	8.8%
Los Angeles - San Joaquin Valley	2.6%	12.5%	12.2%
San Joaquin Valley - San Joaquin Valley	7.2%	7.5%	7.1%

[9] Northeast Corridor Intercity Travel Study, September 2015. https://nec-commission.com/app/uploads/2018/04/2015-09-14_NEC-Intercity-Travel-Summary-Report_Website.pdf
[10] California High-Speed Rail 2020 Business Plan. https://hsr.ca.gov/wp-content/uploads/docs/about/business_plans/2020_Business_Plan_Ridership_and_Revenue_Forecasting.pdf

One final point of comparison would be to the established HSR services in Europe and Asia. Those HSR systems have achieved mode shares in excess of 50% for most of the major corridors, with some corridors in Asia that have historically higher auto use seeing shares closer to 20%.[11] For context it is important to note that almost all of these HSR services in Europe and Asia were introduced into markets with already high conventional rail markets, relatively low intercity auto use and significant accessibility to robust urban public transit services.

Revenue

The revenue forecasts from the Feasibility Study (CONNECT model) are shown in Table 30, while the revenue forecasts resulting from the Business Case (Steer model) are shown in Table 31.

TABLE 30: CONNECT MODEL REVENUE BY SCENARIO AND YEAR (MILLIONS)

SCENARIO	2035 ANNUAL TICKET REVENUE	2055 ANNUAL TICKET REVENUE
1A HSR	$146	$231
1A Maglev	$153	$243
2 HSR	$146	$223
2 Maglev	$152	$235
4 HSR	$132	$207
4 Maglev	$138	$218

Source: Feasibility Study

TABLE 31: STEER MODEL REVENUE BY SCENARIO AND YEAR (MILLIONS)

SCENARIO	2035 ANNUAL TICKET REVENUE	2055 ANNUAL TICKET REVENUE
1A	$188	$242
1B	$205	$263
1C	$157	$203
1D	$224	$287
1E	$158	$204
2A	$195	$251
2B	$211	$272
2C	$139	$181
3	$198	$255

Given that these revenue projections are based on reasonable ridership forecasts and estimated fare levels, we find them to be reasonable, as well.

[11] Givoni, M. and Dobruszkes, F. "A review of ex-post evidence for mode substitution and induced demand following the introduction of high-speed rail," *Transport Reviews, 33 (6)*, 720–742, 2013.

3.2 COST ANALYSIS

Capital costs and operations and maintenance (O&M) costs are two distinct types of expenses that should be evaluated when examining a proposed high-speed rail project. Capital costs refer to the upfront expenses incurred during the development and construction of the rail system, including the cost of building the infrastructure, acquiring equipment, and purchasing land. Operations and maintenance costs refer to the ongoing expenses associated with operating and maintaining the rail system, including the cost of fuel, labor, and maintenance of track, signals and vehicles.

Capital Costs

***Key Finding**: A capital cost analysis was not conducted as a part of the Business Case analysis and therefore the most recent and robust system models do not have a capital cost analysis associated with them. A capital costs analysis was completed for the Feasibility Study (using the CONNECT model) but this is based on a hypothetical system with little detail. For the most part, default values were used, meaning that the unique and complex urban and natural environment in the Pacific Northwest were not fully considered.*

Overall, we find the previous cost analysis to be unreasonably low due to escalating capital construction costs, and unreasonable tunnel-related construction costs due to low per-mile costs and potential under-estimation of the extent of tunneling necessary to achieve proposed speed and travel time targets.

Capital costs refer to the expenses incurred during the construction and development of the project. The construction of a high-speed rail system requires significant investment in infrastructure, including track construction, station building, signaling equipment and land acquisition.

The capital costs that are referenced in both the Feasibility Study and Business Case Analysis are outputs of the CONNECT tool that was developed as a part of the Feasibility Study. As already noted, the CONNECT tool is a high-level sketch planning tool that does not include corridor details but calculates an estimate of capital costs based on approximate track miles by track type, number of stations, maintenance facilities and other line items. Generic costs are used for each of these, with an opportunity for the user to override the generic costs if more information is available. The Feasibility Study used primarily generic cost estimates.

The capital costs from the CONNECT scenarios published in the Feasibility Study are shown in Table 32. The CONNECT tool outputs include low, medium, and high estimates for each scenario.

TABLE 32: CONNECT MODEL INITIAL CAPITAL INVESTMENTS BY SCENARIO (MILLIONS)

SCENARIO	LOW ESTIMATE	MEDIUM ESTIMATE	HIGH ESTIMATE
1A HSR	$23,980	$32,252	$40,524
1A Maglev	$27,750	$34,131	$40,511
2 HSR	$24,997	$33,292	$41,587
2 Maglev	$28,726	$35,748	$42,769
4 HSR	$23,543	$31,956	$40,368
4 Maglev	$27,524	$34,266	$41,007

Three aspects of the capital cost estimate were considered in our analysis:

1. What may have changed between the previous studies and now with the inherent capital costs? This mainly focuses on escalation of construction costs since the previous estimates.
2. Were the previous unit costs accurate? This mainly focuses on how the assumed unit costs compare to peer projects.
3. Were the assumed alignment parameters for the cost estimates realistic? This mainly focuses on whether the assumed mixture of at-grade, aerial, and tunnel alignments is realistic.

We find the previous estimate of capital costs to be unreasonably low in 2023 due to the following factors:.

- **Escalating overall construction costs**: There have been significant increases in construction costs for infrastructure projects in the past five years. From February 2018 through April 2023, the Sant Louis Federal Reserve's Producer Price Index for Non-Residential Construction has risen by over 50%. [12]***This means that absent any other changes, the $24B-42B capital cost estimates presented in the 2018 study would now be equivalent to $36B-63B capital costs in 2023 dollars given the overall rise in construction prices.***
- **Tunnel construction costs**: The estimate included in the Feasibility Study assumes that tunnels can be constructed for approximately $230M per mile for high speed rail service. Recent tunnel construction projects both within and outside Washington suggest that number may be too low (not withstanding general escalation in construction costs as noted in the first bullet). This is also exacerbated by the fact that many of the tunnels would be expected to be constructed in complex, highly urbanized areas. ***All of these factors suggest that tunnels would be expected to cost closer to $450M per mile to***

[12] https://fred.stlouisfed.org/series/WPU801

construct, as opposed to $350M per mile as would be suggested by escalated tunnel construction costs from the Feasibility Study.

- **Areas of Significant Constraint**: While the previous studies estimate there is significant tunneling needed for a 200 mph+ high speed rail line, it is likely that even more extensive tunneling could be needed once detailed design is completed. This is due to the lack of current 200 mph+ rights of way in nearly all urban areas of the corridor from Vancouver to Portland. The current BNSF Railway line and Interstate 5 (the two most likely existing corridors for a HSR line) are design to conventional rail and highway speeds that are typically under 100 mph, so 200 mph trains will have to follow new rights of way in urban areas to keep up their high speeds without very significant right-of-way acquisitions. ***Significant constraints exist for 80-90 miles of alignment in urban areas for which current rights-of-way do not seem feasible for high-speed operations and for which tunnels, significant right-of-way acquisitions, and/or alternative corridors should be examined:***
  - Vancouver: Pacific Central Station to Frasier River/Richmond: 10 miles
  - Bellingham: Airport to Samish: 10-15 miles
  - Everett to Seattle: 30 miles
  - Sumner to Lakewood via Tacoma: 10-15 miles
  - Centralia and Chehalis: 5 miles
  - Kelso: 5 miles
  - Vancouver, WA and Portland: 10 miles
  - Total length: 80-90 miles

There are less costly alternatives to much of this tunneling (described in more detail in Section 4.0), but they involve fewer stations, different corridors, extensive right-of-way acquisition, and/or slower speeds, which have direct implications for travel time, ridership, and overall project benefits.

