WSDOT

Appendix E: Washington's Freight Transportation System Performance

(2022 Washington State Freight System Plan Update)

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Table of Contents

Table of Figures

Acronyms & Abbreviations

Abbreviation	Description
AADTT	Annual Average Daily Truck Traffic
ATRI	American Transportation Research Institute
BFI	King County International Airport
BIL	Bipartisan Infrastructure Law
BLI	Bellingham International Airport
BNSF	Burlington Northern Santa Fe Railway
BTS	Bureau Of Transportation Statistics
BUILD	Better Utilizing Investments to Leverage Development
CO	Carbon Monoxide
DOT	Department Of Transportation
DPM	Delay Per Mile
ED	Excessive Delay
EDTTT	Excessive Delay Threshold Travel Time
FAA	Federal Aviation Administration
FAF	Freight Analysis Framework
FAST	Fixing America's Surface Transportation
FHR	Friday Harbor Airport
FHWA	Federal Highway Administration
FGTS	Freight And Goods Transportation System
FRA	Federal Railroad Administration
GEG	Spokane International Airport
GHG	Greenhouse Gas
HSIP	Highway Safety Improvement Program
ICAO	International Civil Aviation Organization
LNG	Liquefied Natural Gas
MAP-21	Moving Ahead for Progress in the 21st Century
MWH	Grant County International Airport
NFSP	National Freight Strategic Plan
NHFN	National Highway Freight Network
NHFP	National Highway Freight Program
NHS	National Highway System
NMFN	National Multimodal Freight Network
NOX	Nitrogen Oxides
NPMRDS	National Performance Management Research Data Set
OSOW	Over-Sized/Over-Weight
PAE	Paine Field Airport
PDO	Property Damage Only
PHED	Peak Hour Excessive Delay
PHFS	Primary Highway Freight System
PIDP	Port Infrastructure Development Program
PSC	Tri-Cities Airport
PSR	Precision Scheduled Railroading
RAISE	Rebuilding American Infrastructure with Sustainability and Equity

Abbreviation	Description
RCW	Revised Code of Washington
SD	Segment Delay
SHSP	Strategic Highway Safety Plan
SR	State Route
TDPM	Total Daily Delay Per Mile
TEU	Twenty-Foot Equivalent Units
TIGER	Transportation Investment Generating Economic Recovery
TTTR	Truck Travel Time Reliability
UNGSF	Underground Natural Gas Storage Facility
UP	Union Pacific
UPS	United Postal Service
U.S.	United States
USACE	U.S. Army Corps of Engineers
UTC	Utilities and Transportation Commission
VMT	Vehicle Miles Traveled
WSDOT	Washington Department of Transportation
YKM	Yakima Air Terminal / McAllister Field

Executive Summary

This document provides an assessment of the current conditions and performance of the multimodal freight system in Washington.

Linking freight performance to the state and federal performance tracking context

The Fixing America's Surface Transportation (FAST) Act sets freight planning requirements for state DOTs both in terms of the planning content and specific performance measures and targets. In addition to the FAST Act requirements, the Bipartisan Infrastructure Law (BIL), signed by President Biden on November 15, 2021, adds content requirements for the state freight plans. These requirements have been addressed in the WSDOT State Freight Plan development so far and will continue to inform the upcoming tasks.

Meanwhile, WSDOT's vision, goals, and objectives are established in their Strategic Plan, which identifies programs and performance measures that are tracked and reported under each of the statewide transportation policy goals established by the state Legislature:[1]

Washington Statewide Transportation Policy Goals
Preservation: to "maintain, preserve, and extend the life and utility of prior investments in transportation systems and services, including the state ferry system;"
Safety: to "provide for and improve the safety and security of transportation customers and the transportation system;"
Stewardship: to "continuously improve the quality, effectiveness, resilience, and efficiency of the transportation system;"
Mobility: to "improve the predictable movement of goods and people throughout Washington state, including congestion relief and improved freight mobility;"
Economic vitality: to "promote and develop transportation systems that stimulate, support, and enhance the movement of people and goods to ensure a prosperous economy;" and
Environment: to "enhance Washington's quality of life through transportation investments that promote energy conservation, enhance healthy communities, and protect the environment."

WSDOT's progress toward achieving the transportation policy goals is reported in the Gray Notebook, which is published quarterly.

This freight plan takes a modal approach to assess the performance and condition of Washington's freight system, using data that is readily available at the state and federal levels and, where available, builds on other relevant studies that have been conducted by WSDOT or other state agencies. The following are key performance areas considered in this report:

- **Mobility:** analysis of delays and reliability of freight movements.

- **Infrastructure condition:** assessment of the suitability of the state's transportation system for serving freight movements.

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[1] Revised Code of Washington (RCW) 47.04.280: Transportation system policy goals, Washington state Legislature, July 2022. https://apps.leg.wa.gov/rcW/default.aspx?cite=47.04.280

- **Safety:** analysis of the safety impacts of freight activities along Washington's transportation system.

Highway system performance

Washington's highway system consists of over 7,034 miles of interstates, U.S. highways, and state routes, serving over 13.4 million truck miles traveled and carrying over 343 million tons of cargo annually. A summary of Washington's highway system condition, performance, and issues is presented below:

Mobility

- Truck Travel Time Reliability (TTTR) Index along the interstates is currently the only federally-required performance measure for freight. The 2021 interstate TTTR Index is calculated to be 1.49 for Washington, which is better than the 1.75 performance target established by WSDOT but marks a slight increase in delay over the 1.43 recorded in the prior year.

- Truck travel time delays are also calculated to complement TTTR Index analysis to better understand the delay in truck hours per mile for trucks. Analysis results show that truck delays are relatively higher in urban areas and along high-volume corridors such as I-5 and I-405 through Seattle, Tacoma, Olympia, and Vancouver, I-90 east of Snoqualmie Pass, and I-90 and US 2 in Spokane.

- Relatively high delays are also observed for trucks traveling to/from major freight facilities, including routes near Port of Seattle and King County International Airport.

Location of Washington's top truck bottlenecks

Truck bottlenecks are segments on the roadway network where trucks experience a significant breakdown in traffic flow. According to the Federal Highway Administration (FHWA), a bottleneck may cause congestion, but congestion is not always the result of a bottleneck. Hence, for the purpose of the freight planning effort, a three-step approach is used to identify and rank the segments along the interstate system that experience truck mobility issues. These locations are known as truck bottlenecks. Figure 1 illustrates the location of Washington's most-significant bottlenecks.

- **Step 1:** Indicate the extent to which truck delays are expected by calculating the TTTR Index;

- **Step 2:** Calculate the total (annual) delays per mile of the National Highway System (NHS) network for trucks;

- **Step 3:** Calculate a combined index that is representative of both delay and reliability challenges for trucks traveling along the NHS network (Delay-TTTR Index).

Each of these steps is described in more detail in Chapter 2 and Reference Chapter A.

Figure 1: Top ten road segments with high reliability-delay index for trucks

Source: WSDOT, NPMRDS. Cartography by CPCS (2022).
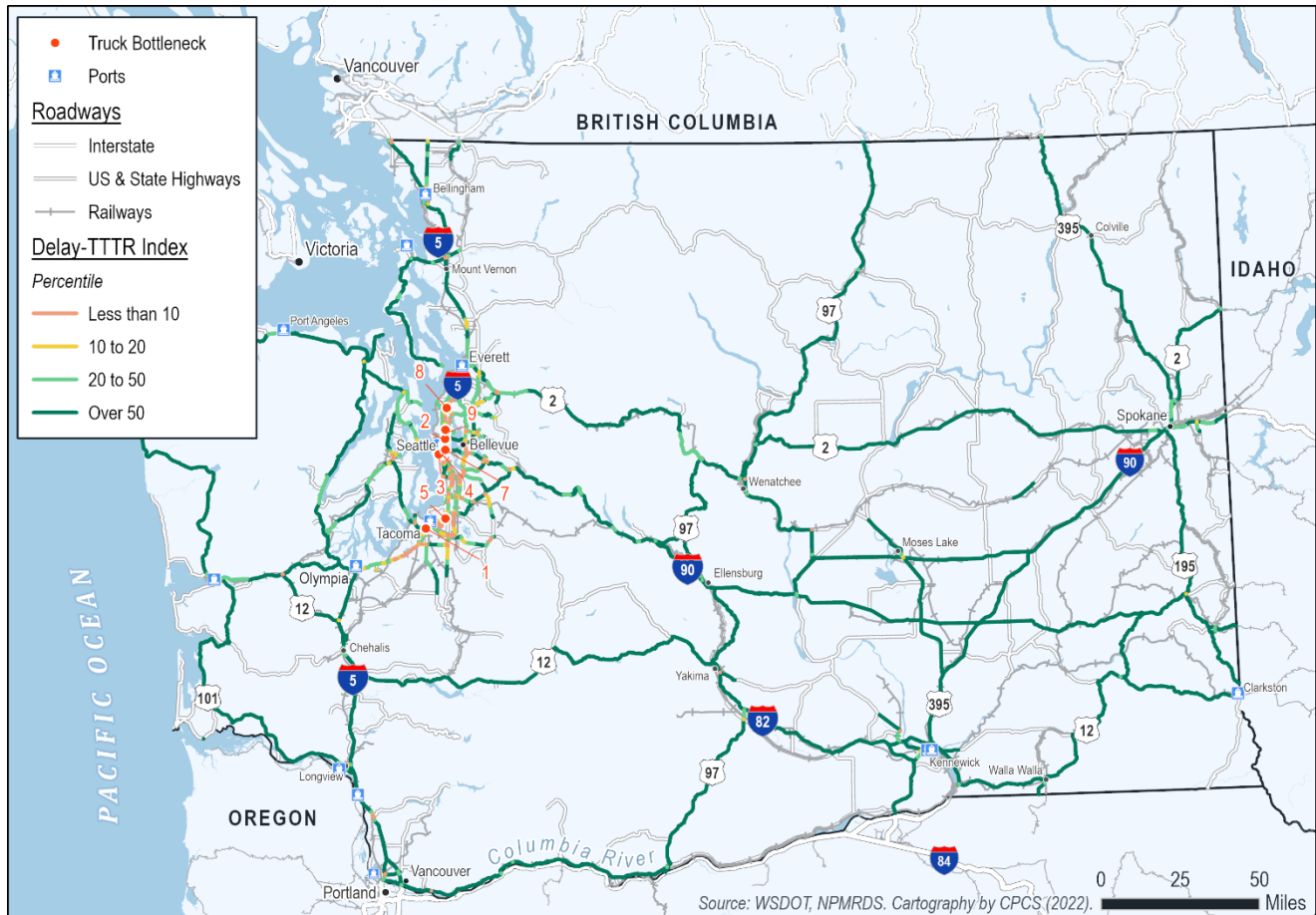
Condition

- The I-5 corridor between Seattle and Portland, Oregon, the I-90 corridor between Seattle and Ellensburg, and I-90 between Ritzville and the state's border with Idaho have the highest frequency of oversized/overweight truck movements, which pose safety and roadway operational/maintenance concerns.

- The state's pavement condition measures, including percent of pavement in fair or better condition, asset sustainability ratio, remaining service life, and deferred preservation liability, have improved in 2021, compared to conditions reported in 2018 and 2019.

- The majority of the bridges in Washington were in fair or better condition in 2021, meeting WSDOT's bridge condition performance goal.

Safety

Between 2016 and 2021, over 40,750 truck-involved crashes occurred in Washington, leading to nearly 980 fatalities, over 3,680 severe injuries, and over 12,270 evident or possible injuries. About 83 percent of the truck-involved crashes that happened in Washington between 2016 and 2021 were property damage only (PDO), leading to no casualties. Analysis of the crashes across the state shows that, while the annual number of truck-involved crashes increased in 2021, the 5-year average truck-involved crashes have declined.

Rail system performance

The major national Burlington Northern Santa Fe Railway (BNSF), Union Pacific (UP), and 27 short line railroads operate on over 3,200 miles of track in Washington. Over 95 million tons of freight is moved by rail across the state annually, primarily serving domestic flows of grain and other agricultural products shipped to ports for export and crude petroleum shipped to refineries across the state.

Mobility

According to the 2019 State Rail Plan, several subdivisions of the freight rail network in Washington are expected to experience significant growth in tonnage and train volumes, particularly Tacoma to Vancouver, Vancouver to Pasco, Pasco to Lakeside, Lakeside to Spokane, and Spokane to Hinkle, Idaho. While the Class I railroads in the state will likely address key capacity issues on their tracks, increased yard and terminal demand can affect first/last mile rail mobility.

Condition

- The two Class I railroads in Washington (BNSF and UP) are capable of handling industry-standard 286,000-pound rail cars over all of their main routes in the state. Also, almost all of the BNSF and UP mainlines can be operated at 25 mph or above.

- Nineteen railroads manage about 1,110 miles of the short line tracks in Washington, accounting for 82 percent of the total short line mileage in the state. A 2019 survey of these short lines showed that about 61 percent of their tracks can be operated at 25 mph or above, and 55 percent are capable of handling 286,000-pound rail cars.

Safety

- Between 2012 and 2021, about 364 highway-rail grade crossing incidents occurred in Washington (including 53 incidents with Amtrak trains), leading to 54 deaths and 104 injuries. Near 80 percent of the incidents were at public highway-rail crossings, and the rest were at private crossings.

- The increase in the length of trains following the implementation of Precision Scheduled Railroading (PSR) is a safety and mobility concern for communities living near at-grade crossings in Washington. In particular, at-grade crossings on UP and BNSF lines southwest of Spokane experience the highest frequency of blocking, causing delays on South Mullink Rd. in Cheney and North Freya St., West Deno Rd., and East Broadway Ave. in Spokane.

Maritime system performance

Washington's maritime system includes the Salish Sea, the Snake-Columbia River, and the Pacific Coast subsystems and includes 74 port districts, 22 major port facilities, two marine highways, and several harbors and marine terminals. This well-connected maritime system primarily serves agricultural, energy, and manufacturing industries, competing with other modes both in terms of efficiency and cost to serve the state's shippers and businesses. Over 26 million tons of cargo is carried by the state's maritime system annually.

Mobility

Road congestion is a common challenge at the state's marine ports. Near the largest ports, heavily congested local road networks hinder truck access between terminals and the regional highway network. Also, at-grade road crossings of railroads near many marine ports delay truck and vehicle traffic, a condition that becomes more severe when train volumes or train lengths increase.

Condition

From a national perspective, Washington's deep-draft marine ports offer exceptional infrastructure, close proximity to the interstate system, and service from two Class I railroads.

Meanwhile, aging locks and dams, unscheduled outages and stalls, and extreme weather conditions can affect lockage processing time and reduce goods movement efficiency along the Columbia-Snake River. According to the U.S. Army Corps of Engineers, the service lives of navigation structures are between 60 and 75 years. There are a total of nine locks in Washington – four each on Columbia and Snake Rivers and one on the Lake Washington Ship Canal. Only the Lake Washington Ship Canal lock exceeds the estimated service life, but it has gone through major renovations in 2018 and 2020.

Air cargo system performance

Air cargo offers statewide economic development opportunities due to its efficiency and reliability when compared to other modes of freight transportation. There are 22 airports in the state that offer air cargo services. The primary industries served by air cargo in Washington are agriculture, electronics manufacturing, pharmaceuticals, aerospace manufacturing, and seafood, which rely on fast transportation to ensure valuable and perishable goods reach domestic and international markets in time.

Mobility

Except for King County International Airport and Tri-Cities Airport, all the other eight cargo airports in Washington have seen major growth in their air cargo tonnages over the past six years.

Condition

The majority of the runways in the top ten cargo airports by volume in Washington are in good or excellent condition. King County International Airport and Tri-Cities Airport have two runways that are in fair condition. The only runway that is in poor condition is at Yakima Air Terminal/McAllister Field.

Pipeline system performance

There are over 46,000 miles of pipeline in Washington, carrying over $22.8B worth of crude oil, petroleum, and natural gas through 30 of the state's 39 counties.

Mobility

The volume of oil movements by pipeline in Washington has been slowly rising over the last decade, from just over 6 billion gallons in 2010 to over 8 billion in 2019. Oil volumes fell to 7.5 billion gallons in 2020 during the COVID-19 pandemic. Meanwhile, crude oil volumes have remained relatively stable. In 2020, almost 72 million barrels, or over 3 billion gallons, of crude oil moved by pipeline in the state.

Safety

In terms of hazmat spills from the pipeline system, data indicates that Washington has relatively a strong pipeline safety performance.

Environmental impacts of transportation operations in Washington

While the transportation of people and goods creates social and economic benefits, it creates negative environmental and social impacts due to the burning of fossil fuels and emitting greenhouse gas (GHG) and pollutants. Road, rail, maritime, and air traffic also create noise pollution that impacts

wildlife and communities. Stormwater runoff, oil spill incidents, and disturbance to fish passages are some other examples of the transportation system's environmental impacts in Washington.

- According to the 2018 Washington Greenhouse Gas Inventory, transportation was the largest GHG generator, creating 44.73 million metric tons of CO_2, accounting for 45 percent of the total GHG emissions in the state. Among the different transportation modes, personal cars and trucks made up over half of the emissions in Washington.

- The Environmental Health Disparities Map developed by the Washington Department of Health incorporates performance indicators to evaluate the environmental impacts across the communities in the state. The communities with high Environmental Health Disparities are clustered in major urban areas, such as the Puget Sound region and Spokane. The communities are also disproportionally impacted along the I-5 corridor, Yakima Indian Reservation, and southeast Washington.

- Analysis of transportation-related NOx-Diesel Emissions reveals that the impact of diesel pollution on the vulnerable population is especially disproportionate along Puget Sound, Centralia, Longview I-5 corridor, I-90 corridor from Moses Lake to Spokane, and I-82 between Yakima and Kennewick.