Operations and Maintenance Costs

Key Finding*: An operational cost analysis was conducted for only one scenario in the Business Case analysis. As with capital costs, operations and maintenance costs vary greatly depending on the specifics of the project and therefore the O&M costs presented in the Feasibility Study and in the Business Case are reasonable, but should be considered as nothing more than a very high level estimate. That said, we find the O&M cost recovery calculation method to be sound and the resulting cost recovery ratios to be reasonable.*

Operations and maintenance (O&M) costs refer to the ongoing expenses associated with operating and maintaining a rail system, including the cost of fuel, labor, and maintenance of track, signals and vehicles.

The CONNECT tool includes an output for annual O&M costs. This output, as with all CONNECT outputs is a rough estimate and is based on seat miles, route miles and number of stations but does not consider actual specific operations and maintenance categories. The O&M costs for the CONNECT scenarios that were presented in the UHSGT Study are shown in Table 33.

TABLE 33: CONNECT MODEL O&M BY SCENARIO AND YEAR (MILLIONS)

SCENARIO	ANNUAL O&M COSTS (2035-2055)	2035 ANNUAL O&M PROFIT/(SUBSIDY)	2055 ANNUAL O&M PROFIT/(SUBSIDY)
1A HSR	$218	($72)	$13
1A Maglev	$187	($34)	$56
2 HSR	$212	($66)	$12
2 Maglev	$181	($29)	$54
4 HSR	$175	($42)	$32
4 Maglev	$143	($5)	$75

Source: Feasibility Study

While no new capital cost estimates were estimated for the Business Case, additional work was done to estimate operating and maintenance costs for one scenario (Scenario 1D with 21 roundtrips per day). This is shown in Table 34.

The O&M costs developed in the Business Case include recurring costs for train operations, infrastructure maintenance, station operations, control center and field operations, staff, and insurance. The Business Case developed unit cost assumptions based on a review of other similar existing and planned systems in the US, Europe, and Japan.

TABLE 34: STEER MODEL OPERATION AND MAINTENANCE COSTS (MILLIONS)

SCENARIO	AVERAGE ANNUAL O&M COSTS (2040)
1D	$277

Source: Feasibility Study

O&M Cost Recovery Ratio

Related to O&M costs is the O&M cost recovery ratio, which is the ratio of ticket revenue to operations and maintenance costs; capital costs are excluded. A ratio higher than 1 indicates that the operations and maintenance expenses of a system are covered by fare revenues, while a ratio less than 1 indicates that operations and maintenance expenses are not covered by fare revenues and will require a subsidy.

The O&M cost recovery ratios for the CONNECT scenarios are shown in Table 35. The CONNECT forecasts suggest that a subsidy would be required to cover the O&M cost in 2035, but that ticket revenue would cover the O&M cost by 2055.

TABLE 35: O&M COST/RECOVERY RATIOS BY SCENARIO AND YEAR

SCENARIO	2035 O&M COST/ RECOVERY RATIO	2055 O&M COST/ RECOVERY RATIO
1A HSR	0.67	1.06
1A Maglev	0.82	1.3
2 HSR	0.69	1.06
2 Maglev	0.84	1.3
4 HSR	0.76	1.19
4 Maglev	0.97	1.52

Source: Feasibility Study

For scenario 1D in the Business Case, the O&M cost recovery ratio at 2040 is 0.87.

O&M cost estimates carry forward into calculations of O&M cost recovery. We find the O&M cost recovery calculation method to be sound and the resulting cost recovery ratios to be reasonable. For sake of comparison, Amtrak's Northeast Corridor, which includes both Acela and regional service, had a cost recovery ratio of 1.7 in 2019. Amtrak's budget outlook indicates that the cost recovery ratio bottomed out at 0.53 in 2021, recovered to 0.90 in 2022, and is expected to be at 1.23 in 2027.[13]

3.3 ECONOMIC IMPACT ANALYSIS

***Key Finding**: The economic impact assessment tool used to support economic impact analysis- TREDIS- was appropriately built and applied and generated reasonable results. However, because an economic impact analysis was conducted for only one scenario (1A- maglev) in the Feasibility Study and the Portland metropolitan area is not included in the model, the full economic impacts are likely under-reported. These limitations should be addressed if and when a more robust analysis is undertaken.*

Economic impact assessments involve analyzing the potential macroeconomic effects that relate to the construction, expansion, or improvement of transportation investments and typically evaluate the direct and indirect impacts on key economic sectors, employment, income, productivity, business attraction, and economic growth. Only the Feasibility Study included a detailed economic impact assessment, using the TREDIS tool, described below.

[13] Eno Foundation Analysis, 2022

TREDIS

TREDIS is among the industry standards for transportation economic evaluation. The tool is used to conduct economic impact analysis, benefit-cost analysis, and financial analysis for transportation projects and programs. Impacts can be viewed at local, regional, state, and national levels. TREDIS is a web-based SAAS (Software As A Service) product that operates on a cloud platform, combining an economic database with economic simulation and forecasting capabilities[14][15]. It is important to note that TREDIS and other economic impact tools do not specifically calculate the opportunity costs or trade-offs associated with investing in one type of transportation need versus another. Discussing the best use of limited transportation investment resources will be important as the JTC considers next steps on UHSGT development.

The TREDIS model developed for the Feasibility Study consists of two components, one for Canada and one for Washington State and only considers the metropolitan areas of Vancouver, BC and Seattle, Washington. The Portland metropolitan area is not included in the model meaning that the results shown do not include the economic impacts on the full region.

The TREDIS travel module requires inputs for at least two years and for the Base and Project alternatives. The travel demand model was run for three scenarios: 2035 Alternative 1A maglev, 2055 Alternative 1A maglev, and 2055 “Do Minimum.” The Alternative 1A maglev scenario serves as the Build Case, while the Do Minimum scenario serves as the Base Case. The main inputs for TREDIS were the CONNECT travel demand model results from Do Minimum and Alternative 1A maglev and the number of trips for passenger rail, auto, air, bus and HSR.

The total impact of the project is the sum of the construction, O&M, agglomeration, and the effects of improved travel options for users (“operational”). To convey a range of impacts, two travel sheds, measured as travel times to access stations, are shown in Table 35. The impacts of the 51-minute travel shed- the approximate HSR travel time between Seattle and Vancouver with the project- are greater than the 40-minute travel shed due to the greater market access (agglomeration) benefits.

The summary of total impacts from the TREDIS model are shown in Table 36 and descriptions of each type of benefit included in the model are included below.

Construction Impacts

Construction Impacts, spanning from 2025 to 2035, are primarily made up of employees hired to build the project. Construction impacts also include indirect effects of the project: newly hired

[14] TREDIS website: https://tredis.com/products/tredis-6/tredis-overview

[15] EBP website: https://www.ebp-us.com/en/projects/tredisr-software-transportation-economic-development-impact-system

construction worker's earnings will increase consumer demand and generate additional jobs across a variety of industrial sectors and occupational categories, and induced effects of the project: purchases of materials and supplies for the project translates to an increase in employment in the industries supplying those goods and services.

The benefit attributed to construction through the TREDIS model makes up about 10-15% of the total benefit.

Operating and Maintenance (O&M) Impacts

The Operating and Maintenance (O&M) Impacts span from 2035 to 2055, once the HSR maglev project is constructed and moves into operation. The direct expenditures associated with operating the new rail corridor, stations, and facility maintenance generate additional jobs. Much like the construction impacts, the new spending of O&M workers and supplies supports the economy and creates new jobs across all sectors. Unlike construction jobs, O&M jobs are recurring and last for the duration of the system's operation.

Market Access Impacts

Market Access Impacts represent the agglomeration impacts of the project. Urban areas are focal points for commercial transaction, generating agglomeration impacts through internal connections and by facilitating connections to other cities. Communication, transport, distribution, and production activities are less costly when collecting producers, suppliers, and consumers in urban centers. For example, retailers benefit from a greater concentration of consumers in a smaller geography, while businesses benefit from being in an urban area due to a greater range of suppliers, access to specialized goods and services that increase cost efficiency of production, and access to larger pools of labor. Agglomeration economies decrease transactions costs and make the urban corridor's firms more productive and more competitive.

The large reduction in travel time due to the implementation of HSR would promote greater accessibility for workers and employers, benefiting business productivity through access to a broader and more diverse labor market. The increase in effective economic density (clustering) of economic activities supported by the HSR will enhance the productivity of the economy due to an ability to access a wider range of locations (offices, retail, other land uses) within the same travel time. Businesses and employees will be more attracted to the region, supporting additional growth and development and resulting in agglomeration economies. These agglomeration economies increase the competitiveness of the corridors in contrast to the absence of the Project. Increased market access resulting from the reduction in travel time between cities is the biggest driver for economic impacts in the corridor.

These benefits make up the vast majority of overall benefits according to the outputs of the TREDIS model at between 85%-90% of the total dollar value.

Operational Impacts

Operational Impacts refers to the improved travel options for users. The improved travel efficiency of HSR attracts customers, leading them away from roadways they would have traveled on in the absence of HSR. These diversions free up capacity on the interstate highways, which allows cars and trucks to travel faster, reduces congestion, reduces automobile accidents, and saves transportation costs. Households redirect these transportation savings through discretionary spending and other uses, which drives economic growth.

Operational impacts constitute an almost negligible amount of the total benefit compared to the other categories (less than 1%).

TABLE 36: TREDIS RESULTS SUMMARY OF TOTAL IMPACTS

	CONSTR. (2025-2035)	O&M (2035-2055)	MARKET ACCESS (2035-2055)	OPERATIONAL	TOTAL IMPACTS
AVERAGE JOBS PER YEAR					
40-min	38,000	3,000	116,000	200	157,200
51-min	38,000	3,000	160,000	200	201,200
LABOR INCOME (2015 $M USD)					
40-min	$29,000	$5,000	$208,000	$300	$242,300
51-min	$29,000	$5,000	$282,000	$300	$316,300
BUSINESS OUTPUT (SALES) (2015 $M USD)					
40-min	$79,000	$9,000	$532,000	$1,000	$621,000
51-min	$79,000	$9,000	$738,000	$1,000	$827,000
VALUE ADDED (GDP) (2015 $M USD)					
40-min	$39,000	$4,000	$264,000	$500	$307,500
51-min	$39,000	$4,000	$355,000	$500	$398,500

3.4 ANALYSIS IN CONTEXT—IMPACTS OF COVID ON TRAVEL DEMAND FORECASTING

As with many recently completed forecasting studies, both the CONNECT and Steer ridership models are based on data that were collected before the COVID-19 pandemic. Utilizing pre-pandemic data remains a recognized best practice in the travel forecasting industry, while also recognizing that the pandemic may have had a long-term impact on intercity travel patterns. Forecasters are really just starting to think about using post-pandemic data as a basis for forecasting. However it is also best practice to discuss the possible long-term changes in travel patterns due to the pandemic.

This section provides some recent data on air, rail, and automobile travel between Seattle and Portland to compare 2022 travel patterns to 2019. While obviously not incorporated into the three studies that were the focus of our work, this can be seen as a "low" scenario – it is possible that long distance travel may continue to recover towards pre-pandemic levels but unlikely that it will decrease from 2022 levels. While useful for providing the context for overall travel in the region, note that this analysis does not include travel to and from Vancouver because the readily available data sources do not include cross-border travel.

Air Travel

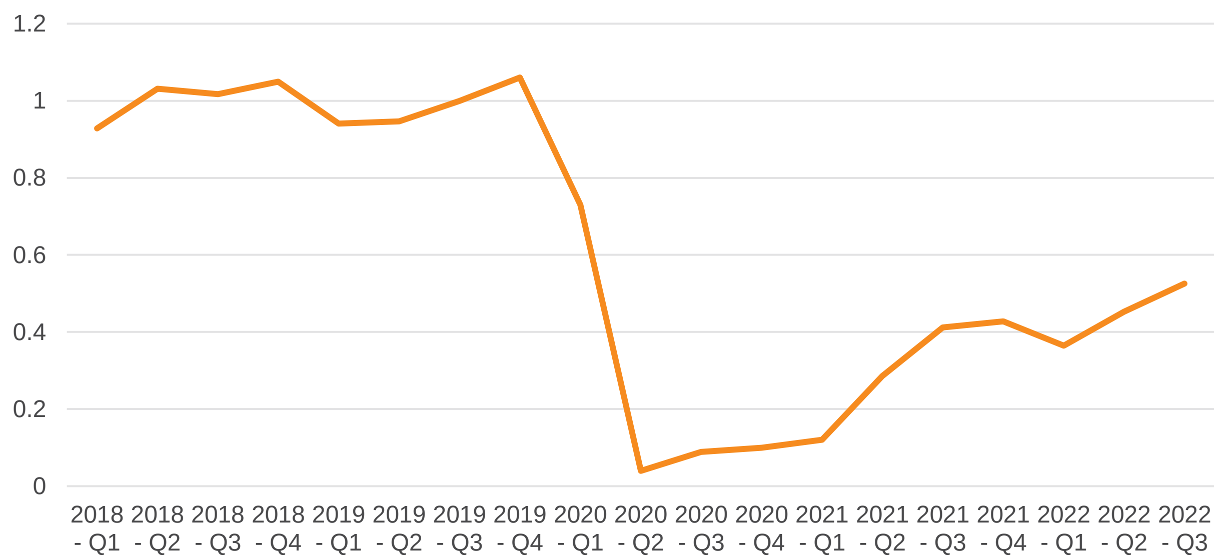
In Q3 of 2022, the air travel between Portland and Seattle has recovered to 52% of pre-pandemic levels, as shown in Table 37 and Figure 4. It is reasonable to assume that air travel between the two cities will continue its upward trajectory, but unclear if a reduction from 2019 levels is a long-term pattern or not. It is also important to note that much of the ongoing reduction in air travel nationally has been in the business travel segment and those travelers are the ones who are generally most receptive to higher-priced services such as HSR.