1.   State and federal performance tracking context

Key chapter takeaway

This chapter summarizes the state and federal guidance and existing efforts for tracking transportation performance measures in Washington. The FAST Act sets the freight planning requirements for the states both in terms of the planning content and the specific performance measures and targets. Meanwhile, WSDOT's vision, goals, and objectives are established in the Strategic Plan, which entails programs and sets of performance measures that are tracked and reported under each of the Strategic Plan goals.

Federal FAST Act guidance for freight planning

The Fixing America's Surface Transportation (FAST) Act was signed into law in 2015, establishing the freight planning requirements for the long-range freight planning. The FAST Act established a national multimodal freight policy and goals as well as a National Multimodal Freight Network (NMFN), including a National Highway Freight Network (NHFN), required the states to develop state freight plans and created the National Highway Freight Program (NHFP), which apportions an average of $1.2 billion annually to states by formula.[2]

As an outcome of the FAST Act, the U.S. Department of Transportation (USDOT) developed a National Freight Strategic Plan (NFSP) to implement the goals of the national multimodal freight policy and to define USDOT's vision and goals for the national multimodal freight system. NFSP also informs the state freight planning efforts and can be used to identify freight data needs and methodologies to assess the conditions and performance of the statewide freight system.[3]

National Freight Strategic Plan's vision for the freight transportation system

"The freight transportation system of the United States will strengthen our economic competitiveness with safe and reliable supply chains that efficiently and seamlessly connect producers, shippers, and consumers in domestic and foreign markets."

Source: USDOT National Freight Strategic Plan, 2022.

Both the National Freight Strategic Plan's vision and goals and the NHFP requirements indicate the principles that must be adhered to while developing a state freight plan, including identifying and investing in infrastructure improvements, policies, and operational innovations that:

- Strengthen the contribution of the NMFN (including the NHFN) to the national economic competitiveness;

- Reduce congestion and eliminate bottlenecks on the NMFN (including the NHFN);

- Improve the reliability of the NHFN; and

- Increase productivity, particularly for domestic industries and businesses that create high-value jobs.

In addition to the FAST Act requirements, the BIL, signed by President Biden on November 15, 2021, adds the following content requirements for the state freight plans:

- Include supply chain cargo flows.

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[2] Fixing America's Surface Transportation Act or "FAST Act", FHWA, (n.d.). https://www.fhwa.dot.gov/fastact/factsheets/nhfpfs.cfm

[3] National Freight Strategic Plan (NFSP), USDOT, 2020. https://www.transportation.gov/freight/NFSP

- Include an inventory of commercial ports.

- Analyze the impacts of e-commerce on freight infrastructure.

- Consider military freight.

- Identify strategies and goals to address extreme weather, air pollution, flooding, and wildlife and habitat loss.

- Assess truck parking facilities.

- Enhance reliability and redundancy of freight transportation, or improve the ability to rapidly restore access to freight transportation.

WSDOT's Performance Framework

WSDOT's vision, mission, and values that guide the agency's activities are established in the Strategic Plan, a living document focused on advancing the inclusion, practical solutions, and workforce development goals.

<div style="text-align:center; color:green; font-weight:bold;">WSDOT's Strategic Plan vision is "to provide a "safe, sustainable, and integrated multimodal transportation system for Washington travelers."[4]</div>

WSDOT programs report on their performance under each of the strategic goals. The performance measures are calculated and reported over varying periods, depending on program schedules, and reported in the Strategic Plan Dashboard.

Additionally, WSDOT is developing a comprehensive Performance Framework to align the transportation projects in the state with the available funds while meeting the Legislature's transportation policy goals. The Framework is being developed incrementally for the following six statewide transportation policy goals established by the state Legislature:[5]

Washington Statewide Transportation Policy Goals
Preservation: to "maintain, preserve, and extend the life and utility of prior investments in transportation systems and services, including the state ferry system;"
Safety: to "provide for and improve the safety and security of transportation customers and the transportation system;"
Stewardship: to "continuously improve the quality, effectiveness, resilience, and efficiency of the transportation system;"
Mobility: to "improve the predictable movement of goods and people throughout Washington state, including congestion relief and improved freight mobility;"
Economic vitality: to "promote and develop transportation systems that stimulate, support, and enhance the movement of people and goods to ensure a prosperous economy;" and
Environment: to "enhance Washington's quality of life through transportation investments that promote energy conservation, enhance healthy communities, and protect the environment."

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[4] WSDOT Strategic Plan Factsheet, 2022.

[5] Revised Code of Washington (RCW) 47.04.280: Transportation system policy goals. Washington state Legislature, July 2022. https://apps.leg.wa.gov/rcW/default.aspx?cite=47.04.280

So far, WSDOT has completed the Mobility and Economic Vitality Performance Frameworks and is currently developing the Environmental, Safety, and Preservation Performance Frameworks. All frameworks are expected to be completed by December 2022, establishing performance tracking guidance and testing draft products through pilots.

WSDOT's progress toward achieving the transportation policy goals is reported in the Gray Notebook, which is the agency's performance and accountability report published quarterly. The latest Gray Notebook was published in September 2021, providing performance measures and targets for highway and rail safety; highway system preservation; highway, rail, and ferry mobility; stormwater management; fish passage improvements; and stewardship metrics related to projects' schedule and budget.

The measures related to safety and mobility are further explored and quantified for the freight system in this Appendix. Meanwhile, the performance measures related to system preservation are pulled from the Gray Notebook and presented in this Appendix. Also, the information provided by the Washington Department of Ecology and the Department of Health on transportation-related emissions and their impacts on the communities are presented in this Appendix.

2.   Freight system performance and condition evaluation

Key chapter takeaway

The Truck Travel Time Reliability (TTTR) Index is the only freight performance measure required by the FAST Act. Other data measurements and supporting information are provided in this chapter to fulfill freight planning content requirements and to provide context on facts and trends surrounding freight system performance in Washington.

Overview

An understanding of freight system condition and performance is needed to evaluate WSDOT's progress towards the goals and objectives that it uses to guide system investments. WSDOT has an established performance benchmarking and reporting system: the Gray Notebook, which is published quarterly and provides updates on the state's transportation system performance. The Grey Notebook places performance measures into the following categories:

- Measures aligning with the statewide transportation policy goals, including safety, preservation, congestion relief, and environmental and stewardship measures.

- Federally mandated Transportation Performance Management (MAP-21) measures, including highway safety baselines and targets.

- Measures extracted from other regular reports, including the annual highway safety report, annual bridge preservation report, capital facilities biennial report, quarterly reports on incident response and state ferry operations, annual water quality report, and capital project delivery quarterly updates.

Figure 2 provides a list of the specific performance measures included in the WSDOT's Gray Notebook. The measures considered as relevant to freight planning and analyzed, adapted, or directly obtained from the Gray Notebook are also highlighted in the table.

Figure 2: Performance measures reported in the Gray Notebook

Type	Measure	Baseline	2021 Target	Adapted/Considered
Statewide Transportation Policy Goals				
Safety	Rate of traffic fatalities per 100 million vehicle miles traveled statewide	0.86	<1	✓
	Rate of recordable incidents for every 100 full-time WSDOT workers	4.7	<5	-
Preservation	Percentage of state highway pavement in fair or better condition by vehicle miles traveled	92.9%	>90%	✓
	Percentage of state bridges in fair or better condition by bridge deck area	93.8%	>90%	✓
Mobility (congestion relief)	Highways: Vehicle Miles Traveled (VMT) on state highways	35.4B	-	✓
	Highways: Average incident clearance times for all Incident Response program responses	15.8B	-	-

Type	Measure	Baseline	2021 Target	Adapted/Considered
	Ferries: Percentage of trips departing on time	88.2%	>95%	-
	Rail: Amtrak Cascades on-time performance	58%	>88%	-
Environment	Number of WSDOT stormwater management facilities constructed	106	-	-
	Cumulative number of WSDOT fish passage improvement projects constructed	352	-	-
Stewardship	Cumulative number of Nickel and TPA projects completed and percentage on time	383/86%	>90%	-
	Cumulative number of Nickel and TPA projects completed and percentage on budget	383/91%	>90%	-
	Variance of total project costs compared to budget expectations	1.5%	-	-
Transportation Performance Management				
Highway Safety	Number of traffic fatalities on all public roads	542.8	444.1	✓
	Rate of traffic fatalities per 100 million vehicle miles traveled (VMT) on all public roads	0.885	0.724	✓
	Number of serious traffic injuries on all public roads	2,208.6	1,807	✓
	Rate of serious traffic injuries per 100 million VMT on all public roads	3.59	2.94	✓
	Number of non-motorist traffic fatalities plus serious injuries	577	472	✓
	Rate of per capita traffic fatalities for drivers and pedestrians 65 or older	Show Progress		-
	Rate of fatalities on high-risk rural roads	Show Progress		-
	Highway-railway crossing fatalities	Show Progress		✓
Pavement and Bridges	Percent of interstate pavement on the NHS in good condition	39.8%	30%	✓
	Percent of interstate pavement on the NHS in poor condition	1.7%	4%	✓
	Percent of non-interstate pavement on the NHS in good condition	45.2%	18%	✓
	Percent of non-interstate pavement on the NHS in poor condition	17.4%	5%	✓
	Percent of NHS bridges classified in good condition (weighted by deck area)	32.8%	30%	✓
	Percent of NHS bridges classified in poor condition (weighted by deck area)	7.8%	10%	✓
Highway System	Percent of person-miles traveled on the interstate system that are reliable	77%	68%	-

Type	Measure	Baseline	2021 Target	Adapted/Considered
Performance, Freight, and Congestion Mitigation & Air Quality	Percent of person-miles traveled on the non-interstate NHS system that are reliable	80.8%	61%	-
	Truck Travel Time Reliability (TTTR) Index	1.54	1.75	✓
	Non-Single Occupancy Vehicle (SOV) travel in Seattle urbanized area (NHS)	33.1%	33.2%	-
	Peak hours of Excessive Delay per capita in Seattle urbanized area (NHS)	23.2	28	✓
	All Pollutants (kg/day)	1,222.87	658.3	✓
	Carbon Monoxide (CO) (kg/day)	714.7	309.06	✓
	Particulate Matter less than 10 microns (PM10) (kg/day)	274.64	224	✓
	Particulate Matter less than 2.5 microns (PM2.5) (kg/day)	56.75	8.7	✓
	Nitrogen Oxides (NOX) (kg/day)	176.77	116.54	✓

Source: WSDOT, Gray Notebook, 2021.

This plan takes a mode-by-mode approach to assess the performance and condition of Washington's freight system, using data that is readily available at the state and federal levels and, where available, builds on other relevant studies that have been conducted by WSDOT or other state agencies. The key areas for monitoring the performance and condition of Washington's freight system include:

- **Mobility:** to analyze the delays and reliability condition of freight movements along the state's freight system and to inform WSDOT's efforts for reducing congestion, eliminating "bottlenecks on the National Multimodal Freight Network," and improving the "reliability of freight transportation."[6]

- **Infrastructure condition:** to investigate the suitability of the state's transportation system for serving freight movements and help WSDOT's decisions for achieving and maintaining "a state of good repair on the National Multimodal Freight Network."[7]

- **Safety:** to assess the safety impacts of freight activities along Washington's transportation system and benchmark the state's ability to meet the national multimodal freight policy goal for improving the "safety, security, efficiency, and resiliency of multimodal freight transportation."[8]

To measure the freight system performance, this plan also relies on the information provided in the most recent version of the Gray Notebook report (published September 30, 2021). For instance, the highway system condition measures reported in this document are directly extracted from the Gray Notebook since pavement and bridge design and maintenance tasks are planned based on heavy vehicle traffic use, and no modification would be required for reporting on freight-related impacts. Meanwhile, some measures (such as measures related to safety and mobility) had to be adapted to show how freight activities impact and are affected by all-vehicle traffic.

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[6] United States Code 49: Transportation - Subtitle IX - Multimodal Freight Transportation, Sec. 70101: National multimodal freight policy, U.S.C, 2019. https://uscode.house.gov/view.xhtml?path=%2Fprelim%40title49%2Fsubtitle9&edition=prelim
[7] Ibid.
[8] Ibid.

Highway system performance

Washington's highway system consists of over 760 interstate miles, 1,600 U.S. Highway miles, and 4,600 state route miles. The state's highway system serves over 13.4 million truck vehicle miles traveled, carrying 343.7 million tons of cargo annually. About 820 miles of Washington's road network is designated as part of the Primary Highway Freight System (PHFS) due to its importance for the national freight transportation system.

7,034 miles	**13.4 M**	**343 M**
Interstate & U.S. Highways and State Routes	Truck Miles Traveled in 2019	Tons of Commodities Carried Annually

Source: CPCS analysis of FHWA HPMS data, 2021 | FAF 5 Tabulation Tool, 2022.

Truck mobility performance

Assessment of the locations where trucks have mobility issues is critical to indicating the solutions and planning the investments. For the purpose of the freight planning effort, a three-step approach is used to identify and rank the segments along the National Highway System (NHS) network that experience truck mobility issues. These locations are known as truck bottlenecks.

- **Step 1:** Indicate the extent to which truck delays are expected by calculating the TTTR Index;

- **Step 2:** Calculate the total (annual) delays per mile of the NHS network for trucks;

- **Step 3:** Identify truck bottlenecks using a combined index that is representative of both delay and reliability challenges for trucks traveling along the NHS network.

Each of these steps is described in the following sections. A detailed description of the methodology and data used in each step is presented in Appendix A.

Step 1: Truck Travel Time Reliability Index

Through MAP-21, FHWA was required to establish measures to assess the performance of freight movements on the interstate system. Therefore, in 2018, FHWA established the TTTR Index as the only federally required freight performance measure to be calculated and submitted to FHWA biennially.[9] TTTR is a measure of the consistency of commercial vehicle travel times or the degree to which delays are unexpected; therefore, it can inform truck bottleneck identification and prioritization.

Truck travel time data and speed data required for TTTR analysis are collected from the National Performance Management Research Data Set (NPMRDS). NPMRDS data is available at the Traffic Message Channel (TMC) link level along the roads that are part of the NHS. A TMC link is a directional road segment, typically with a length of about 0.5 to 1 mile in urban areas and up to 5 to 10 miles in rural areas.[10] Therefore, NPMRDS data allows for the calculation of TTTR Indices at the TMC link level. A statewide TTTR Index is also calculated and reported.

Figure 3 shows Washington's Interstate TTTR Indexes reported to FHWA in 2018 and 2020, calculated based on NPMRDS data of 2017 and 2019. Two-year and four-year TTTR Index targets and 2022 measures calculated based on 2021 NPMRDS data are also included in the table. As

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[9] Transportation Performance Management Guidebook, FHWA, June 2018.

[10] The National Performance Management Research Data Set (NPMRDS) and Application for Work Zone Performance Measurement, FHWA, September 2020. https://ops.fhwa.dot.gov/publications/fhwahop20028/fhwahop20028.pdf

shown, Washington achieved its two-year target for the statewide TTTR Index since the 2019 Index was about 9.5 percent (1.5 points) below the two-year target of 1.7. According to WSDOT, this improvement can be associated with various state and regional efforts undertaken to reduce truck congestion and alleviate bottlenecks through the planning process and TIP and STIP investments, including but not limited to mobility, operational and system management improvements, and pavement preservation.[11] The TTTR Index for the interstate system in Washington was 1.49 in 2021. Therefore, the state has achieved its four-year target of 1.75.

Figure 3: Washington's statewide TTTR Index and targets

Measure	2017	2019	2020	2021	2-year Target	4-year Target
TTTR Index on interstate	1.63	1.54	1.43	1.49	1.7	1.75

Source: CPCS analysis of NPMRDS data, 2022 | FHWA State Biennial Reports, 2018 & 2020.

The TTTR ratios calculated (based on 2021 NPMRDS data) for highway segments are used (along with other factors) to determine what parts of the system have the greatest reliability. Figure 4 shows the 2021 TTTR ratios calculated for the highways in Washington. Red segments show high TTTR ratios, which means low reliability. The map shows that TTTR ratios on interstates passing through and near cities are relatively higher, meaning that delays are more expected on those road segments.

Step 2: Truck delay per mile

Travel time delay is a performance measure based on speed, usually calculated from the difference between free-flow travel time and observed peak hour travel time for particular road segments, multiplied by the peak hour traffic volume. The peak hour travel time delay is used to calculate the total annual hours of delay for each road segment. The annual truck hours of delay for each segment (TMC link) is then divided by the segment length to get the annual truck hours of delay per mile (DPM), which allows for the comparison of all roadway sections across the NHS. DPM is used by many states as a preferred measure for decision-making regarding freight mobility issues since it captures the mobility performance of the roadway segments (travel time and speed) while taking traffic volumes into account.

NPMRDS data is used to calculate DPM for each NHS segment in 15-minute time intervals, and the truck volume data is extracted from the Highway Performance Monitoring System (HPMS) database. Figure 5 illustrates the truck DPM along Washington's NHS network. As shown, delays are relatively higher in urban areas and along high-volume corridors such as I-5 and I-405 through Seattle, Tacoma, and Olympia, I-90 east of Snoqualmie Pass, and I-90 and US 2 in Spokane.

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[11] CPCS review of Washington DOT's biennial transportation performance report submittals to FHWA, 2018 and 2020.