TABLE 37: 2022 PERCENT OF PORTLAND/SEATTLE AIR TRAVEL RECOVERY FROM 2019 BY QUARTER

QUARTER	2022 AS A % OF 2019
Q1	39%
Q2	44%
Q3	52%

Source: RSG analysis

FIGURE 4: SEATTLE/PORTLAND AIR PASSENGER VOLUME INDEX, 2018-2022

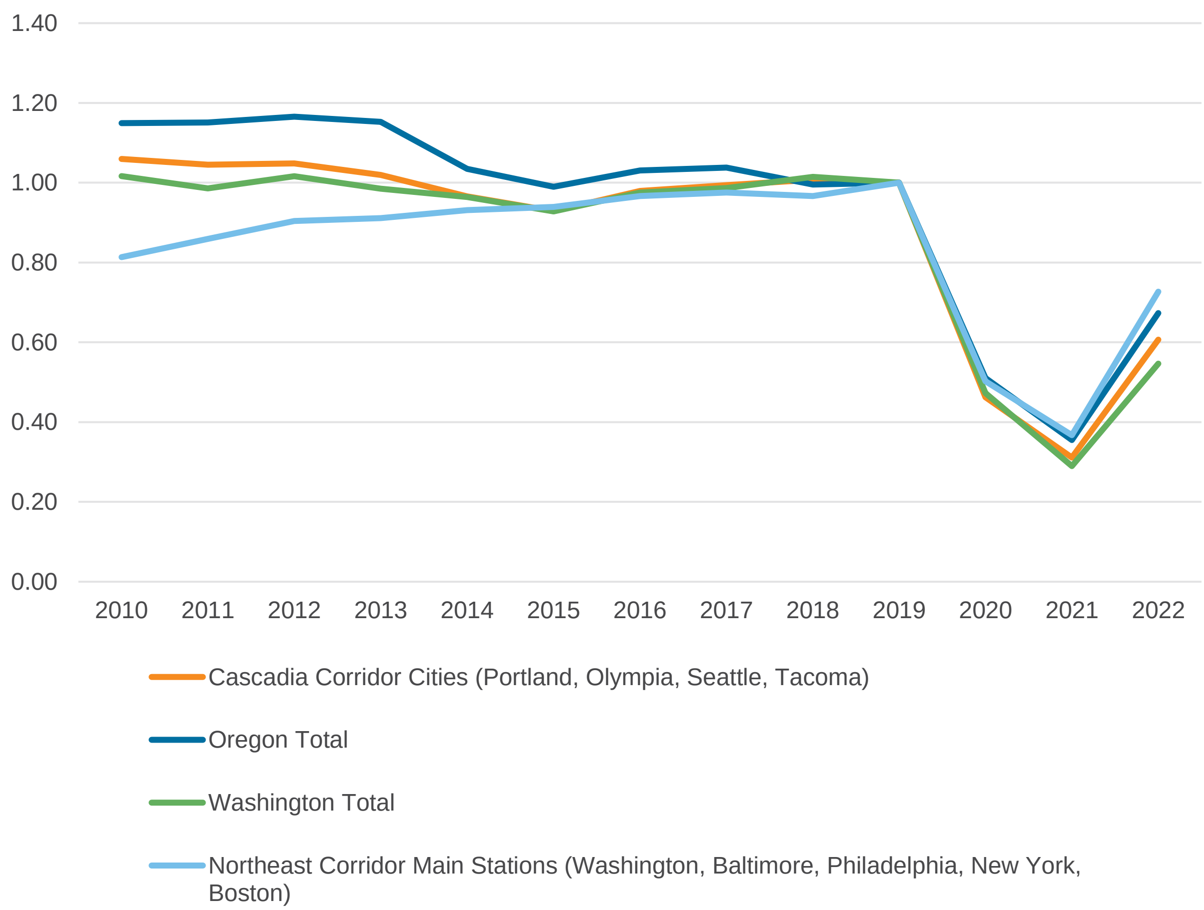


Source: Bureau of Transportation Statistics Airline Origin Destination Survey (DB1B)

Rail Travel

To examine the pandemic's impact on rail travel, we looked at Amtrak boardings in the Northeast Corridor (as an example of a mature rail market) as well as in the Cascadia corridor. In the Northeast Corridor, 2022 rail travel between major cities was at 73% of 2019 level, as shown in Figure 5 and Table 38. In the Cascadia region, rail travel has been slower to return and ranges from 55% - 67% of 2019 levels. However, rail travel has increased from 2021 so it is reasonable to assume that it is still in the recovery phase and could continue to approach 2019 levels.

FIGURE 5: AMTRAK BOARDING INDEX RELATIVE TO 2019



Source: Bureau of Transportation Statistics Amtrak Ridership

TABLE 38: AMTRAK BOARDINGS IN 2019 AND 2022

REGION	2019 AMTRAK BOARDINGS	2022 AMTRAK BOARDINGS	% OF 2019 BOARDINGS
Cascadia Corridor Stations (Portland, Olympia, Seattle, Tacoma)	1,550,094	940,914	61%
All Oregon Stations	812,067	546,938	67%
All Washington Stations	1,301,585	711,749	55%
Northeast Corridor Major Stations	23,870,506	17,360,824	73%

Source: Amtrak

Auto Travel

According to the Replica origin-destination data[16], trips in personal automobiles (as a driver or a passenger) between the Portland and Seattle Combined Statistical Areas have decreased to 84% of 2019 levels while trips made by other modes have decreased to 46% of 2019 levels (Table 39). The Replica model is an extremely high-level tool and does not completely capture mode splits at intercity levels, so it is difficult to be certain about what is actually included in the "other" mode category. However, overall the Replica data suggest that total travel between Seattle and Portland is down in 2022 vs 2019 and that automobile travel is down but not to the extent that non-automobile travel is down.

TABLE 39: PERCENT OF PERSON TRIPS IN 2022 RELATIVE TO 2019 FROM REPLICA MODEL[17]

TRIP TYPE	SEATTLE - PORTLAND	PORTLAND - SEATTLE	TOTAL
Auto	83%	84%	84%
Other	43%	50%	46%

Source: Replica OD data, analyzed by RSG

[16] https://www.replicahq.com/. 2022 regional OD data analyzed by RSG
[17] Replica Places Activity Based Model Northwest Fall Weekday 2022 and Fall Weekday 2019 (cite?)

4.0 TRADE-OFF ANALYSIS

Previous studies have considered ultra high-speed systems operating at speeds of over 200 mph. To accomplish such speeds, the system would mainly require new, dedicated infrastructure which has high construction costs as well as many potential impacts on the environment and adjacent communities. This study provides a high-level trade-off analysis of HSR systems with different operating speeds. The objective of this trade-off analysis is to identify the factors that need to be understood by the JTC when considering next steps on the Cascadia UHSGT Project.

4.1 HSR SCENARIOS

For this trade-off analysis, we considered three HSR infrastructure scenarios, described in more detail below. An overview of the areas of analysis is provided in Figure 6. For each scenario, we considered constraints such as geography and land uses. This approach differs from previous studies, which mainly considered straight-line distances between markets and ridership model inputs to estimate information such as costs and impacts.

The team developed concepts to include enough information to allow for a realistic comparison of benefits/trade-offs as well as rough cost estimates based on assumed track configuration. However, it is important to note that they are ***high-level, representative concepts of the various scenarios, and were used only for the purpose of understanding the trade-offs between the different HSR infrastructure systems. No discussions with current or potential owners or operators of the corridors were conducted***.

A REMINDER ON METHODS

As discussed earlier, the three previous UHSGT studies were “technology agnostic,” and considered a range of technologies that could meet the objective of one hour travel times between major city pairs (Vancouver, Seattle, and Portland). However, because our assessment indicates that only high-speed rail (HSR) technologies are mature enough to be reasonably viable, we focused our trade-off analysis on HSR services.

- **Incremental HSR** scenario uses the existing Amtrak Cascades railroad corridor, similar to Acela service in the Northeast Corridor (Boston-Washington DC). This concept also assumes operational improvements to the existing corridor, as described in the 2006 Long-Range Plan for Amtrak Cascades.[18] The operational improvements could allow for

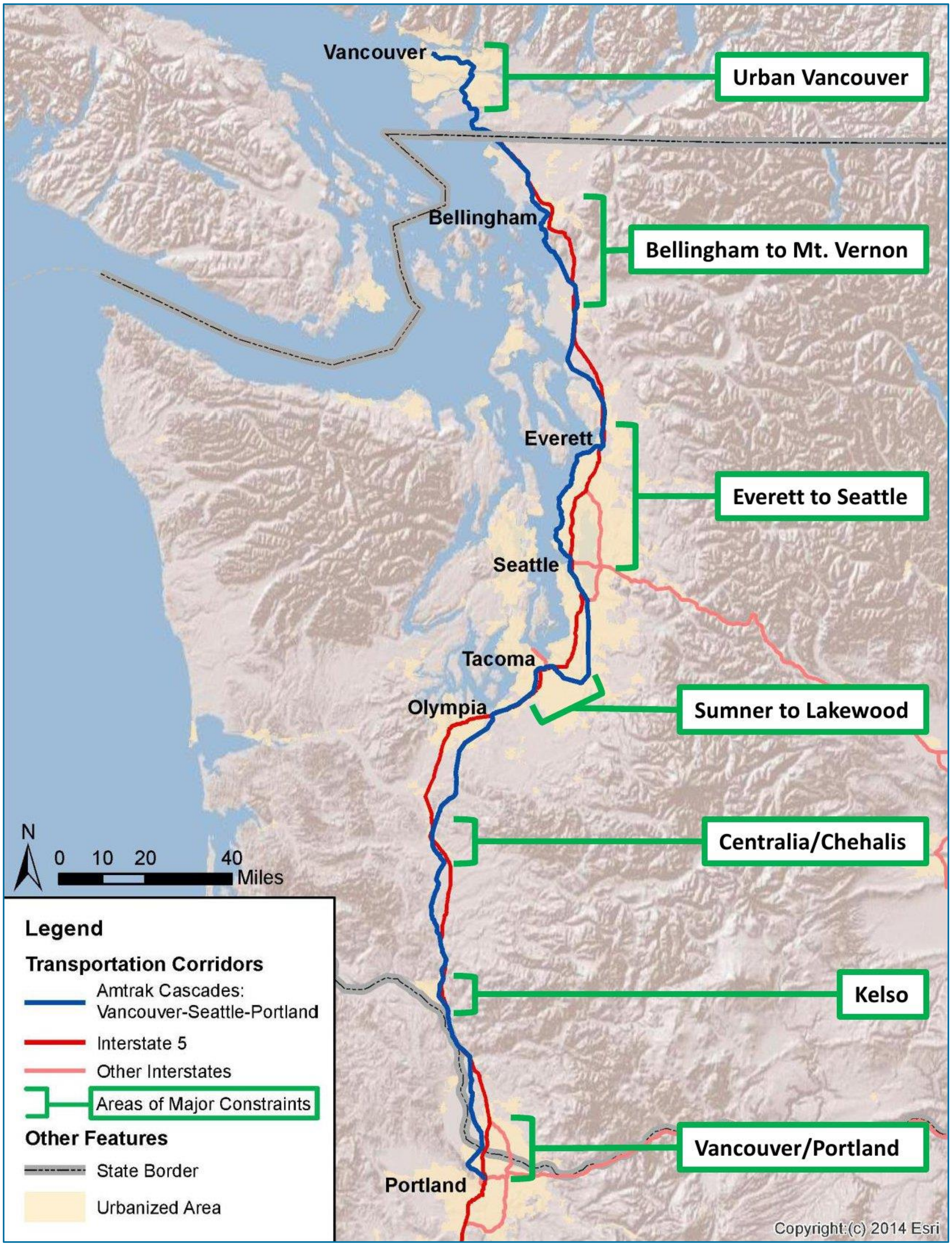
[18] The team used the 2006 Plan as is it the most relevant source available, acknowledging that some of these projects have already been completed and WSDOT is currently creating an updated service development plan for the corridor. Much of the 2006 plan is likely obsolete given its age, but it was the most up-to-date proposal for improvements in the existing Amtrak Cascades corridor available at the time of this analysis.

speeds above the existing 79 mph maximum within the corridor. Similar to Amtrak, trains would be diesel-powered.

- **State of the Art HSR** scenario uses mainly new infrastructure in a dedicated corridor, similar to 200+ mph systems in Europe and Asia. Speed maximization was the primary consideration when developing the concept. The concept is assumed to follow existing highway and rail corridors where possible. Tunnels were assumed in many developed areas to minimize property acquisitions. Aerial structures were used in developed areas that had geographic features (e.g., a river) that made tunneling infeasible, or in open space areas where speed improvements were required. At-grade track was assumed for the rest of the corridor. The maximum speeds would be over 200 miles per hour, and trains would be electric. Stations were assumed to be located in the seven cities identified in the legislation (similar to Scenario 1A in the Feasibility Study).
- **Hybrid HSR** scenario assumes a mix of new rights of way in rural areas for maximum speeds, and existing corridors in developed areas to minimize costs, similar to the California High-Speed Rail Project. This concept is a mix of the Incremental and State of the Art scenarios. In developed areas, the existing railroad corridor was used, in order to minimize tunneling, property acquisitions and community impacts. Outside developed areas, the State of the Art assumptions were used. The maximum speeds would be over 200 mph in dedicated areas and up to 110mph in shared corridor areas, and trains would be electric.

Figure 6 shows the existing and new corridors that are part of these conceptual trade-off scenarios, as well as general locations of constrained areas.

FIGURE 6: OVERVIEW OF CASCADIA CORRIDOR FOR TRADE-OFFS ANALYSIS



4.2 TRADE-OFF ANALYSIS METHODOLOGY AND CRITERIA

The team evaluated the three HSR scenarios using the following criteria.