Figure 4: TTTR ratio for heavy- and medium-duty trucks, 2021

Source: WSDOT. Cartography by CPCS (2022).
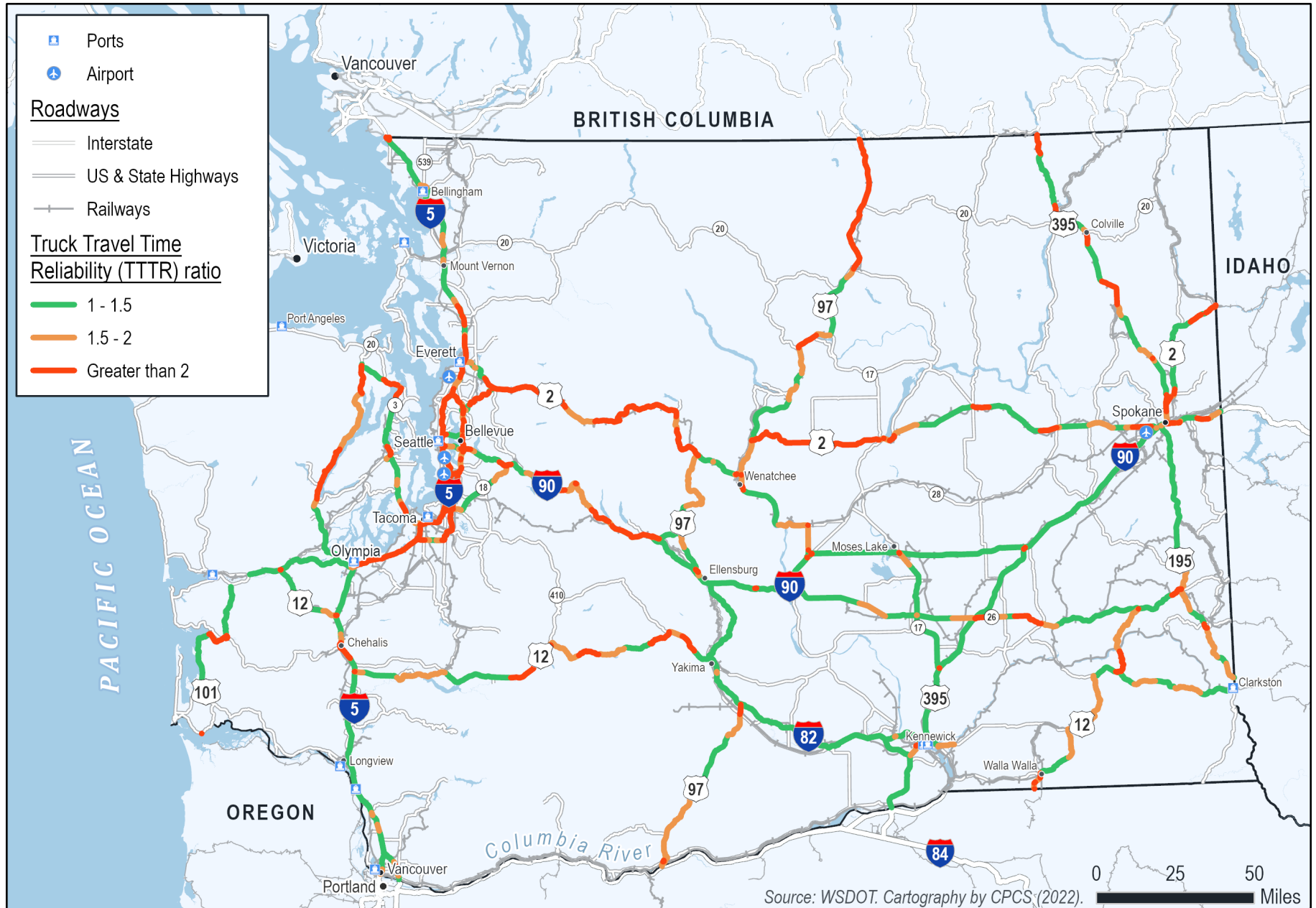
Figure 5: Truck travel time delays along Washington's highway system

Source: WSDOT. Cartography by CPCS (2022).
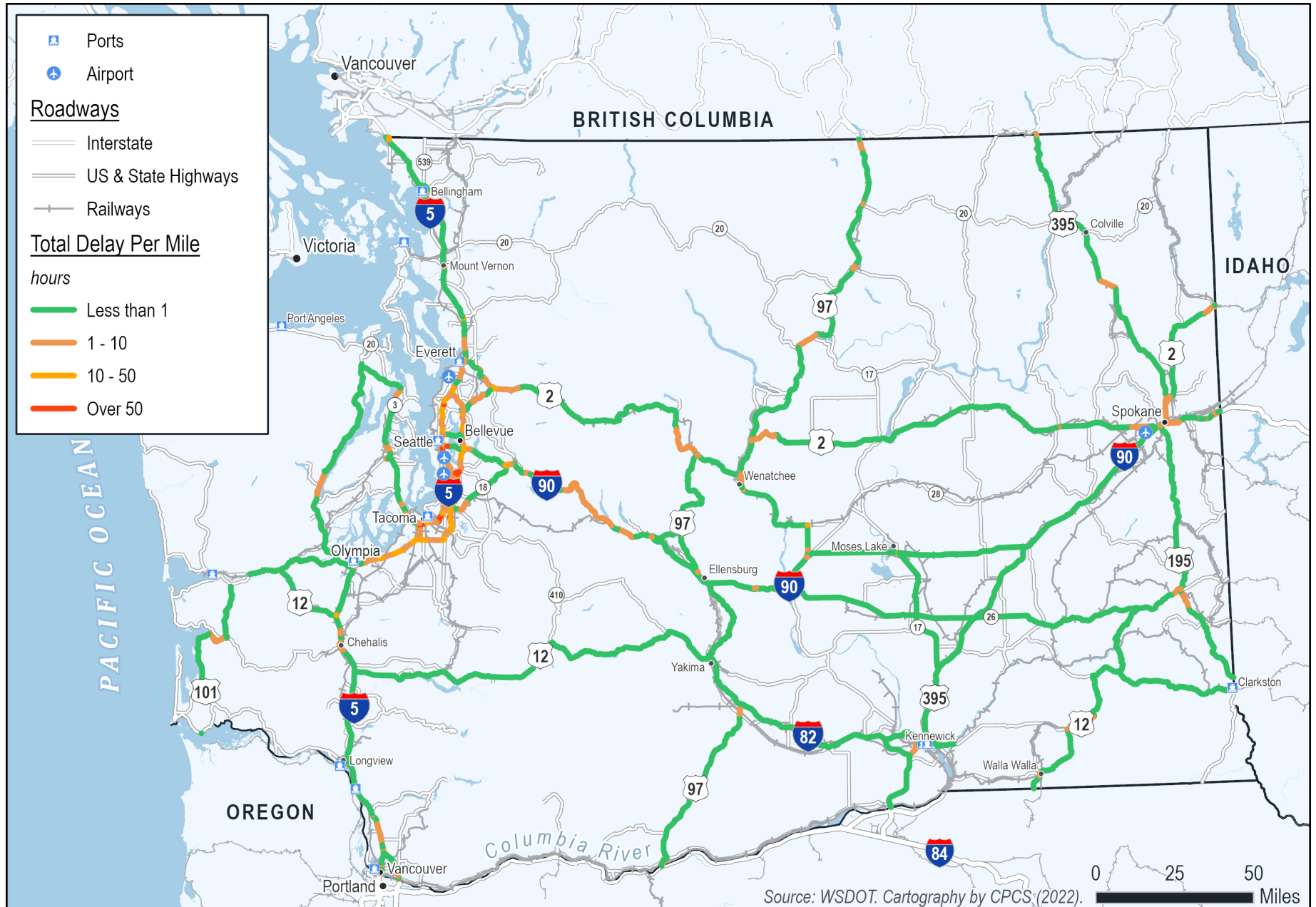
Step 3: Identify Washington's truck bottleneck locations

Truck bottlenecks are areas or segments on the roadway network on which the trucks experience a significant breakdown in traffic flow. According to the FHWA, a bottleneck may cause congestion, but congestion is not always the result of a bottleneck. Hence, a combined Delay-TTTR Index is used to identify bottlenecks that are not only associated with truck travel time delays but also the extent to which the delays are unexpected.

The total hours of delay per mile is multiplied by the TTTR ratios for each segment to calculate the TTTR-TDPM Index values. These TTTR-TDPM Index values are then used to identify the major bottlenecks in Washington.

The road segments shown in the maps on the following pages are also color-coded based on the TTTR-TDPM Index values so that the segments with the highest index values (top 10 percent) are highlighted as orange. As shown, almost all of the segments in the top 10 percent category are located along the road networks in Seattle and Tacoma and roads that connect Tacoma and Olympia. A list of the specific top 10 bottleneck locations is also provided in Figure 6.

.

Figure 6: List of top 10 truck bottleneck segments in Washington, 2019

Rank	Corridor Name	Location	Segment	Segment Length (mile)	Annual Average Daily Truck Traffic	Annual Truck Delay Hours per Mile (DPM)	TTTR Index	TDPM-TTTR Index
1	I-5 NB	Tacoma	I-705/WA-7/Exit 133 and WA-16/Exit 132	2.00	7,159	59,693	6.10	363,882
2	West Seattle* Bridge EB	Seattle	Delridge Way Intersection	0.54	1,463	43,867	7.17	314,673
3	West Seattle* Bridge WB	Seattle	Wa-99/Alaskan Way and Delridge Way	0.77	2,350	61,185	4.31	263,737
4	I-5 SB	Tacoma	HOV Lane	0.37	6,807	55,968	4.29	240,255
5	I-5 NB	Seattle	236th St/Exit 177	0.44	4,322	31,307	7.44	232,855
6	I-5 SB	Seattle	Lakeview Blvd./Exit 168 and WA-520/Exit 168	7.08	5,448	36,168	5.93	214,497
7	I-5 SB	Tacoma	I-5 (NORTH) to I-5 (SOUTH)	0.59	6,807	40,147	4.45	178,624
8	I-5 SB	Seattle	WA-522/73rd St/Exit 171 to 85TH ST/EXIT 172	0.97	4,823	15,789	9.91	156,473
9	I-405 SB	Bellevue	4TH ST/SE 13TH ST/EXIT 13 and I-90/EXIT 11	2.73	4,956	30,907	4.98	153,865
10	I-5 NB	Seattle	JAMES ST/EXIT 164 to ALBRO PL/SWIFT AVE/EXIT 161	4.41	7,913	41,369	3.19	131,993

Source: CPCS analysis, 2022.

*Note: bottleneck ranking reflects 2019 traffic conditions, before West Seattle Bridge was closed.

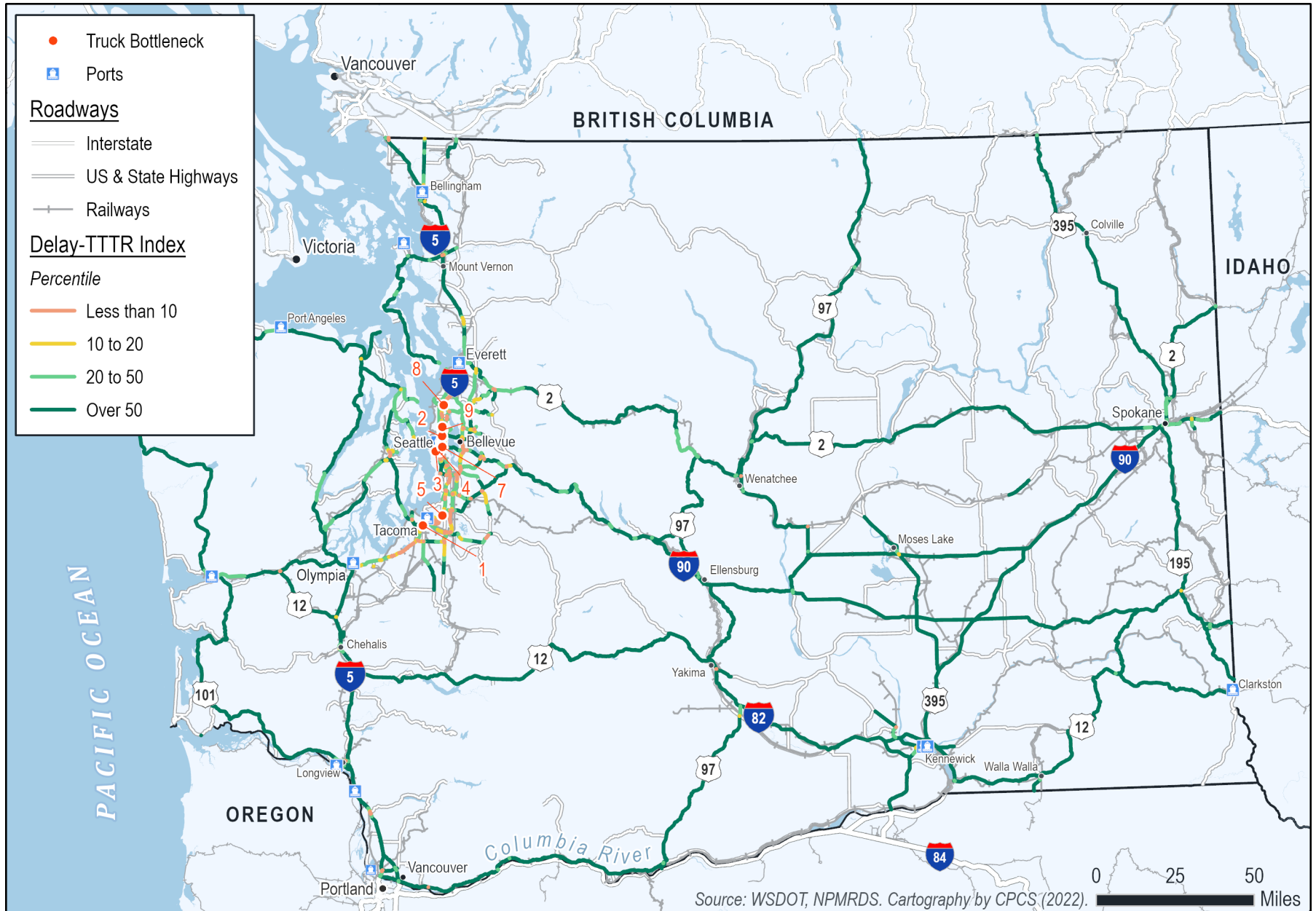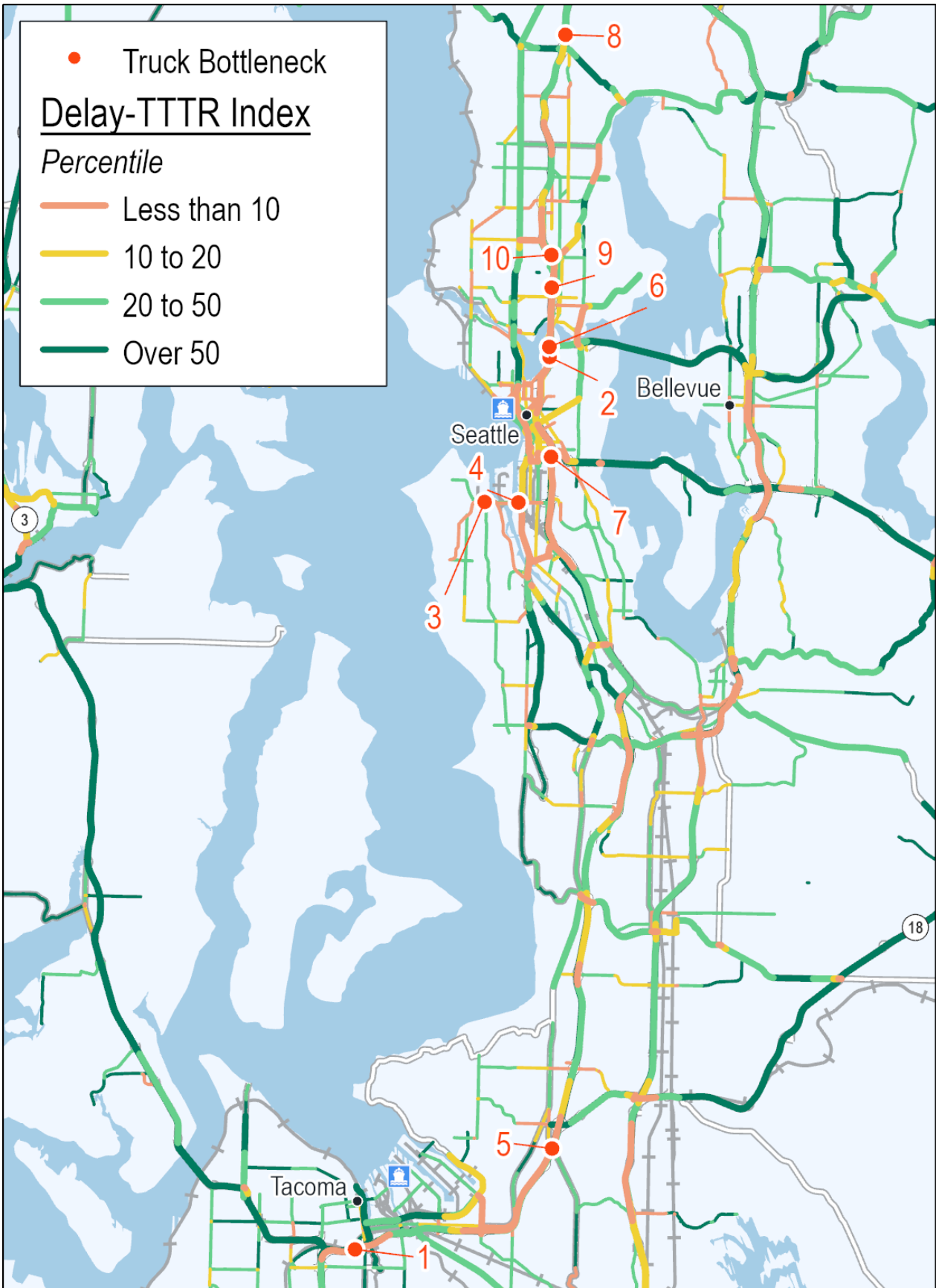**Figure 7: Washington's truck bottleneck locations**

Source: WSDOT, NPMRDS. Cartography by CPCS (2022).