- **Ridership**. As described in Section 3, ridership is primarily dependent on markets served, travel time, and frequency. This trade-off analysis qualitatively assessed how these three factors would change under each HSR scenario and uses the previous studies' findings to make comparisons. The Feasibility Study and Business Case modeled 12 trains a day and 21 trains a day, respectively; for purposes of this analysis, we assumed 12 daily trains for the Hybrid and State of the Art scenarios.
- **Cost.** For the Incremental scenario, the team used the 2006 Amtrak Plan as the basis, escalating the amounts to 2023 dollars. Capital costs for the Hybrid and State of the Art Scenarios were estimated based on standard cost categories, such as track type (at-grade, aerial, tunnel), stations, structures, etc. The unit costs were derived from the 2012 California High-Speed Rail Business Plan and escalated to 2023 dollars. Similarly, O&M costs were estimated using standard categories such as track maintenance, fuel, labor, vehicles, administrative costs, etc. The unit costs were derived from the 2015 Atlanta to Charlotte to Atlanta Passenger Rail Corridor Alternatives Development Report and escalated to 2023 dollars.
- **Economic Potential.** The economic potential and benefits of the scenarios were described qualitatively, based on amount of new construction required and ridership factors.
- **Environmental Impacts.** We looked at the natural resources that the three scenarios would cross through. The resources included water bodies, wetlands, sensitive habitats, open space/parks, and agricultural land. Additionally, other geographic constraints were considered, such as volcanic hazard zones and seismic hazards. Impacts to communities were assessed at a high-level by examining the type of track that would be constructed in developed areas (urban, mixed use, suburban land uses) versus undeveloped areas (rural land use, open space). Additionally, the team looked at potential impacts to economic justice (EJ) communities as well as if the routes crossed through Native American tribal lands.
- **Constructability.** The team calculated the percentage of track type (at-grade, aerial, tunnel), which have different constructability challenges. Property acquisitions were assessed qualitatively, based on the amount of alignment that would be located within developed and undeveloped areas. Similarly, the amount of the route within the existing railroad corridor was used to determine the level of disruption to existing infrastructure during construction.

- **Governance/Implementation.** Each type of scenario would have different governance and implementation strategies and challenges, including owner/operator and level of coordination with other passenger or freight operators.

4.3 TRADE-OFF ANALYSIS FINDINGS

Key Findings *This high-level trade-off analysis found that the Hybrid scenario was able to achieve major travel time savings compared to the Incremental scenario, while also minimizing impacts and costs compared to the State of the Art scenario.*

The trade-off analysis revealed the following:

- The State of the Art and Hybrid scenarios have an opportunity to open up new markets, as some of the stations would be entirely new and could be located in the urban core of cities. The faster travel times would also increase ridership, compared to the Incremental scenario. However, additional analysis and modeling would be needed to determine the degree to which the higher speeds and different station locations would affect ridership.
- For capital costs, the amount of tunneling is a major cost driver. The State of the Art concept assumed a high percentage of tunnel (roughly 30% of the route) through developed areas, in order to avoid significant amounts of property acquisitions and community impacts, resulting in a capital cost estimate between $36 billion and $150 billion. The Hybrid concept replaced the tunnel sections in the State of the Art scenario with improvements in the existing Amtrak Cascades corridor, which dropped the cost significantly to between $10 billion and $25 billion. These two concepts were meant to represent minimum and maximum amounts of tunneling. The actual route would likely include both tunnels and aerial structures in constrained areas, and detailed design is needed to develop a conceptual alignment for the corridor.
- For O&M costs, the main differentiating factors include the cost of diesel fuel versus electricity and the cost of maintaining dedicated track versus an existing, shared track.
- Constructing an entirely dedicated corridor would require large amounts of property acquisitions and environmental impacts. These impacts could be greatly reduced by using the existing corridor in more developed, urban areas, with the trade-off being a loss of speed.

Key Findings

Table 40 summarizes our findings for each of the three scenarios.

TABLE 40: SUMMARY OF FINDINGS FOR THREE SCENARIOS

CRITERIA	INCREMENTAL	STATE OF THE ART	HYBRID
RIDERSHIP			
Station Areas/Markets Served	Trains would stop at the existing Amtrak Cascades stations, for a total of 14 stations from Portland to Vancouver, BC. This concept would serve the same markets that are served by the existing Amtrak Cascades line.	This concept assumes service only to the seven cities identified in legislation, and it would therefore directly serve the fewest areas of the three scenarios. The alignment would operate on all new tracks, and many of the existing Amtrak Cascades stations would be bypassed. Some existing Amtrak station facilities could likely be retrofitted for HSR service (for example the Olympia/Lacey station), but new HSR platforms and facilities would need to be constructed in many of the cities. This provides an opportunity to locate the stations within the downtown, urban core of these cities, potentially serving new markets.	This concept assumes service to the seven cities identified in legislation. In some areas, the dedicated tracks would need to bypass existing station areas in order to improve speeds, and therefore it would serve fewer markets than the Incremental system. However, under this scenario, there is an opportunity to provide service at several additional existing Amtrak stations if desired (such as Mount Vernon and Centralia), where the concept runs within the existing railroad corridor. Trade-offs would need to be further analyzed for these intermediate stops to determine if the travel time penalties for stopping would outweigh the ridership benefits of added stations.
Travel Time (note assumes current customs check at US-Canada border can be eliminated)	• Seattle to Portland - 2:40 • Seattle to Vancouver – 2:30 • Vancouver to Portland – 5:20 The operational improvements included in the 2006 study would result in about a 3-hour improvement in travel time from Vancouver to Portland.	• Seattle to Portland - 1:00 • Seattle to Vancouver – 1:00 • Vancouver to Portland – 2:00 This concept would see a 6-hour improvement in travel time from Vancouver to Portland.	• Seattle to Portland - 1:50 • Seattle to Vancouver – 1:50 • Vancouver to Portland – 3:40 This concept would see a 4.5-hour improvement in travel time from Vancouver to Portland.

CRITERIA	INCREMENTAL	STATE OF THE ART	HYBRID
Frequency	Per the 2006 Plan: • 13 daily roundtrip trains from Portland to Seattle • 4 daily roundtrip trains from Seattle to Vancouver	12 trains a day	12 trains a day
COST			
Capital Cost	~$5-13B (2006 Plan estimate escalated to 2023$) This estimate includes the costs of the operational improvements identified in the 2006 Plan.	~$36-150B	~$10-25B
O&M Cost	~$124M/year (2006 Plan estimate escalated to 2023$)	~$210M/year	~$180M/year
ECONOMIC POTENTIAL			
Economic benefits/job creation	This concept would require the fewest capital improvements within the existing corridor and would result in the fewest jobs created during construction. It would also have the lowest ridership gains, as it would serve existing markets and have the lowest travel time improvement, and therefore lowest potential for market access benefits.	100% of this concept would be a new corridor, and would be newly constructed, resulting in the most jobs created and indirect benefits during construction. During operations, this concept would have the potential to increase market access benefits in the station areas, as a result of the reduced travel times	Approximately 40% of the concept would be in a new corridor. The level of job creation and indirect benefits would be between the Incremental and State of the Art scenarios. Market access benefits would be similar to the State of the Art Scenario, as it would serve the same seven stations.
ENVIRONMENTAL			
Impacts to natural resources	The Incremental system would operate within the existing corridor, and therefore would introduce the fewest new impacts to natural resources.	This scenario includes the greatest amount of "greenfield" construction, and would cross through natural resources, such as wetlands, sensitive habitats, and open spaces. While the existing corridor also passes through most of these areas, the State of the Art scenario would result in new impacts as it would construct new infrastructure in areas that currently do not have a rail line.	Impacts of this scenario would be between Incremental and State of the Art. About 60% of the route would be within the existing corridor and would have the potential to increase impacts to those surrounding areas during construction and operation. The new corridor segments are primarily located in open spaces and agricultural areas.

CRITERIA	INCREMENTAL	STATE OF THE ART	HYBRID
Impacts to community	Construction of capital improvements would result in temporary impacts in some areas, and the introduction of additional train service would also have the potential to increase impacts to the surrounding land uses and the environment.	Within developed areas, the State of the Art scenario would be located in closer proximity to residential land uses, in contrast to the existing rail corridor which is typically bordered by industrial uses and runs along the coast in several areas. In rural areas, the route would primarily be at-grade and cross through large amounts of agricultural land. This scenario would cross through two additional Native American tribal lands, compared to the other two scenarios.	This scenario has a mix of community impacts from the two other scenarios, with similar urban impacts to the Incremental scenario and similar rural impacts to the State of the Art scenario.
CONSTRUCTABILITY			
Length of at-grade/elevated/tunnel	100% at-grade Construction complexity would be low. Construction would occur within the existing corridor but would primarily consist of adding siding tracks and crossovers, with some new bridges.	• Approximately: • 50% at-grade • 10% aerial • 40% tunnel Construction complexity is high, with half of the route being aerial structures or tunnels. There would also need to be consideration for designing systems in areas with seismic hazards and volcanic hazards.	• 90% at-grade • 10% aerial Construction complexity would be fairly low. There are some aerial structures assumed in this concept. However, the majority of the track would be at-grade and/or located within the existing railroad corridor.
ROW acquisitions/ Disruption to existing structures	Property acquisitions would be low, as the capital improvements are primarily within the existing railroad corridor. However, there would be disruption to existing rail infrastructure, and construction would need to be staged to ensure the other rail operators in the corridor can maintain their operations during construction.	100% of this scenario would be new track. Although parts of it in rural areas could follow the existing rail and interstate corridors where possible, there would likely be property acquisitions needed in many areas to accommodate higher speed curves where it is at-grade or aerial (which is approximately 60% of the route). However, it would have minimal disruptions to the existing railroad corridor.	Approximately 40% of this scenario would be on a new tracks following existing rail and interstate corridors in rural areas. Property acquisitions would be needed to accommodate the new rail line in parts of these corridors to accommodate higher speed curves. For the 60% of the scenario that is within the existing Cascades corridor, there would be disruption to existing rail infrastructure, similar to the Incremental scenario.

CRITERIA	INCREMENTAL	STATE OF THE ART	HYBRID
Geographic features/ constraints	Approximately 25% of the existing corridor passes through volcanic hazard zones. Additionally, approximately 20% of the existing corridor runs adjacent to Puget Sound (mainly between Vancouver, BC and Seattle), making it more susceptible to tsunami hazard risks than an inland route.	Approximately 14% of this concept passes through volcanic hazard zones. This concept is located further inland, which could lower the risk related to seismic hazards such as tsunamis.	Approximately 16% of this concept passes through volcanic hazard zones, and approximately 20% runs adjacent to Puget Sound in areas susceptible to tsunamis.
GOVERNANCE/IMPLEMENTATION			
Owner/ operator	This scenario would most likely involve BNSF continuing as the owner and maintainer of the track infrastructure and assets, with Amtrak continuing to operate and maintain the trains.	As this system would run along entirely dedicated tracks, it would most likely have its own owner/operator separate from the current BNSF/Amtrak operations.	It is likely that this scenario's owner/operator model would be closer to the State of the Art scenario, since it would involve construction and operation of completely new corridors. There would need to be agreement with BNSF and Amtrak on operations in the 60% of the alignment that follows the existing corridor to ensure an optimal mix of effects on current operations and a reliable schedule for the HSR service – this would likely depend on how much the high-speed trains would operate on mixed versus exclusive tracks in the existing Cascades corridor.
Interagency coordination	A high level of coordination would be needed with Amtrak, BNSF, and Sound Transit (Sounder) to both construct and operate this scenario. All agencies would need to coordinate on their operating plans and come to an agreement regarding infrastructure maintenance. There would also be a need for significant third party coordination with corridor landowners, cities, and major utilities similar to other major infrastructure projects.	There would be a lower level of interagency coordination required, as this concept would operate on an entirely dedicated set of tracks. There would still need to be significant coordination with WSDOT, the BNSF Railway, corridor landowners, cities, and major utilities similar to other major infrastructure projects.	Although only part of the corridor would be within the existing railroad corridor, the level of agency coordination needed would still be similar to the Incremental scenario. Sharing any amount of the existing corridor would require the coordination during construction and operations to ensure that other operators are not impacted. There would also be a need for significant third party coordination with corridor landowners, cities, and major utilities similar to other major infrastructure projects.

5.0 FINANCE AND GOVERNANCE METHODS

This report reviewed the past studies' recommendations for governance, procurement, delivery methods, and financing methods, and found that the previous recommendations are comprehensive and sound. The previous studies – particularly the Framework Study- have laid the beginning groundwork for this project, but in order for it to proceed into the next phase, a more formal agreement is needed to lay out the general powers and responsibilities of the multiple agencies involved.

This section also provides some additional detail and lessons learned from other recent megaprojects, related to challenges in governance and construction.

5.1 GOVERNANCE

While all the previous studies touch upon governance, funding and financing, and procurement, the 2020 Framework Study is the most detailed in laying out strategies and scenarios for the different project phases, from initiation to development to construction to operation. The Framework Study charts out a path forward that is based on experience from other successful megaprojects. In order to complete project initiation tasks, the current informal partnership between Oregon, Washington, and British Columbia would need to more formally commit to the project and form a Coordinating Entity. As described in the Framework Study, forming this entity will require a memorandum of understanding or partnership agreement, as well as strong political support and dedicated resources for project planning.

Following the establishment of a Coordinating Entity, a Development Entity should be formed. This Development Entity would have the decision-making authority, financial management capabilities, and procurement experience to take the project through development and construction. There would need to be enabling legislation to create this entity. As described in the Framework Study, the Coordinating Entity could plan for the governance structure of the Development Entity, or this could be decided in advance by the current informal partnership. Creating the Development Entity would require enabling legislation or an additional partnership. Multijurisdictional projects can be challenging to implement, not simply because of the scale of the project, but also because each party has their own regulations, customs, and culture, as well as interests and goals. Therefore, the formal agreement should establish clear responsibilities and legally bind all parties to their commitments.

Based on the complexity of this project and the steps needed to establish a Development Entity, it may behoove the project to follow the two-step approach, by establishing the Coordinating Entity first. This provides agencies with the necessary time to continue to build momentum for the project, as well as provide flexibility to further adjust the governance model elements/needs as the project evolves.

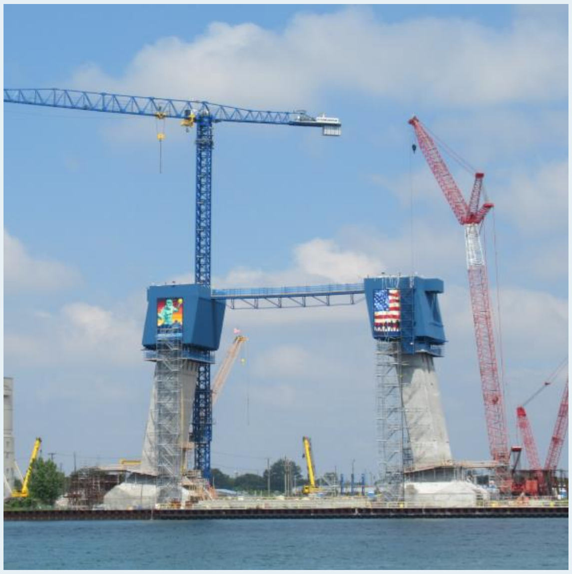
The Gordie Howe International Bridge, which will connect Detroit (MI) and Windsor (ON) is referenced throughout the Framework study because it serves as a model of a multi-national governance structure for a complex megaproject. The following case study describes the governance structure and provides an update of the project status since the Framework Study was completed in 2020.