Figure 8: Washington's top 10 truck bottleneck locations

Truck mobility issues along the non-NHS network

Travel time delays on first/last mile routes that connect the major intermodal facilities to the NHS network cause inefficiencies and additional costs to shippers, third-party logistics, and consumers. Studies have shown that between 21 percent to 53 percent of the total logistics costs are due to first/last mile freight inefficiencies.[12] Mobility inefficiencies in the vicinity of the state's largest ports, airports, and rail terminals also lead to safety and air quality issues.

Intermodal Connector (IC) routes are part of the NHS, defined as "public roads leading to major intermodal terminals" with "a critical bearing on the efficient operation of that facility."[13] Since the DPM measure presented earlier in this chapter captures the delays on the NHS network, including IC routes, INRIX truck GPS data is used to assess truck travel delays along the non-NHS connector routes. Raw GPS truck data of medium and heavy-duty trucks is filtered for the routes within a 1-mile buffer of major ports, airports, and rail terminal facilities in Washington to provide context on first/last mile corridor congestion.[14] A list of facilities considered in this analysis is provided along with a map in Appendix B. DPMs for these routes are calculated as the average daily delay hours for medium and heavy-duty trucks per mile.

To calculate the delays, first the non-NHS routes where HPMS truck traffic data was available were filtered out. Truck traffic data is used to weigh the daily delay hours calculated for each segment before normalizing by length. Next, the remaining segments within the 1-mile buffer that were not part of the WSDOT's Freight and Goods Transportation System (FGTS) were filtered out to ensure that only routes critical for freight activities are considered as last mile freight connectors. Finally, FHWA's method (Appendix A) was used to calculate the segment-level annual truck hours of DPM. In this method, segment-level delays are calculated based on the difference between weekday peak hour speeds at segment level (extracted from truck GPS data) and the reference speed or the free flow speed.[15] The resulting delays for each link were then aggregated by the unique identifier for a given roadway and the reported mile markers.

As Figure 9 shows, the highest truck delays are observed along connector routes leading to the Port of Seattle. The Port of Olympia, the port and rail yards of Tacoma, the Port of Bellingham, and the King County International Airport also observe truck delays.

Figure 9: Top 5 non-NHS connector routes in terms of truck delays

Corridor/ At	Between	Freight Facility Served	FGTS Tier	Annual Average Daily Truck Traffic	Annual Truck Delay Hours per Mile (DPM)
Denny Way	Western Ave and Virginia St	Port of Seattle	T-3	2,289	13,059
Fairview Ave N	Denny Way and Harrison St	Port of Seattle	T-2	1,314	12,566
Corson Ave S	S Michigan St and S Homer St	King County International Airport	T-2	2,480	9,658
Mercer St	Westlake Ave N and 5th Ave N	Port of Seattle	T-1	2,085	7,736
Boren Ave	Howell St and Denny Way	Port of Seattle	T-3	726	7,638

Source: CPCS analysis of truck GPS data, 2022.
*NA indicates that the corridor is not on the FGTS network.

[12] A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision, MDPI, Luigi Ranieri et al., 2018.

[13] Freight Management and Operation, Background and Definitions – What is an Intermodal Connector?, FHWA, March 2020.

[14] The raw data was obtained for peak hours on weekdays of four months (i.e., February, May, August, and November) in 2022.

[15] Calculated as the 95th percentile of the overnight truck travel speed.

Highway system condition

State highway conditions

WSDOT reported pavement performance measures to FHWA in 2022. As shown in Figure 10, Figure 11, and Figure 12, Washington has achieved its 4-year pavement condition target for interstates on the NHS by the time of the 2020 mid-performance review. However, the pavement conditions of non-interstate pavement on the NHS still need improvements, and Figure 12 on the following pages illustrates areas on Washington state-owned T1 and T2 freight corridors that have poor pavement condition. In 2019, 17.4 percent of the non-interstate pavement on the NHS was still in poor condition, 12.4 percent more than the 4-year target.

WSDOT's pavement condition measures, including percent of pavement in fair or better condition, asset sustainability ratio, remaining service life, and deferred preservation liability, worsened from 2019 to 2020.[16]

In 2020, the percent of pavement in fair and better condition evaluated by lane miles and vehicle miles traveled (VMT) exceeded WSDOT's target of 90 percent. Besides the short-term measure, WSDOT also tracks three other long-term performance measures listed in the figure below. Asset sustainability ratio is the years of pavement service life added to the roadway network through

Washington State Freight and Goods Transportation System (FGTS) is a classification system that identifies the most heavily used roads for trucks on state routes, county roads, and city streets. The classification system is based on freight tonnage carried on roadway segments.

- T-1 more than ten million tons per year (Strategic Freight Corridor)
- T-2 four million to ten million tons per year (Strategic Freight Corridor)
- T-3 300,000 to four million tons per year
- T-4 100,000 to 300,000 tons per year
- T-5 at least 20,000 tons in 60 days

rehabilitation works divided by the service life consumed each year. The 2020 asset sustainability ratio decreased 0.17 from 2019, indicating that the rehabilitation investments were insufficient to help the pavement network reach longer service life. Similarly, the remaining service life also demonstrates a downward trend between 2019 and 2020, showing the pavement condition has been weakened in the long term. Another unmet performance target is the deferred preservation liability. Washington still faced a $478 million pavement rehabilitation work backlog in 2020, an $126 million increase from 2019.

Figure 10: WSDOT pavement performance measures

Annual Pavement Performance Measures		2019 (Without chip seal)	2020 (Without chip seal)	Agency Target
Short-term	Percent of pavement in fair and better condition	92.9% (Lane Miles)	93.0% (Lane Miles)	90.0%
		94.0% (VMT)	93.5% (VMT)	
Long-term	Asset Sustainability Ratio (Years of pavement service life added to the pavement network through rehabilitation in a given year divided by the service life consumed in that year.)	1.01	0.84	0.90 – 1.10
	Remaining Service Life (Average percentage of original total useful life remaining before rehabilitation or replacement is needed; average	48.0% (7.8 years)	47.1% (7.6 years)	45% - 55%

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[16] Gray Notebook Edition 80, WSDOT, December 2020. https://wsdot.wa.gov/publications/fulltext/graynotebook/gray-notebook-Dec20.pdf

Annual Pavement Performance Measures	2019 (Without chip seal)	2020 (Without chip seal)	Agency Target
years remaining before rehabilitation or replacement is needed.)			
Deferred Preservation Liability (backlog) (An estimate of the accumulated cost (in current dollars) to fund the backlog of past-due (deferred) pavement rehabilitation work.)	$352 million	$478 million	$0

Source: WSDOT Pavement Office.

Figure 11: Washington NHS pavement condition

Measure	Current Data (2019)* / 2-year Actuals	2-year Target	4-year Target
Percent of interstate pavement on the NHS in good condition	39.8%	N/A	30%
Percent of interstate pavement on the NHS in poor condition	1.7%	N/A	4%
Percent of non-interstate pavement on the NHS in good condition	45.2%	45%	18%
Percent of non-interstate pavement on the NHS in poor condition	17.4%	21%	5%

Source: WSDOT Transportation Asset Management Plan, June 2022.

Note: The data reflects the 2019 short-term condition. The 2020 short-term condition information was not collected for chip seal pavement due to COVID-19 restrictions.

Pavement condition ratings

The Pavement Condition is rated using Pavement Structural Condition, International Roughness Index, and Rutting. The following table demonstrates the thresholds of each category.

Category	Pavement Structural Condition (PSC)	International Roughness Index (IRI)	Rutting
Very Good	80-100	<=95	<=0.23
Good	60-79	96-170	0.24-0.41
Fair	40-59	171-220	0.42-0.58
Poor	20-39	221-210	0.59-0.74
Very Poor	0-19	>320	>0.74

Source: WSDOT, 2022.

Figure 12: Areas of poor condition on state-owned T1 and T2 state-owned freight routes

Source: HPMS, WSDOT. Cartography by CPCS (2022).
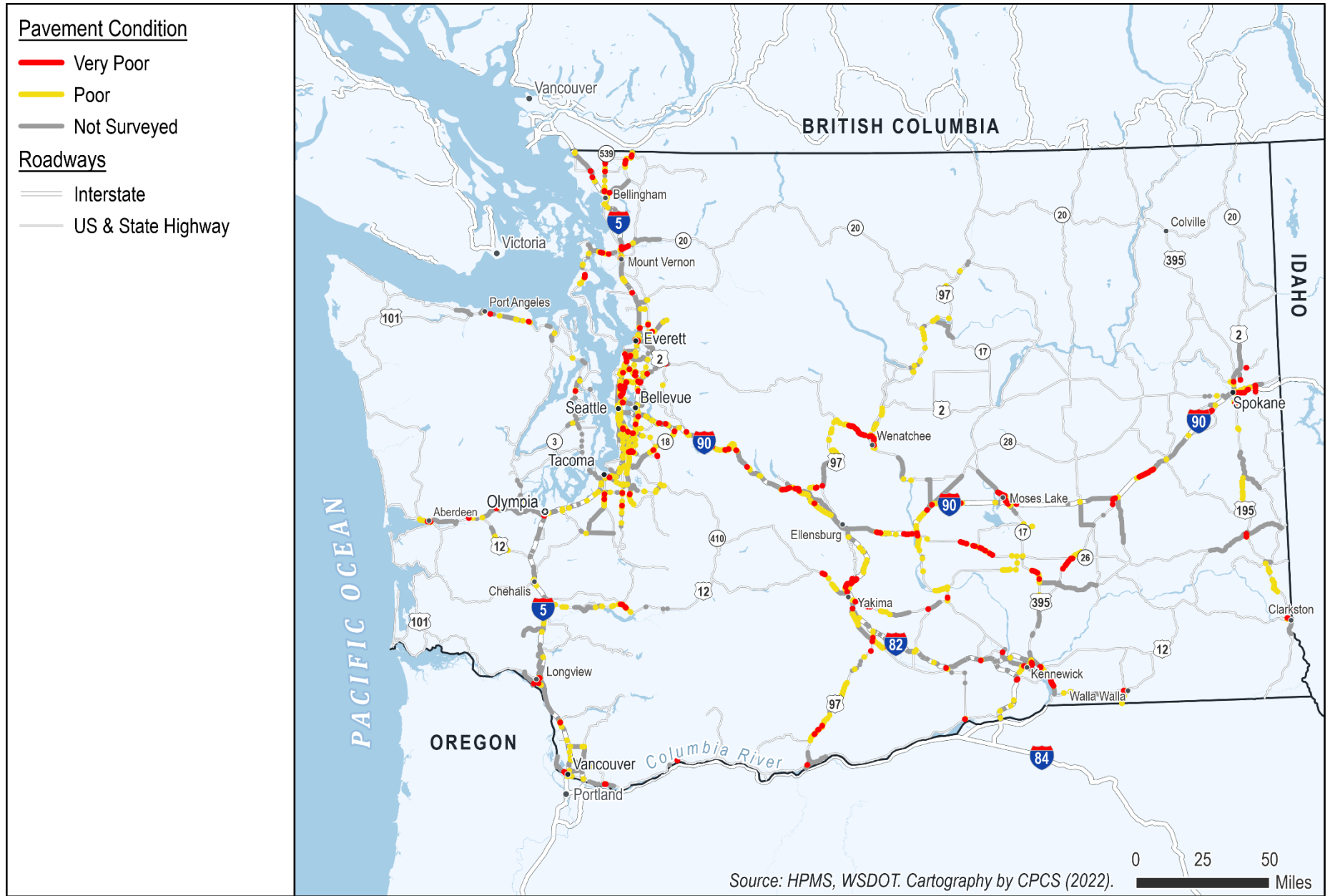
State bridge conditions

WSDOT's goal for bridge conditions is to have at least 90 percent of the bridges by deck area in good or fair condition. The state has reached the goal since 2017. However, the percentage of bridges in good or fair conditions has decreased since 2019. As of June 2021, the number of bridges in poor condition increased from 6.2 percent (164 bridges) in June 2020 to 6.7 percent (179 bridges).

As of June 2021, 93.2 percent of bridges in Washington were in fair or better condition, meeting WSDOT's performance goal.

Bridge condition ratings

- **Good** – indicating the condition of bridges with either no problems or some minor deterioration of structural elements.

- **Fair** - bridges with primary structural elements in sound condition. Some bridges may have minor deterioration, cracking, spalling, or scour.

- **Poor** - bridges with "advanced deficiencies such as section loss, deterioration, scour, or seriously affected structural components" that are safe for travel but may have some restrictions in terms of vehicle sizes and weights.

Source: WSDOT Gray Notebook, September 2021,

As depicted below, about 6.8 percent (3.3 million) of WSDOT's bridge deck area on the NHS had a structural condition rating of poor in June 2021. This was an increase from 6.4 percent in June 2020. There are 18 bridges requiring replacement and 22 bridges needing rehabilitation based on the 2021 data. Figure 15 demonstrates that over 716,700 square feet of deck area were in need of rehabilitation in 2021, a 32.6 percent increase from the 540,608 square feet of deck area recorded in 2020. WSDOT estimates that 79 bridges (616,181 square feet of deck area) will require replacement or rehabilitation over the next ten years.

Figure 13: Washington's bridge condition, 2017-2021

Structural Condition Rating		June 2017	June 2018	June 2019	June 2020	June 2021
Good	Bridge deck area	20.3	20.9	21.3	21.1	20.8
	Percent of deck area	**37.3%**	**38.4%**	**37.1%**	**37.5%**	**37.0%**
	Number of bridges	1,699	1,701	1,729	1,726	1,725
Fair	Bridge deck area	29.7	29.4	32.0	31.8	31.5
	Percent of deck area	**54.5%**	**54.1%**	**55.7%**	**56.3%**	**56.2%**
	Number of bridges	1,450	1,456	1,457	1,452	1,461
Poor	Bridge deck area	4.5	4.1	4.1	3.5	3.8
	Percent of deck area	**8.2%**	**7.5%**	**7.1%**	**6.2%**	**6.7%**
	Number of bridges	163	165	158	164	179
Total	**Bridge deck area**	**54.4**	**54.4**	**57.4**	**56.5**	**56.1**
	Number of bridges	**3,312**	**3,332**	**3,326**	**3,336**	**3,365**

Source: Gray Notebook, WSDOT, September 2021.

Notes: The data shows WSDOT-owned bridges, culverts, and ferry terminals longer than 20 feet that carry vehicular traffic. All numbers shown in the table are based on the "out-to-out" calculation method (which includes curbs and rails on the bridge) instead of the bridge width from curb to curb.

Figure 14: Washington bridge conditions on the NHS, 2021

Bridge Ownership	Deck Area in Millions	Number of Bridges
WSDOT-owned	47.7	2,361
Amount poor (%)	3.3 (6.8%)	111
Locally owned	4.1	217
Amount poor (%)	356,405 (8.2%)	16
Total	**51.8**	**2,578**
Total poor (%)	**3.6 (7.0%)**	**127**

Source: Gray Notebook, WSDOT, September 2021.

Figure 15: Washington bridge rehabilitation and replacement needs, 2020 – 2021

Bridge Status	Number of Bridges		Deck Area	
	2020	**2021**	**2020**	**2021**
Contract work – Active	6	3	63,838	127,058
Replacement currently needed	12	18	104,464	174,589
Rehabilitation currently needed	18	22	540,608	716,752
Border bridges	1	0	102,700	0
Rehabilitation/replacement needed within 10 years	81	79	405,578	616,181
Total 10-year needs	**117**	**122**	**1.1 million**	**1.6 million**

Source: Gray Notebook, WSDOT, September 2021.

Notes: WSDOT funds 50 percent of preservation for 11 border bridges that cross state lines.

Over-sized/over-weight movements

Over-sized/over-weight (OSOW) movements pose safety and roadway operational/maintenance concerns. Therefore, DOTs use various permitting processes to ensure the safe movement of OSOW loads and mitigate damage to pavement and bridge structures.

WSDOT processes self-issued OSOW permits for interstate, U.S., and state highways using an online program called the Electronic System Network for Oversize and Overweight Permit Information (eSNOOPI). Carriers are required to complete online registration and check weight limits, truck access restrictions, and height restrictions clearances prior to moving OSOW cargo. A variety of permit types may be available based on a carrier's goods and operations. For example, monthly and annual OSOW permits are available for specific routes, and specific commodities such as manufactured homes and log tolerance permits are available for the agricultural and forestry industries.[17]

Figure 16 shows the number and percentage of OSOW permits by type provided in Washington during 2021. As shown, the majority (over 88 percent) of the OSOW permits were for a combination of oversized (over 16 ft width or 16 ft height or 125 ft length) and overweight (over 200,000 lbs) cargo conditions.

Figure 16: WSDOT OSOW permit types, 2021

Permit Type		Number of Permits	% of Total OSOW Permits
Size	Over 16 ft Wide	121	0.1%
	Over 16 ft High	121	0.1%
	Over 125 ft Long	1,564	1.5%
Gross Weight: Over 200,000 lbs		1,201	1.1%
Size and Weight: Combination of Above Conditions		94,472	88.3%
Unknown Condition		9,383	8.9%
Total		106,850	100%

Source: CPCS analysis of WSDOT OSOW data, 2022.

Figure 17 illustrates the frequency by which the highway system in Washington is used for OSOW movements. As the map shows, the I-5 corridor between Seattle and Portland, Oregon, the I-90 corridor between Seattle and Ellensburg, and I-90 between Ritzville and the state's border with Idaho have the highest frequency of OSOW movements.

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[17] How to self-issue permits and which permits can be self-issued, WSDOT, (n.d.). https://wsdot.wa.gov/travel/commercial-vehicles/commercial-vehicle-permits/self-issue-permit

Figure 17: Washington's most frequently used corridors for oversized/overweight movements, 2021

Source: WSDOT. Cartography by CPCS (2022).

Highway freight safety

The Highway Safety Improvement Program (HSIP) and Safety Performance Management Measures (Safety PM) final rules are published by the Federal Highway Administration (FHWA) under 23 CFR Part 924, in alignment with the requirements of the FAST Act.[18] As a result of these rules (which clarified and expanded previously published safety-related mandates), the states are required to develop and submit HSIP and Railway-Highway Crossing Program reports by the end of August of each year, using FHWA's online reporting tool. These reports provide the state and local governments access to safety funds, such as the County/City Safety and Rail-Highway Safety programs.[19]

> WSDOT's Target Zero plan establishes a bold vision: **zero deaths and serious injuries on Washington's roadways by 2030.** However, crash data from the most recent years has shown that the number of crashes, fatalities, and injuries are increasing. Therefore, **Target Zero report takes a action-focused approach** and provides key actions that a state and local agency can take to improve safety.

Source: Target Zero Report, WSDOT, 2020.

This section provides a summary of the freight safety issues along Washington's highway system. Between 2016 and 2021, over 40,000 truck-involved crashes occurred in Washington, leading to 420 fatalities.[20] Also, over 980 persons were severely injured, and over 12,800 persons suffered from evident or possible injuries as a result of the truck-involved crashes over the past 6 years. About 77 percent of the truck-involved crashes that occurred in Washington between 2016 and 2021 were property damage only (PDO), leading to no casualties but causing monetary costs to society.

Figure 18 presents the annual number of truck-involved crashes in the state. Five-year (rolling) average truck-involved crash numbers are also shown for 2020 and 2021. As per guidelines of the Highway Safety Improvement Program (HSIP), the 5-year averages are used as the baseline for establishing the performance target for the following year.[21] As shown, while the annual number of truck-involved crashes increased in 2021, the 5-year average truck-involved crashes have declined.

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[18] Safety Performance Management Measures Final Rules Overview, FHWA, February 2018.

[19] Highway Safety Improvement Program (HSIP) Funds, FHWA.

[20] WSDOT crash database of 2016 through 2021. For the purpose of freight plan analysis, truck-involved crashes are defined as those crashes that involve trucks (such as flatbed, van, etc.), trucks pulling a trailer, truck tractors, semi-trailers, and/or double trailer combinations. Such definition is broader than the heavy truck definition adopted in WDOT Target Zero Plan in order to capture all truck types. Washington State Highway Patrol officers record the number and types of vehicles involved in the standard Washington Crash Report form along with other information, including crash location and severity, road surface condition, weather condition, traffic control devices, and primary factors contributing to the crashes. For more information, see: https://one.nhtsa.gov/nhtsa/stateCatalog/states/wa/washington.html.

[21] National Performance Management Measures: Highway Safety Improvement Program, FHWA, 2016. https://www.federalregister.gov/documents/2016/03/15/2016-05202/national-performance-management-measures-highway-safety-improvement-program

Figure 18: Truck-involved crashes in Washington
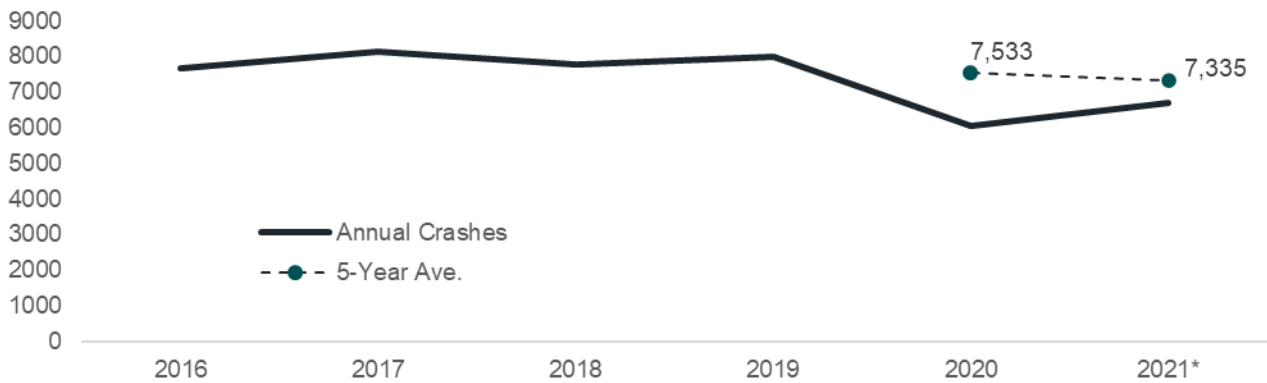
Source: CPCS analysis of WSDOT's crash data, 2022.
*Note: 2021 data is preliminary and incomplete. WSDOT's 2021 crash data will be verified and finalized in June 2022.

Figure 19 and Figure 20 present the annual and 5-year average fatalities and serious injuries resulting from truck-involved crashes in Washington. As shown, the 5-year averages for both fatalities and serious injuries show increasing trends. HSIP recommends that in such cases, the 5-year averages should be used as the performance target for the following year. The target 5-year averages calculated using this method are also shown on the following graphs.

Figure 19: Truck-involved fatalities in Washington

Source: CPCS analysis of WSDOT's crash data, 2022.
*Note: 2021 data is preliminary and incomplete. WSDOT's 2021 crash data will be verified and finalized in June 2022.

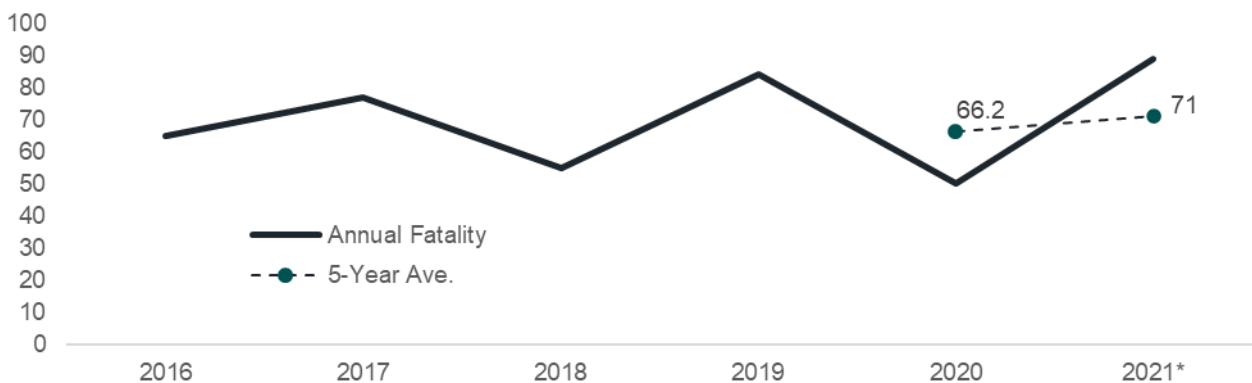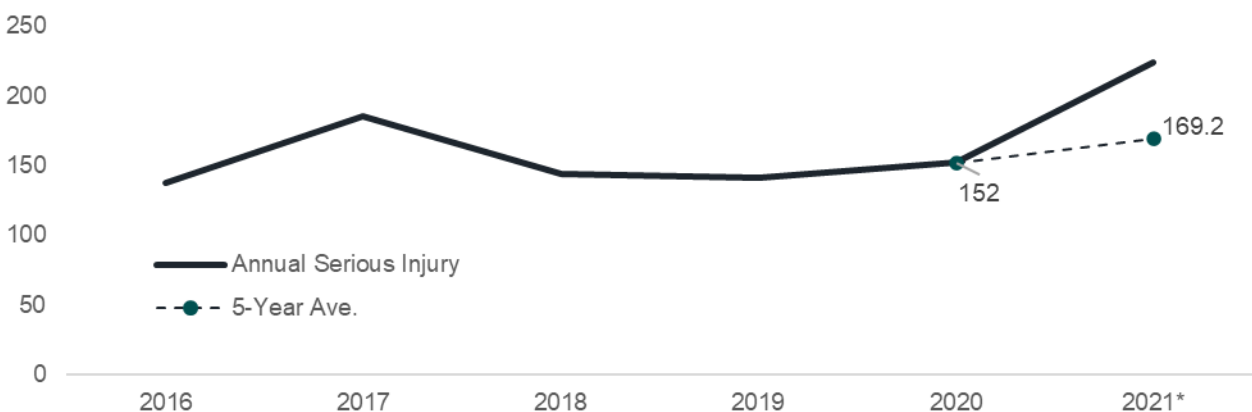**Figure 20: Truck-involved serious injuries in Washington**

Source: CPCS analysis of WSDOT's crash data, 2022.
*Note: 2021 data is preliminary and incomplete. WSDOT's 2021 crash data will be verified and finalized in June 2022.

Truck-involved crashes are more likely to result in casualties when vulnerable road users such as pedestrians and cyclists are involved. As Figure 21 shows, 113 of the truck-involved crashes that happened in Washington in 2019 also involved pedestrians and cyclists, leading to 18 deaths and 19 serious injuries. These types of crashes decreased by about 20 percent in 2021, while the number of fatalities increased by 11 percent and serious injuries increased by more than 40 percent.

Recently, a complete streets requirement was added to the state highways section of the Revised Code of Washington. The goal of this addition is to ensure safety and mobility for all road users. The requirement will apply to all projects of $500,000 or more and will go into effect in July 2022. The new requirement will provide renewed focus on locations of potential conflicts between freight and other modes and the need for careful consideration of truck loading areas, deliveries, location of facilities, and congestion.

Figure 21: Truck-involved crashes with pedestrians/cyclists in Washington
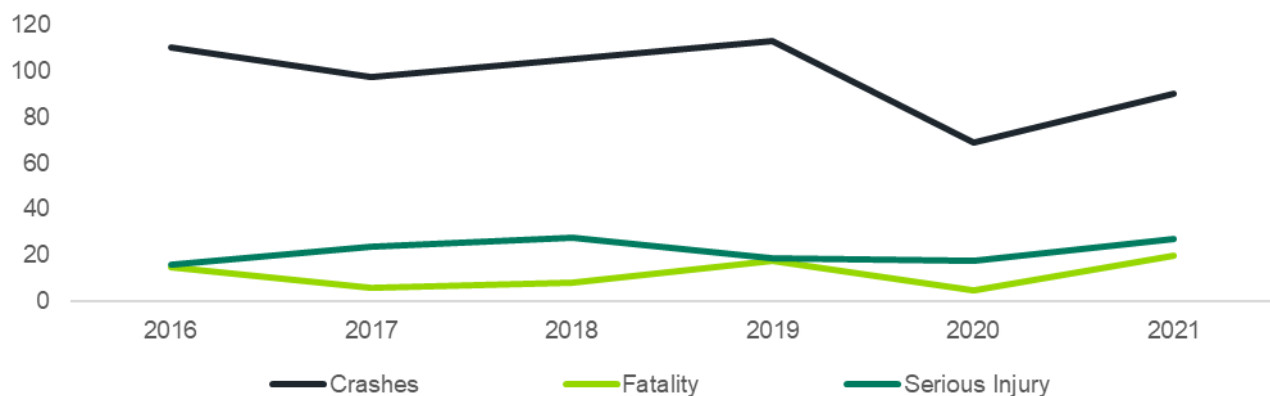
Source: CPCS analysis of WSDOT's crash data, 2022.
Note: Traffic count data is not available.

In terms of the geographic distribution across the state, truck-involved crashes that happened between 2016 and 2021 primarily clustered along the high-volume corridors such as I-5, I-405, and I-90. In particular, King, Pierce, and Snohomish Counties have the highest concentration of truck-involved crashes between 2016 and 2021, with about 36, 13, and 9 percent of the total statewide truck-involved crashes, respectively (Figure 22).

Figure 22: Washington's truck safety hotspots, 2016-2021

Source: WSDOT. Cartography by CPCS (2022).
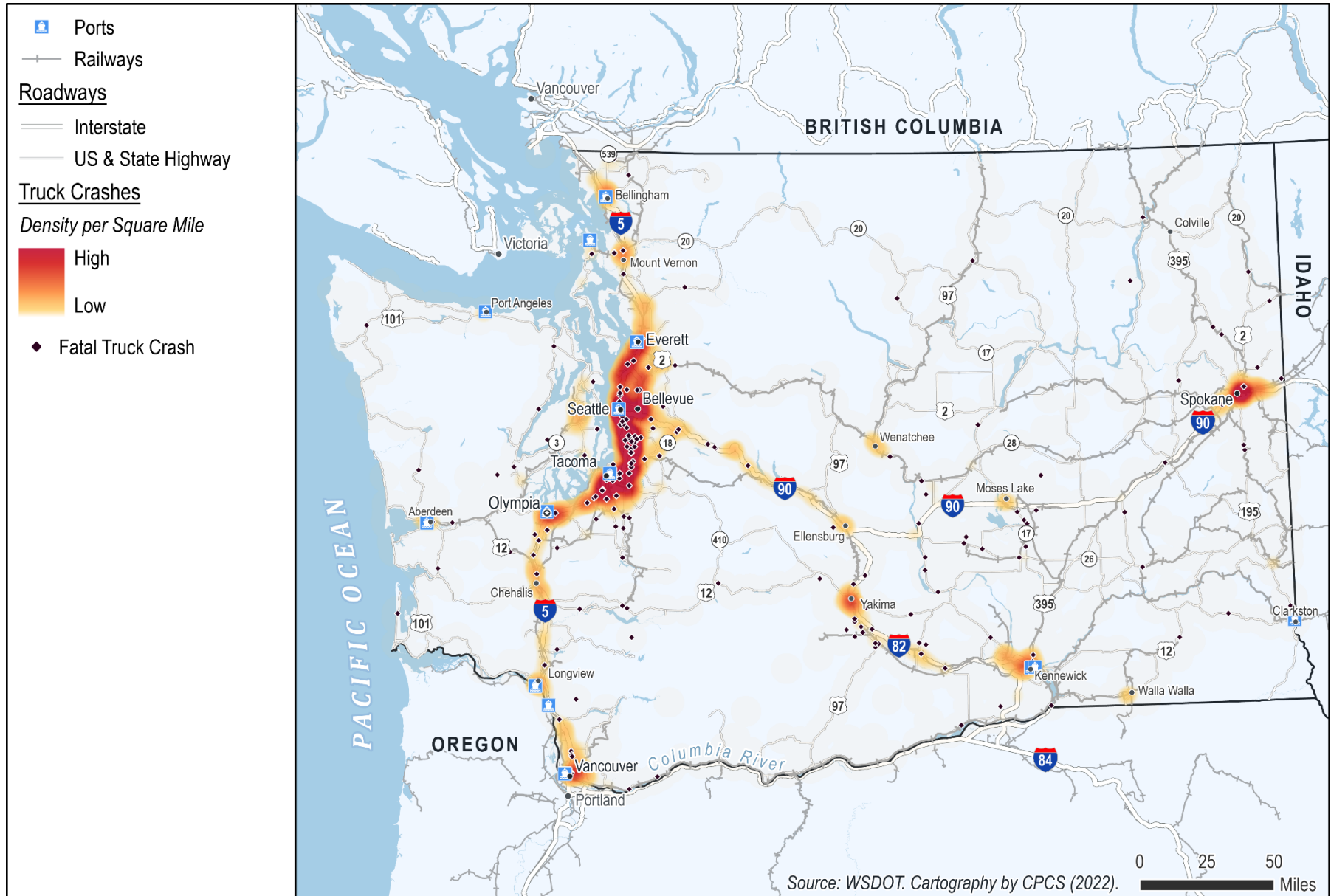
Rail system performance

Freight railroads serve Washington's primary freight generators and attraction points through an integrated system of over 3,200 miles of tracks. Two Class I railroads (Burlington Northern Santa Fe Railway [BNSF] and Union Pacific [UP]) and 27 short lines operate in the state. Over 95.2 million tons of freight is moved by rail across Washington annually, primarily serving domestic flows of cereal grains and other agricultural products shipped to ports for export and crude petroleum shipped to refineries across the state.

1,900 miles	1,300 miles	211 facilities	95 M
Operated by Class I Railroads	Operated by Short Lines	Generating and Attracting Rail Freight	Tons of Commodities Carried Annually

Source: CPCS analysis of WSDOT data and FAF 5 Tabulation Tool, 2022.

Rail freight mobility performance

Based on freight rail tonnage and freight train volume growth forecasts presented in the Washington State Rail Plan 2019-2040, several subdivisions of the state freight rail network may experience significant growth in tonnage and train volume, particularly Tacoma-Vancouver, Vancouver-Pasco, Pasco-Lakeside, Lakeside-Spokane, and Spokane-Hinkle, Idaho.[22] BNSF and UP will likely address key capacity issues on the Class I-owned rail system as they emerge.

Other infrastructure and facilities may be impacted by increases in freight rail tonnage and train volume on the Class I railroads. Demand for yard and terminal capacity is expected to increase along with the growth of freight rail tonnage and train volume. Increased yard and terminal demand is also likely to be most significant at train origin and destination locations adjacent to the most highly utilized freight rail corridors, such as those between Everett and Vancouver through the I-5 corridor.

As freight rail tonnage grows, train volumes will grow, and typical train lengths are likely to increase. Accommodating longer trains will require enhancement or expansion of existing yards and terminals. Near origin and destination points where trains often move at relatively low speeds, longer and more frequent train movements will likely result in more significant vehicle traffic delays at grade crossings.

Rail capacity is a derived demand based on the geographical relationships between the producers of goods and the buyers of goods. While many segments of the state's short line rail system offer available capacity, opportunities to utilize that capacity to meet growing demand on the Class I rail system will be limited to cases where a short line or facility located on a short line can be utilized to accommodate rail movements in a way that offers favorable economic parameters in comparison to alternatives such as Class I capacity expansion. Addressing the deferred maintenance of the short line rail system and continuing to enhance the short line system to accommodate 286,000-pound cars are important steps to ensuring these elements of the state's freight rail systems can be utilized to support current and forecast rail demand.