CASE STUDY: GORDIE HOWE INTERNATIONAL BRIDGE

The Gordie Howe International Bridge project serves as an excellent model of a multi-national governance structure for a complex megaproject. It also provides a realistic expectation for the timeline needed to deliver such a project.

The project followed a two-step model, starting with an informal partnership agreement. A joint international authority was then created by a formal project agreement, which established important provisions for the design, build, financing, operation and maintenance of the bridge. It took a decade-and-a-half of planning, environmental review, and permitting to finally reach the procurement stage, and the procurement process itself took another three years. It is considered to have been successful in effectively allocating risk and achieving the highest value for money, with the delivery model being design-build-finance-operate-maintain.

The project is nearing completion but has seen cost and schedule setbacks due to the COVID-19 pandemic and recent construction cost escalation. The contractor has formally requested schedule relief and cost compensation, as they face financial penalties if the project is extended beyond the contractual deadline; discussions with the owner are ongoing. An interesting lesson learned involved the incorporation of a community benefits plan, to offset impacts on the local communities. Unlike in the US, where project sponsors routinely incorporate benefits into the project planning and budget, there was not a previous precedent on the Canadian side, which created a political obstacle to the formal agreement. Ultimately, this plan was added after strong advocacy from the US partners and after years of significant community consultation.



Early construction of Gordie Howe International Bridge (2021)

5.2 FUNDING, FINANCING, AND PROJECT DELIVERY

While all the previous studies touch upon funding and financing, the 2020 Framework Study lays out detailed strategies and scenarios for the different project phases, from initiation to development to construction to operation. This report emphasizes the following key takeaways from that study, and ties them to some more recent lessons learned from other megaprojects :

- **Political changes can greatly affect funding sources**. The governance structure should be designed to withstand changes in government, and dedicated funding streams may be more resilient to political trends. It is unlikely that US federal funding will be able to cover a significant portion of the project costs, given experience from similar past projects such as the California HSR Project. Although the federal funding opportunities for that project are now more stable, the California HSR Authority continues to evaluate other funding strategies and financing options, from cap-and-trade, local and regional funding, and private sector finance. Additionally, an important part of the California HSR funding strategy is making targeted investments in specific areas to increase public support, which is something that the Cascadia UHSGT project may need to consider.
- **A mix of public and private funding will likely be needed.** The California HSR Project, as well as other HSR projects across the globe, has experienced a lag in private investment in the earlier stages, as private sector partners are typically unwilling to engage until the risks and returns are better understood. The California HSR Project is relying on state and federal funds, and has developed a phased construction approach for its initial operating segment as public funding becomes available; at this point, there is no identified timeline for completion of the entire system. Private financing options can advance the project more quickly, and private activity bonds have been an important financing mechanism for other US HSR projects in development, including the Florida Brightline and Brightline West, and should eventually be considered for this project. Another viable option is the Canada Infrastructure Bank, which to date has funded several other rail projects; additional coordination and ridership/revenue analysis is needed to determine the Cascadia HSR’s eligibility. The Cascadia UHSGT decision-makers will need to keep in mind that the private sector wants to see project risks reduced and certainty in project definition and operational capacity before investing.

Table 41 summarizes some project delivery models that are commonly used for large-scale infrastructure projects. Traditionally, public agencies have taken on the greatest risk and funding/financing responsibilities, but they are increasingly using alternative methods that transfer some of those risks and costs to the private sector, which bring opportunities for reduced cost, increased efficiency, and improved quality.

TABLE 41: PROJECT DELIVERY MODELS FOR LARGE-SCALE INFRASTRUCTURE PROJECTS

DELIVERY METHODS		ADVANTAGES/DISADVANTAGES
Traditional	Design-Bid-Build (DBB): Design and construction are performed sequentially, and the separate contractors are selected through a competitive process	Commonly used for public infrastructure, and is the most familiar to public agencies and the contracting industry. This method clearly defines construction requirements, but it typically leaves less room for design innovation. It has the lengthiest timeline for completion, due to the sequential nature of the process. The public sector takes on the most risk, as they must oversee both phases of work. Funding is from tax revenues or bonds on a "pay-as-you-go" basis.
Alternative	Design-Build (DB): Similar to DBB, but it uses a single contract for both design and construction.	As the designer and contractor are under a single contract, it can compress the project timeline, by allowing some design and construction work phases to be conducted in parallel. This method could allow for more efficiency, lowering costs and providing more room for design innovation. However, the owner may not get the most competitive pricing, as there is no competitive bid process. This method assigns some risk to the private sector, as they assume the risk for design error and interfaces with the construction contractor.
	Construction Manager/General Contractor (CM/GC): The owner has separate contracts for a designer and contractor, and brings them on board around the same time.	This method is similar to DB, but gives the owner greater control over both design and construction; it also requires the owner to take on additional risk and responsibility in overseeing two separate contracts.
	Progressive DB: Similar to DB, but the contractor is brought into project development at a very early phase of design, with the team working together to achieve the final design and cost estimate.	This delivery method is a newer variation of DB, and is becoming increasingly popular as it offers the owner additional advantages. The owner involves the team very early in the process, which can minimize future change orders and provide more transparency into costs.
	Design-Build-Operate-Maintain (DBOM): Adds operation and maintenance responsibilities to the DB agreement.	This method can allow for greater efficiency, as the designer has a better sense of the long-term maintenance program and costs, and can better address those needs earlier on. The public sector remains responsible for the project's financing and retains the operating revenue risk. Maintenance costs, which often have unreliable sources of public funding, are transferred to the private sector.
	Design-Build-Finance, can also include Operate, and/or Maintain: Typically used for large-scale infrastructure projects with a long life span.	These alternative methods include private financing in the agreement, where the contractor is responsible for financing the construction costs. These costs can be spread out over the life of the project, in contrast to traditional methods. If operations and maintenance are also included, the private partner is responsible for all aspects and for providing a service for a long horizon with specifications at the end. Bringing together all elements of the project under one contract can result in greater efficiency in project delivery. This method transfers the most risk to the private sector, and results in significant public sector cost savings. However, these contracts are typically very complex to set up and manage.
Market-based	Privatization: Transfers all aspects of the project to a private owner. Not typically used in the US.	This method would allow public agencies to close the budget gap and deliver the project sooner, but would require relinquishment of control over service delivery to the private sector.

Members of the future Development Entity will need the appropriate project management experience to not only select an optimal delivery method but to also manage a complex procurement. For example, Canadian agencies generally have more experience dealing with P3 projects, compared to the US where the model is still emerging; it will be important to leverage each party's strengths and areas of expertise. There is much work that lies ahead before a preferred delivery method can be selected, as the project costs, operations, and revenue potential need to be better understood.

CASE STUDY: CALIFORNIA HIGH-SPEED RAIL

The California HSR Authority has had to adjust its procurement and delivery strategy over the years, as it takes into account lessons learned from earlier construction packages as well as adapting to changing federal funding sources, supply chain issues during the COVID-19 pandemic, and high inflation. The first three packages of the California HSR project were procured as design-build contracts, but the Authority has had to deal with multiple change orders, partially as a result of scope that was not clearly defined. As they now near completion of their initial operating segment, they have developed a staged delivery process where they evaluate all delivery and procurement methods to determine the one that is most suitable for each extension. Recently, they have also identified a need to augment their governance process, by establishing a new decision committee with oversight of project delivery and contracting methods.