Rail asset condition

The physical condition of the state's rail system can be measured by two metrics:

- Percent of the railroad system that can be operated at 25 mph or above.

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[22] State Rail Plan, WSDOT, August 2020. https://wsdot.wa.gov/construction-planning/statewide-plans/freight-rail-plans/2019-washington-state-rail-plan

- Percent of the railroad systems capable of handling 286,000-pound rail cars.

The two Class I railroads in Washington (BNSF and UP railroads) are capable of handling 286,000-pound rail cars over all of their main routes in Washington. Almost all of the BNSF and UP mainlines can be operated at 25 mph or above. The BNSF corridors, which accommodate Amtrak Cascades and Amtrak long-distance services, support higher operating speeds for freight trains (up to 60 mph).

Short line railroads provide a vital link to the two Class I railroads in Washington and provide access to the national freight rail network for communities and businesses. Switching or terminal railroads that primarily offer services to other railroads are also considered short line railroads.

The condition of short line railroads in Washington is quite varied. To assess the current conditions of the state's short line railroads, WSDOT surveyed 26 short line railroads in 2019 and received responses from 19 of them. Combined, these 19 short line railroads manage about 1,110 miles of tracks in Washington, accounting for 82 percent of the total short line mileage in the state. Although the survey results did not fully capture condition data for the entire short line system, it provided a reasonable assessment of the system based on survey data.

The survey results indicate that out of the 1,110 miles of short line railroads:[23]

- 91 percent is still active and in operation.

- 61 percent can be operated at 25 mph or above.

- 55 percent is capable of handling 286,000-pound rail cars.

The future viability of the short line system is largely driven by rail industry trends. As the industry standard has moved towards the use of 286,000-pound railcars rather than 263,000-pound cars, only about 55 percent of the surveyed short line railroads can handle the heavier cars. It will be critical for the future success of short line railroads to make improvements in order to meet the industry's 286,000-pound rail car standards.

Rail freight safety

Crossing incidents

The Washington Utilities and Transportation Commission (UTC) is the state agency with regulatory authority over rail safety in Washington. UTC is responsible for highway-rail crossing safety inspections, inventorying, and documentation and reporting of incident data.

Between 2012 and 2021, about 364 highway-rail grade crossing incidents happened in Washington (including 53 incidents with Amtrak trains), leading to 54 deaths and 104 injuries. Near 80 percent of the incidents were at public highway-rail crossings, and the rest were at private crossings.[24] Figure 23 shows the state's highway-rail grade crossing 10-year crash trends. The number of incidents has stayed somewhat constant during the 10 years of analysis, with a slight decline in rail crossing-related incidents, fatalities, and injuries in 2021.

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[23] Ibid.

[24] Private crossings are on privately owned roads while the road approaches at a public highway-rail crossing are under the jurisdiction of and maintained by public authorities.

Figure 23: Highway-rail grade crossing incident trends
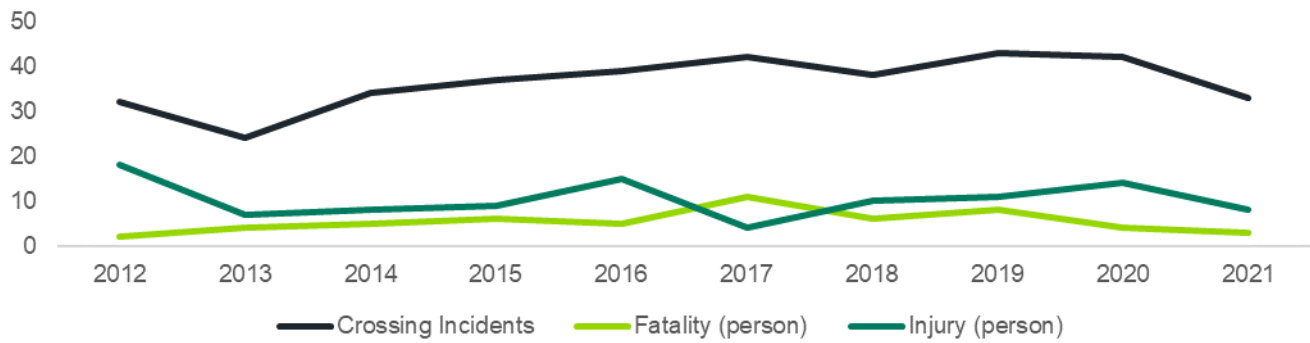
Source: CPCS analysis of FRA Safety Data, 2022.

In addition to 33 highway-rail crossing incidents, 24 other/equipment incidents and 37 accidents with trespassers happened in Washington during 2021. As Figure 24 shows, trespassing accidents have steadily increased since 2012, with a slight decline in 2021 injuries but an increase in the number of fatalities. Between 2012 and 2019, about 50 percent of the trespassers in Washington were 20 to 40 years old. The number of fatalities and injuries has also been relatively higher for this age group. Trespassing incidents in Washington were primarily in King, Pierce, and Snohomish Counties. The relatively higher density of trespassing incidents happening in these Counties can be linked to a wide range of factors, such as population density and frequency of passenger and freight train activity.

Figure 24: Trespassing accident trends
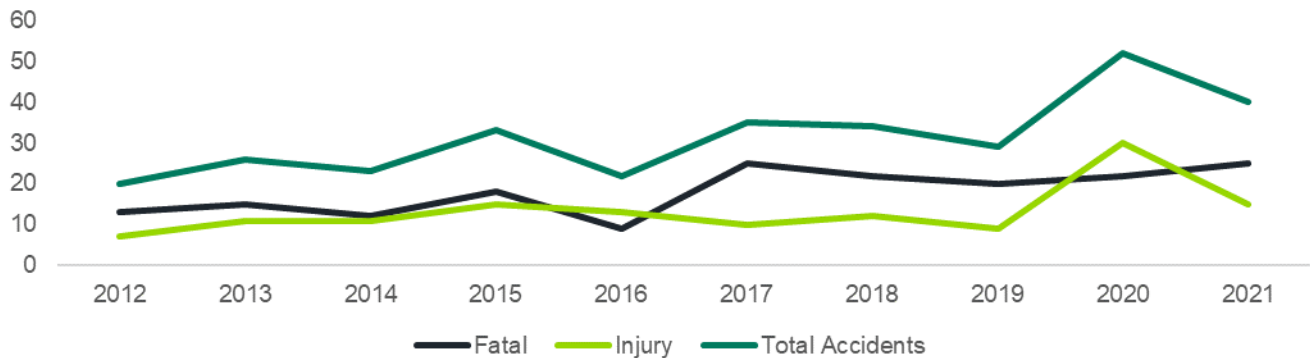
Source: CPCS analysis of FRA Safety Data, 2022.

Blocked crossing

Precision Scheduled Railroading (PSR) operating model is adopted by almost all North American Class I railroads. PSR operations are built upon five principles: improve service, control costs, optimize asset utilization, operate safely, and develop employees.[25] Trains operating on PSR have a fixed schedule, meaning that they depart at a certain time regardless of the number of loaded cars rather than using the number of cars to determine when a train should depart. Therefore, the train sizes following the implementation of PSR is a particular concern for transportation agencies due to the potential for longer trains to block at-grade rail crossings for a longer period.

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[25] Talking Freight: The Operational Nuts and Bolts of Precision Scheduled Railroading, FHWA, Carl Van Dyke, March 2020.
https://www.fhwa.dot.gov/Planning/freight_planning/talking_freight/march_2020/talkingfreight3_18_20cvd.pdf

Additionally, PSR models also increase the number of trains that can slow down rail operations. As a result, trains may sit for long periods of time at or near busy yards and therefore block vehicle and pedestrian access at grade crossings.

Studies have shown that drivers will attempt to clear the crossings in front of arriving trains at locations where crossings are routinely blocked for extended periods. Pedestrians may also attempt to cross the blocked crossings by crawling between stopped railcars.[26]

To address such safety issues, the FRA has established the Blocked Crossing Dashboard, a crowdsourced database collecting inputs from the road users and communities living near grade crossings to identify the priority locations and offer effective solutions. A summary of the number of blocked crossing reports in 2020 and 2021, reasons for blocked crossings, and average durations of blocking in Washington is presented in Figure 25. As shown, the majority of the reports flagged a stationary train blocking the roadway. However, some reports were associated with crossings that were blocked due to moving long trains or closed to roadway users due to malfunctioning crossing safety devices.

Figure 25: Washington's blocked crossing reports and reasons

Year	Reason for Blocked Crossing			Total	Average Blocking Duration (minutes)
	A Moving Train	A Stationary Train	No Trains Passing or Present but The Lights and/or Gates Were Activated		
2020	10	96	2	108	49
2021	157	265	10	432	34

Source: CPCS analysis of FRA Blocked Crossing Database, 2022.

Figure 26 shows the blocked crossing hotspots in Washington. As shown, the at-grade crossings on UP and BNSF lines southwest of Spokane experience the highest frequency of blocking, causing delays on South Mullink Rd. in Cheney, and North Freya St., West Deno Rd., and East Broadway Ave. in Spokane. The occurrence of blocked crossings is also an issue raised by the stakeholders in Washington. In particular, at-grade crossings close to port rail yards and terminals suffer from prolonged blockages, including the rail facilities between Everett and Vancouver through the I-5 corridor.

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[26] Federal Railroad Administration Launches Web Portal for Public to Report Blocked Railroad Crossings, FRA Newsroom, December 2019. https://railroads.dot.gov/newsroom/press-releases/federal-railroad-administration-launches-web-portal-public-report-blocked-0

Figure 26: Washington's blocked crossing frequencies, 2020-2021

Source: INRIX. Cartography by CPCS (2022).
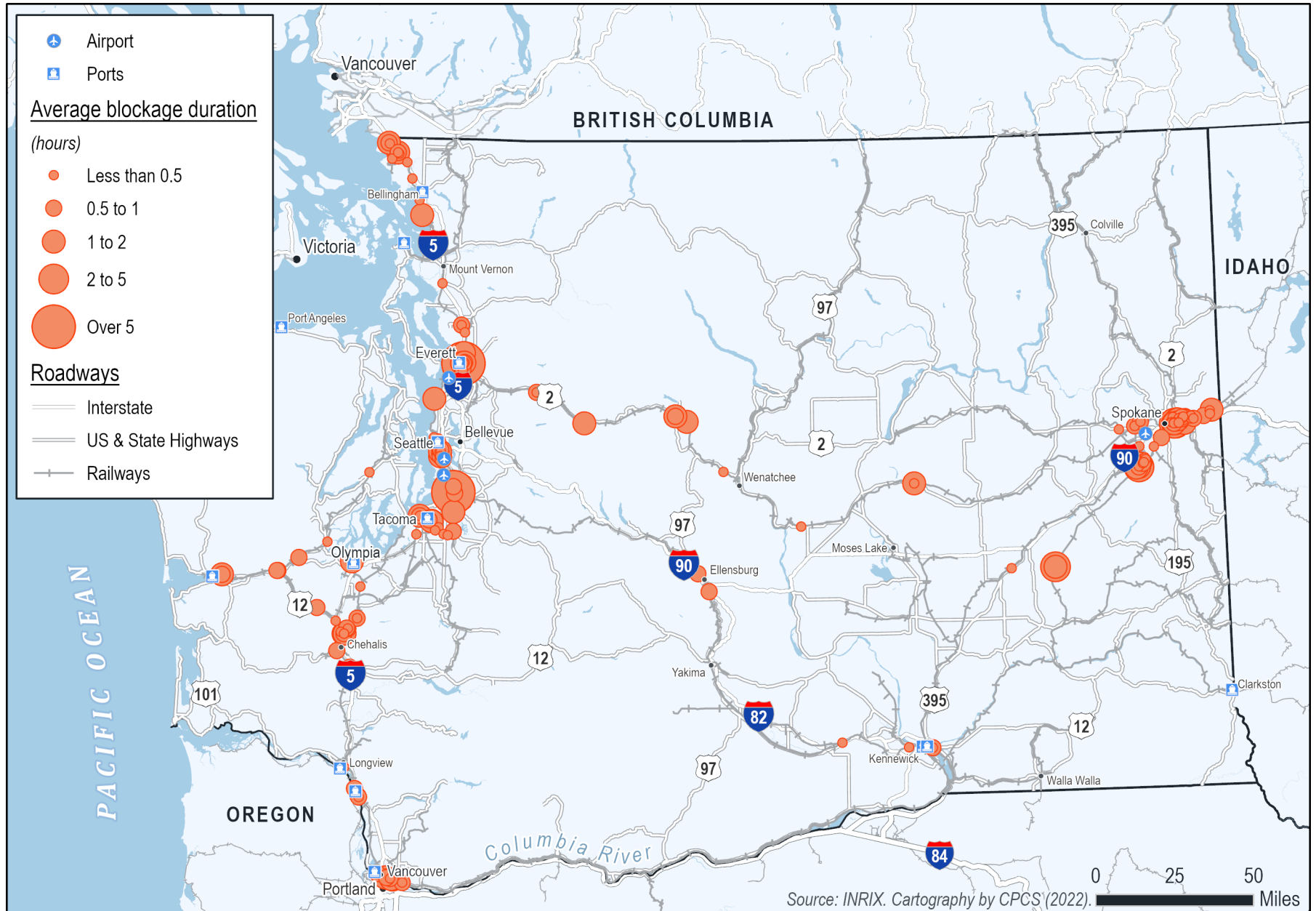
Maritime system performance

Washington has the largest locally controlled public port system in the world, with 75 port districts, handling 7 percent of the U.S. exports and 6 percent of all imports. Washington's maritime system encompasses the Salish Sea, the Snake-Columbia River, and the Pacific Coast subsystems and includes 22 major port facilities, two marine highways (M-5 and M-84), and several harbors and marine terminals. This well-connected maritime system primarily serves agricultural, energy, and manufacturing industries, competing with other modes both in terms of efficiency and cost to serve the state's shippers and businesses. The vast majority of containerized cargo served by Washington's maritime system moves through the ports of Seattle and Tacoma, where the intermodal container terminals handle over 1,800 vessel calls and more than 3.7 million twenty-foot equivalent units (TEUs) annually.[27]

828	**624**	**22**	**26 M**
Marine Freight Economic Corridor Miles	Marine Highway Miles	Major Port Facilities	Tons of Commodities Carried Annually

Source: CPCS analysis of FAF data provided, 2022.

Port mobility performance

The mobility condition at Washington's marine ports is highly dependent on their landside transportation links, including both highways and railroads. While port infrastructure and facilities such as marine berths and freight loading and unloading systems are in a state of continuous enhancement, the intended benefit of these enhancements in infrastructure and facilities can only be realized if there are also investments in capacity, safety, and fluidity of landside connections.

Port-related freight mobility is a common challenge at the state's marine ports. In the vicinity of the largest ports, heavily congested local road networks hinder truck access between terminals and the regional highway network. Also, at-grade road crossings of railroads near many marine ports delay truck and vehicle traffic, a condition that becomes more severe when train volumes or train lengths increase.

As operators and tenants at ports grow, the increased economic activity allows ports to fund necessary terminal infrastructure, facilities, and equipment improvements to support that growth, and ports are often able to implement improvements on port-owned property relatively quickly. However, funding off-terminal infrastructure is a challenge for most ports, as are the timelines for entitlement and construction of off-terminal infrastructure improvements. Container ports need to be able to accommodate the growing size of container vessels. The Northwest Seaport Alliance is the 4th largest U.S. container port gateway and its terminals will need to continue to provide stronger berths and larger cranes to adapt to these fleet changes. As container vessels continue to grow larger, they will require deeper and wider navigation channels as well.

Lock delay

The lock delay is the waiting time between the arrival of vessel/tow at a lock and the start of the lockage process, while the processing time indicates the time a vessel/tow spent at the start of the lockage till the end of the lockage (Figure 27). Aging locks and dams, unscheduled outages and stalls, and extreme weather conditions can all lengthen lockage processing time and reduce navigational efficiency. In 2020, Columbia River processed 27.1 million tons of freight, while Snake River carried 10.6 million tons of cargo. In the same year, the locks on the Port of Columbia River in

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[27] Annual Trade Report, NWSA, 2019. https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2/prod/2020-10/2019-Annual-Trade-Report.pdf

Washington processed 6,381 total trips, while Snake River had 3,372 trips. As shown in Figure 28, locks on both Columbia River and Snake River experienced declines of total lockage between 2010 and 2020. Lock delays not only impact the efficiency of goods movements on Washington's river systems but also increase the transportation cost for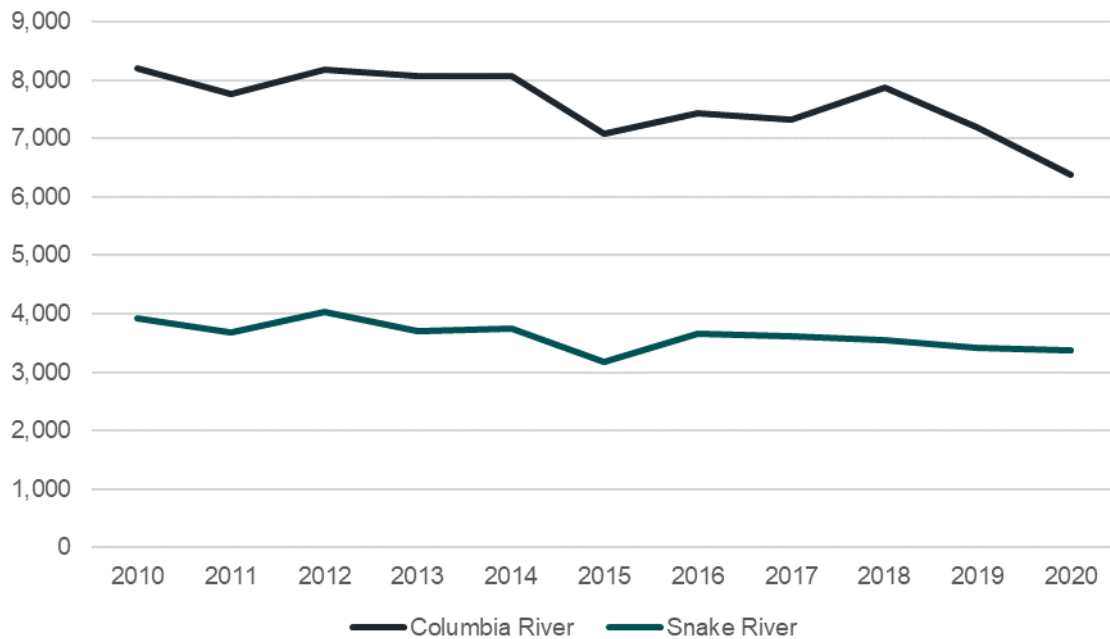 shippers. The following section analyzes the U.S. Army Corps of Engineers' (USACE's) lock use data and evaluates the lock efficiency in 2019 and 2020.

Figure 27: Lock transit process
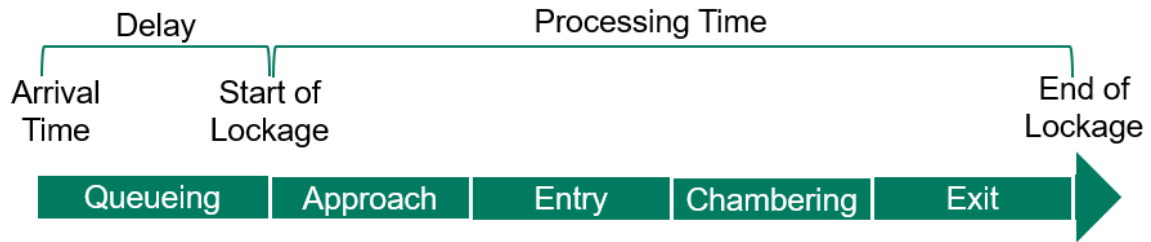
Source: CPCS analysis of USACE data, 2022.

Figure 28: Total lockage trend

Source: Public Lock Usage Report files, Calendar Years 1993-2020, USACE.

Figure 29 shows the monthly average lock queue time in 2019 and 2020. Besides the John Day Lock on Columbia River and the Ice Harbor Lock on Snake River, the wait time at the locks on Columbia/Snake River and the Lake Washington Ship Canal deceased in 2020. Vessels and tows delayed on the river system in Washington was generally above 80 percent in 2019, except for the John Day Lock on Columbia River and the Lower Granite Lock on the Snake River. Similar to the trend of the lock delay time, the percent of delayed vessels and tows in 2020 all demonstrates various degrees of decrease, except for the Lower Granite Lock on the Snake River and the Hiram M. Chittenden Lock on the Lake Washington Canal.

Figure 29: Lock queue time and percent of vessels/tows delayed

River	Lock	Monthly Average Delay (Tows) (minutes)		Monthly Average Processing Time (minutes)		Percent of Vessels Delayed		Percent of Tows Delayed	
		2019	2020	2019	2020	2019	2020	2019	2020
Columbia River	Bonneville	6.6	9	34.8	39.6	80%	77%	85%	81%
	The Dalles	49.2	55.8	38.4	41.4	89%	86%	91%	88%
	John Day	6.6	6.6	52.8	57.6	23%	17%	22%	18%
	McNary	22.8	99.6	36	40.8	84%	74%	89%	79%
Snake River	Ice Harbor	7.8	6	27.6	30.6	94%	88%	98%	96%
	Lower Monumental	162	28.8	36	42	94%	91%	98%	97%
	Little Goose	10.2	18.6	29.4	33	92%	86%	97%	90%
	Lower Granite	1.8	1.8	18	23.4	29%	36%	31%	37%
Lake Washington Ship Canal	Hiram M. Chittenden	52.2	71.4	2.4	2.4	29%	30%	80%	86%

Source: CPCS analysis of USACE data, 2022.

Port infrastructure condition

Economic development is a fundamental mission of the state's ports. To remain economically competitive, the state's marine ports continually invest in the enhancement and maintenance of port infrastructure, freight facilities, freight handling equipment, and development and redevelopment of terminals. Examples of terminal and infrastructure enhancements currently in development include:[28]

- "Rail Span" Barge Dock Rehabilitation at the Port of Bellingham.

- Terminal 3 and Terminal 4 Shore Power Project at the Port of Tacoma.

- Terminal 5 Improvements project at the Port of Seattle.

- Industrial Rail Corridor Expansion at the Port of Longview.

- Norton Terminal at the Port of Everett.

In addition to these specific terminal and dock investments, ports are also making investments in sustainability improvements, such as conversion to lower emissions equipment (e.g., shore power and cargo handling equipment electrification). Ports have also partnered off-terminal to invest in surface transportation serving the freight systems. The ports of Seattle and Tacoma, along with NWSA, have invested in projects such as road/rail grade separations on SR519, the SR99 tunnel, the SR509 and SR167 Puget Sound Gateway program.

From a national perspective, Washington's deep-draft marine ports offer exceptional infrastructure, close proximity to the interstate highway system, and service from two Class I railroads.

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[28] Port websites, March 2022.

Additionally, Washington's marine ports have been awarded federal grants from recent programs, including TIGER, RAISE, BUILD, and PIDP, demonstrating their importance to the regional and national freight transportation system as well as the commitment of federal partners to the continued success of Washington ports.

Lock age

Aging locks directly impact the efficiency and reliability of the waterway freight movements. The USACE suggests the service lives of navigation structures are between 60 and 75 years.[29] There are a total of nine locks on the Washington river system – four each on Columbia River and Snake River and one on the Lake Washington Ship Canal. As Figure 30 shows, only two 106-year-old locks on Lake Washington Ship Canal exceed the estimated service life. However, the locks have gone through major renovations in 2018 and 2020, including the replacement of 100-year-old large lock gates and the filling culvert valves.[30,31] The locks on Columbia/Snake River underwent similar improvements and upgrades in 2017.[32]

Figure 30: Washington lock age

River	Lock	Year Open	Age (as of 2022)	Note
Columbia River	Bonneville	1993	29	The Columbia – Snake River locks went through major repairs in 2017. Some of the upgrades include navigation lock controls, lock gate replacement, gate machinery upgrade, etc.
	The Dalles	1957	65	
	John Day	1968	54	
	McNary	1953	69	
Snake River	Ice Harbor	1962	60	
	Lower Monumental	1969	53	
	Little Goose	1970	52	
	Lower Granite	1975	47	
Lake Washington Ship Canal	Hiram M. Chittenden	1916	106	The large chamber went through renovations in 2018 and 2020.
	Hiram M. Chittenden Aux.	1916	106	

Source: CPCS analysis of USACE Lock Characteristics General Report; King5.com; MyBallard.com; Feedstuffs.com, 2022.

Air cargo system performance

Air cargo is crucial to Washington's economic development due to its efficiency and reliability when compared to other modes of freight transportation. There are 22 airports in the state that offer air cargo services. The primary industries served by air cargo in Washington are agriculture, electronics manufacturing, pharmaceuticals, aerospace manufacturing, and seafood, which rely on fast transportation to ensure valuable and perishable goods reach domestic and international markets in time.

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[29] Capital Stock: Infrastructure Age, USACE, (n.d.). https://www.iwr.usace.army.mil/Missions/Value-to-the-Nation/Fast-Facts/Capital-Stock/Infrastructure-Age/

[30] Ballard Locks awarded $10.5m to replace 100-year-old large lock gates, My Ballard, Meghan Walker, September 2018. https://www.myballard.com/2018/09/13/ballard-locks-awarded-10-5m-to-replace-100-year-old-large-lock-gates/

[31] Large chamber at Chittenden Locks in Ballard closes for upgrades, KING 5, February 2020. https://www.king5.com/article/news/local/seattle/hiram-chittenden-ballard-locks-seattle-renovations/281-586095fc-0e22-4efa-90ef-37ebbe6a03b6

[32] Columbia-Snake River system closed until March, Feedstuffs, Krissa Welshans, January 2017. https://www.feedstuffs.com/markets/columbia-snake-river-system-closed-until-march

Air cargo volumes

WSDOT Gray Notebook has been using annual air cargo tonnage as one of the measures for air cargo performance. Figure 31 demonstrates the growing trends of air cargo volume in Washington between 2014 and 2020, a 28.6 percent increase during the 7-year period. Besides statewide air cargo tonnage, the Gray Notebook also tracks the cargo volume moved by major cargo airports, including Seattle-Tacoma International Airport, Boeing Field/King County International Airport, Spokane International Airport, and Paine Field Airport. Based on the annual cargo tonnage reported by the Bureau of Transportation Statistics, Figure 32 lists the 2019 cargo tonnages and the 5-year changes of the top nine airports that transported more than 1,000 tons of cargo in 2019. Except for King County International Airport and Tri-Cities Airport, all the other eight cargo airports show major growth in air cargo tonnage.

Figure 31: Washington annual air cargo volume (tons)
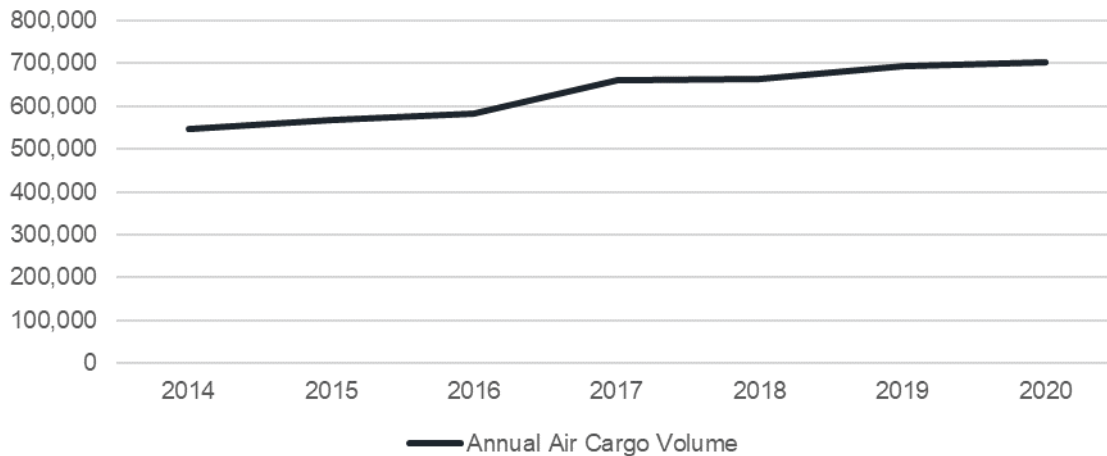
Source: CPCS analysis of Bureau of Transportation Statistics T-100 Data, 2021.

Figure 32: Top nine air cargo facilities in Washington, 2019

Cargo Airports	Air Cargo Type	2019 Tonnage	% Change between 2014 and 2019
Sea-Tac International Airport	Domestic and international belly cargo; domestic and international freighter cargo, and integrator/express cargo (FedEx)	499,956.6	64.6%
King County International Airport	Integrator and all-cargo carrier (UPS)	112,391.4	-3.3%
Spokane International Airport	Integrator/express cargo (FedEx and UPS); belly cargo	69,001.1	5.2%
Paine Field Airport	Wide-body freighters; integrator/ express cargo	33,813.7	127.0%
Yakima Air Terminal / McAllister Field	Integrator/express cargo (FedEx and UPS)	2,426.3	14.8%
Tri-Cities Airport	Integrator/express cargo (FedEx and UPS); belly cargo	1,652.4	-33.4%
Bellingham International Airport	Integrator/express cargo (FedEx); belly cargo	1,715.8	42.1%
Grant County International Airport	Integrator/express cargo (FedEx), seasonal freighter service	1,520.6	278.4%
Friday Harbor Airport	Integrator/express cargo (FedEx); seaplane cargo	1,353.0	525.2%

Source: CPCS analysis of T-100 Market Data; Port of Seattle; Spokane International Airport, 2021.
Note: T-100 doesn't include Ameriflight data and might be double-counting FedEx volumes.
*NA: Information not available.

Airport runway condition

The Federal Aviation Administration (FAA) keeps a runway inventory that records runway dimensions, surface types, and conditions. Distress type, distress quantity, and distress severity determine the runway pavement condition ratings. The ratings include the following five levels:

- **Excellent**: Pavement has no visible defects, such as cracking and raveling. Initial thermal cracks are less than 3 millimeters in width. This condition is typical for pavements with less than 5 years of service. The surface texture meets ICAO/FAA roughness levels for new pavement.

- **Good**: Pavement surfaces are over 5 years in service and have a recently sealed coat. Cracks are all sealed and spaced at 3 to 6 meters apart, and less than 10 percent of the surface has cracks. The surface does not manifest distortion or patches and meets ICAO/FAA roughness levels.

- **Fair**: Pavement has moderate raveling. Thermal cracks and joints are around 15 meters apart. Ten percent to twenty-five percent of cracks or joints require crack sealing or sealant repair. Ten percent or less of pavement edges have cracks. Block cracks are 2 to 3 meters apart. Previous patches are not holding up. Surface texture exceeds the minimal ICAO/FAA roughness levels yet falls below maintenance planning levels.

- **Poor**: Pavement contains moderate to severe raveling and frequent thermal cracks. Over 25 percent of pavement edges have cracks. Block cracks are less than 2 meters apart. About 20 percent of surface area contains alligator cracks. Pavement patches show distortion up to 25 to

50 millimeters. Surface texture is slightly above minimal ICAO/FAA roughness levels yet falls below maintenance planning levels.

- **Failed**: Pavement has widespread severe cracking with raveling and deterioration. Alligator cracking and pot holes are over 20 percent of the pavement surface. The distortion of pavement surface is over 50 millimeters. Previous patches have failed and settled up to 50 millimeters. Surface texture is below minimal ICAO/FAA roughness levels.

Understanding the pavement condition is crucial to safe and efficient cargo operations and maintenance decision making. As shown in Figure 33, the majority of the runways in the top ten cargo airports by volume in Washington are in good or excellent condition. King County International Airport and Tri-Cities Airport have two runways that are in fair condition. The only runway that is in poor condition is at Yakima Air Terminal/McAllister Field.

Figure 33: Top nine air cargo facility runway condition, 2021

Airport	Runway	Dimensions	Surface Type	Runway Condition
Sea-Tac International Airport (SEA)	16C/34C	9,426 ft. x 150 ft.	Concrete	Excellent
	16L/34R	11,901 ft. x 150 ft.	Concrete	Excellent
	16R/34L	8,500 ft. x 150 ft.	Concrete	Excellent
King County International Airport (BFI)	14L/32R	3,709 ft. x 100 ft.	Asphalt	Fair
	14R/32L	10,007 ft. x 200 ft.	Asphalt	Good
Spokane International Airport (GEG)	03/21	11,002 ft. x 150 ft.	Asphalt/Concrete	Excellent
	08/26	8,199 ft. x 150 ft.	Asphalt	Good
Paine Field Airport (PAE)	16L/34R	3,004 ft. x 75 ft.	Asphalt	Good
	16R/34L	9,010 ft. x 150 ft.	Asphalt/Concrete	Good
Yakima Air Terminal / McAllister Field (YKM)	04/22	3,835 ft. x 150 ft.	Asphalt	Poor
	09/27	7,604 ft. x 150 ft.	Asphalt	Excellent
Tri-Cities Airport (PSC)	05/23	8,000 ft. x 150 ft.	Asphalt	Good
	09/27	4,442 ft. x 150 ft.	Asphalt	Fair
Bellingham International Airport (BLI)	16/34	6,700 ft. x 150 ft.	Asphalt	Good
Grant County International Airport (MWH)	04/22	10,000 ft. x 100 ft.	Concrete	Good
	09/27	3,500 ft. x 90 ft.	Concrete	Good
	14L/32R	13,503 ft. x 200 ft.	Concrete	Good
	14R/32L	2,936 ft. x 75 ft.	Concrete	Good
	18/36	3,327 ft. x 75 ft.	Asphalt	Good
Friday Harbor Airport (FHR/FRD)	16/34	3,402 ft. x 75 ft.	Asphalt	Good

Source: Federal Aviation Administration Airport Data and Information Portal, 2022.

Pipeline system performance

There are over 46,000 miles of pipeline in Washington, carrying over $22.8 billion worth of crude oil, petroleum, and natural gas through 30 of the state's 39 counties.[33] In 2020, Washington's pipelines carried about 7.5 billion gallons of oil of any kind.[34] These data are presented in Figure 34.

Figure 34: Pipeline performance snapshot

46,300 miles	7.5B gallons	$22.8B
of pipeline in Washington	of oil (of any kind) moved by pipeline in Washington	value of commodities moving through Washington

Source: CPCS analysis of USDOT, Pipeline and Hazardous Materials Safety Administration, State of Washington Department of Ecology, Washington Utilities and Transportation Commission, and FAF5 data, 2021.

Oil movement performance

Figure 35 shows that the volume of oil movements by pipeline in Washington has been slowly rising over the last decade, from just over 6 billion gallons in 2010 to over 8 billion in 2019. Oil volumes fell to 7.5 billion gallons in 2020 as the pandemic took hold. Note that oil here refers to any kind of oil, including crude oil, petroleum, gasoline, fuel oil, oil sludge, oil refuse, and biological oils and blends.

Figure 35: Volume of oil (of any kind) movements by pipeline in Washington, 2010-2020
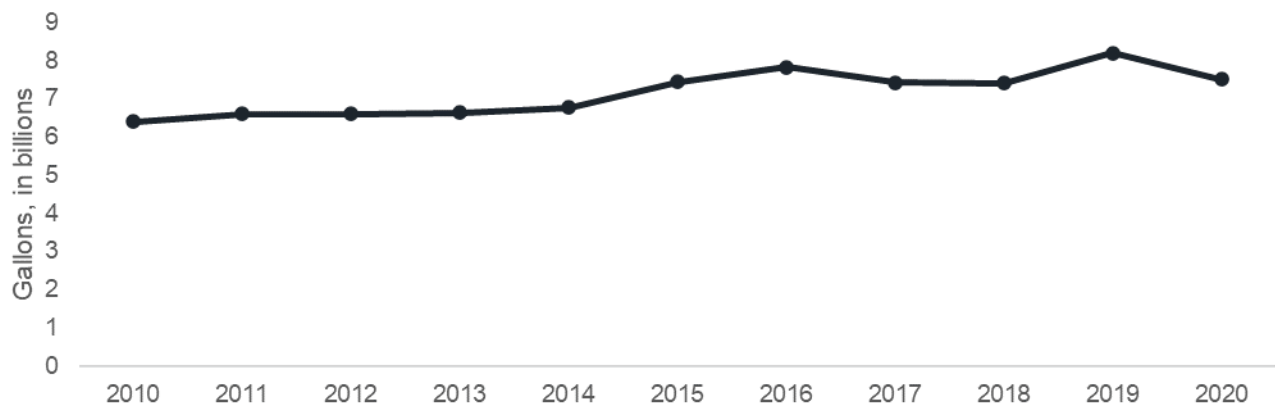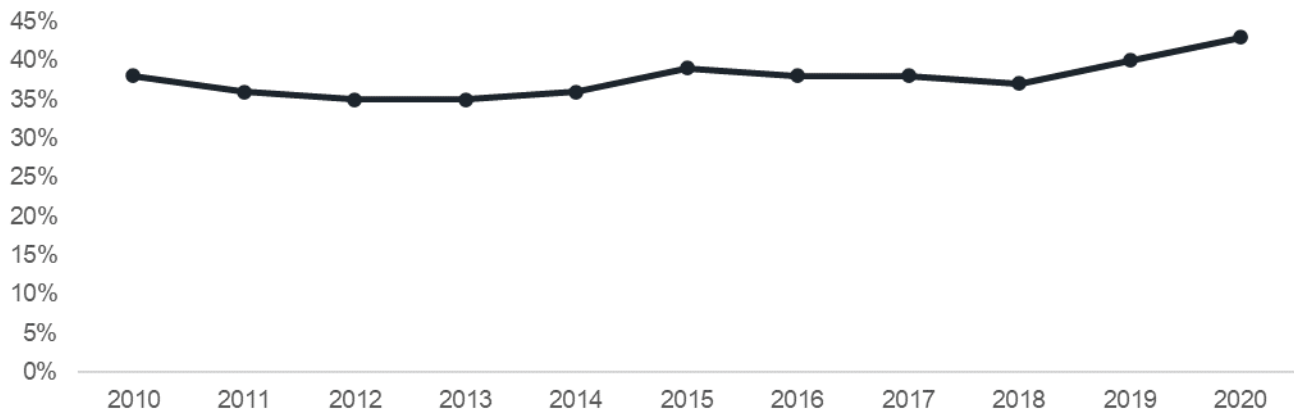

Source: CPCS analysis of State of Washington Department of Ecology, Total Oil Moved by Year and Mode, 2021.

Figure 36 shows the percentage of all oil movements in Washington carried by the pipeline as opposed to other modes. On average, pipelines carry about 38 percent of all oil movements by volume in the state. In both 2019 and 2020, the percentage rose over 40 percent.

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[33] Pipeline and Hazardous Materials Safety Administration, USDOT, January 2020. https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-mileage-and-facilities; FHWA FAF 5; Pipeline Operators by County, Washington Utilities and Transportation Commission, (n.d.). https://www.utc.wa.gov/pipeline-operators-county
[34] Total Oil Moved by Year and Mode, State of Washington Department of Ecology, March 2022. https://apps.ecology.wa.gov/publications/documents/1708014.pdf
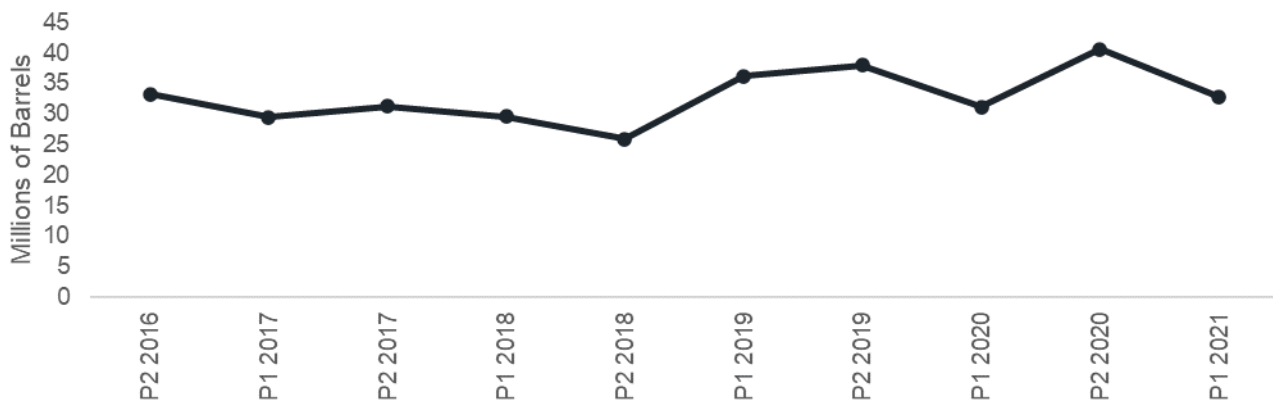
Figure 36: Percentage of all oil (of any kind) movements in Washington carried by pipeline, 2010-2020

Source: CPCS analysis of State of Washington Department of Ecology, Total Oil Moved by Year and Mode, 2021.

Figure 37 shows the volume of crude oil moved on pipelines in Washington over the last 5 years. Crude oil volumes have remained relatively stable. In 2020, almost 72 million barrels, or over 3 billion gallons, of crude oil moved by pipeline in the state.

Figure 37: Volume of crude oil movements by pipeline in Washington, 2016-2021

Source: CPCS analysis of Washington Department of Ecology Crude Oil Movement by Rail and Pipeline Quarterly Reports, various, 2022.
Note: P here stands for "period." Data recorded in half-year increments.

Figure 38 shows the percentage of all crude oil movements carried by pipeline as opposed to other modes in Washington since 2016. Despite recent fluctuations caused by the pandemic, pipelines have carried an average of about 31 percent of all crude oil movements between 2016 and 2021.

Figure 38: Percentage of all crude oil movements in Washington carried by pipeline, 2016-2021
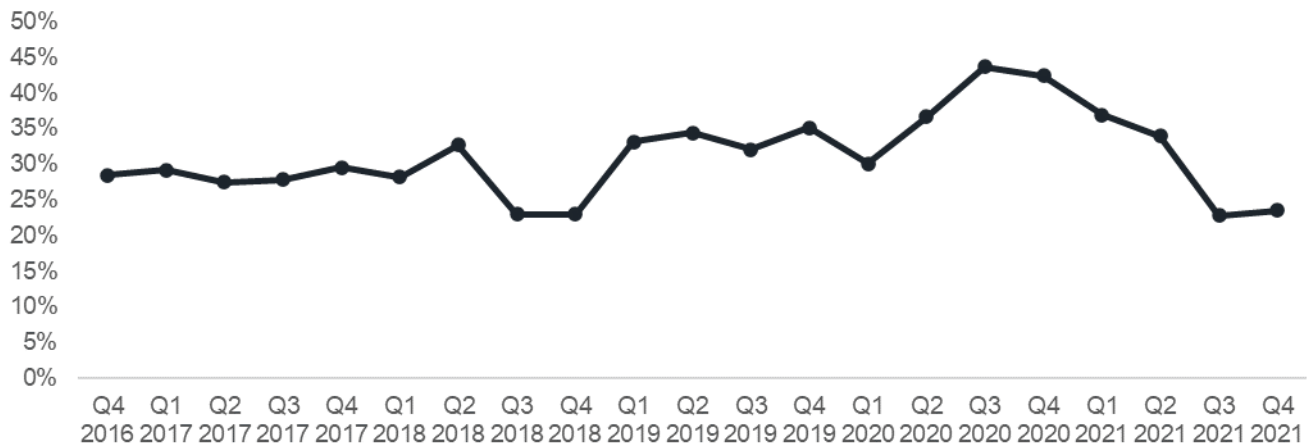
Source: CPCS analysis of Washington Department of Ecology Crude Oil Movement by Rail and Pipeline Quarterly Reports, various, 2022.

Pipeline safety performance

One way of assessing pipeline safety performance is by examining the number of pipeline spills. A transmission pipeline was the source of only one reported spill to water between 2016 and 2021. Refineries were the source of four spills to water between 2016 and 2021. Figure 39 provides details on these five pipeline system hazardous spills.

Figure 39: Pipeline system hazardous spills to water, 2016-2021

Source	Date	Location	Volume	Material Type
Refinery	March 2016	Phillips 66 in Ferndale	100 gallons	Diesel/Marine gas oil
Refinery	December 2017	U.S. Oil and Refining in Tacoma	170 gallons	Oily water mixture
Refinery	January 2018	Phillips 66 in Ferndale	44 gallons	Oily water mixture
Transmission Pipeline	January 2019	Bayview on the Lake Condominium in Kirkland	1 gallon	Oily water mixture
Refinery	November 2021	Puget Sound Refinery in Anacortes	1 gallon	Oily water mixture

Source: CPCS analysis of Washington Department of Ecology Reported Spills data, 2022.

Another way of assessing pipeline safety performance is to examine the number of incidents per pipeline mile. The following box describes USDOT's definition of a pipeline incident.

The **USDOT Pipeline and Hazardous Materials Safety Administration** defines a pipeline incident as:

(1) An event that involves a release of gas from a pipeline, gas from an underground natural gas storage facility (UNGSF), liquefied natural gas, liquefied petroleum gas, refrigerant gas, or gas from an LNG facility, and that results in one or more of the following consequences:

(i) A death, or personal injury necessitating in-patient hospitalization;

(ii) Estimated property damage of $122,000 or more, including loss to the operator and others, or both, but excluding the cost of gas lost. For adjustments for inflation observed in calendar year 2021 onwards, changes to the reporting threshold will be posted on PHMSA's website. These changes will be determined in accordance with the procedures in appendix A to part 191.

*(iii) Unintentional estimated gas loss of three million cubic feet or more.*

(2) An event that results in an emergency shutdown of an LNG facility or a UNGSF. Activation of an emergency shutdown system for reasons other than an actual emergency within the facility does not constitute an incident.

(3) An event that is significant in the judgment of the operator, even though it did not meet the criteria of paragraph (1) or (2) of this definition.

Source: 49 CFR § 191.3 – Definitions, (n.d.).

Figure 40 shows the number of incidents per pipeline mile between 2011 and 2020 scaled by pipeline miles in Washington, select states, and the U.S. overall. Washington experiences far fewer hazardous spill incidents per pipeline mile than the U.S. and most of its neighboring states. However, compared to Oregon, Washington performs less well.

Figure 40: Average number of incidents of per pipeline mile, 2011-2020
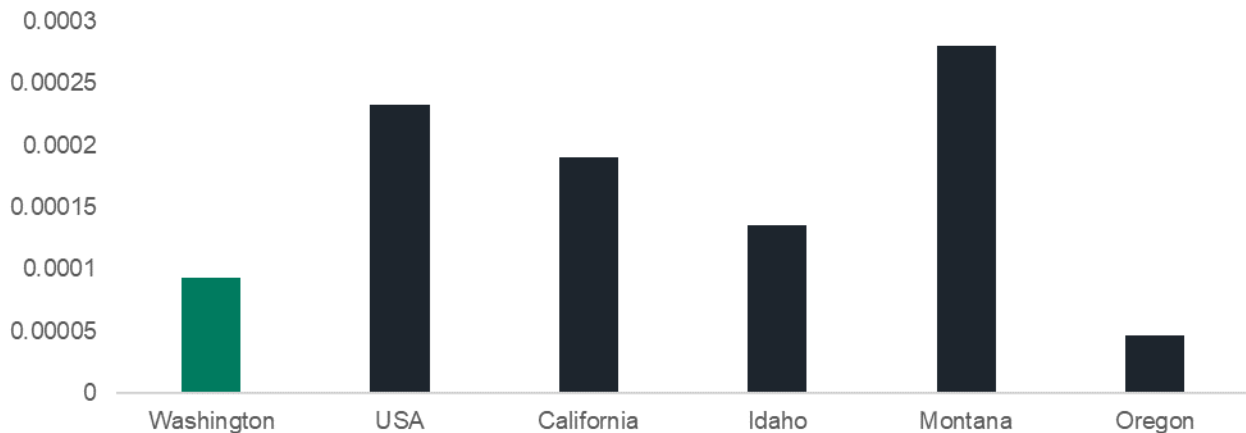
Source: CPCS analysis of USDOT Pipeline and Hazardous Materials Safety Administration's Pipeline Miles and Facilities 2010+ and All Reported Incidents data, 2022.
Note: Pipeline miles and incidents are for all pipeline types (gas distribution, gas gathering, gas transmission, hazardous liquid) and all pipeline types (gas, hazardous liquid, LNG, etc.). Values are calculated by year and then averaged.

Figure 41 and Figure 42 focus in on only hazardous liquid incidents. Figure 41 shows the average rate of hazardous spill incidents between 2011 and 2020 scaled by pipeline miles in Washington, select states, and the U.S. overall. Washington experiences fewer hazardous spill incidents per pipeline mile than the U.S. and most of its neighboring states. Figure 42 shows the average barrels spilled between 2011 and 2021 scaled by pipeline miles in Washington, select states, and the U.S. overall. Washington sees a far smaller volume of materials spilled per pipeline mile than the U.S. average. Among the neighboring states analyzed, only Oregon performs better than Washington on this metric and, even so, only by a relatively small margin.

Figure 41: Average number of hazardous spill incidents per liquid pipeline mile, 2011-2020
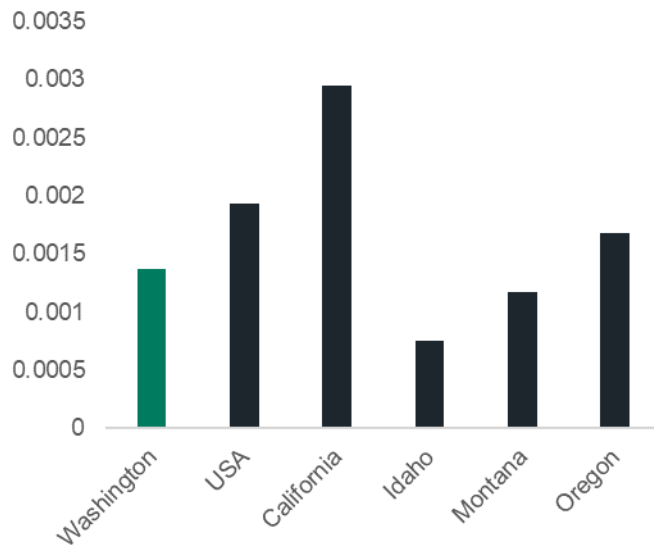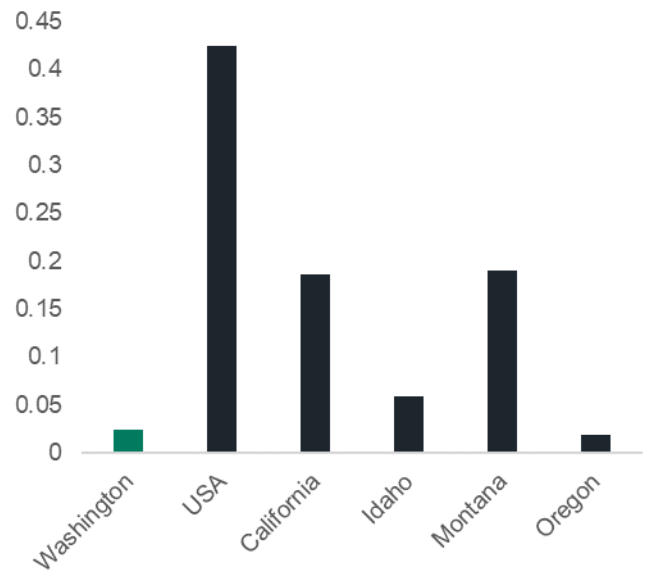
Figure 42: Average barrels spilled per liquid pipeline mile, 2011-2020

Source: CPCS analysis of USDOT Pipeline and Hazardous Materials Safety Administration's Pipeline Miles and Facilities 2010+ and All Reported Incidents data, 2022.
Note: Pipeline miles and incidents are for hazardous liquids only (crude oil, refined PP, H.V.L. flamm toxic, CO2, biofuel). Values are calculated by year and then averaged.

These data indicate that Washington has relatively strong pipeline safety performance. This is likely the result of significant investments in spill prevention and spill response equipment. Indeed, the Washington Department of Ecology touts that the state has "one of the most comprehensive spill prevention, preparedness, and response programs in the nation and the world (see Figure 48)."[35]

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[35] Oil spill prevention in Washington, State of Washington Department of Ecology, (n.d.). https://ecology.wa.gov/Spills-Cleanup/Spills/Oil-spill-prevention

3. Environmental impacts of transportation operations in Washington

While the transportation of people and goods creates enormous social and economic benefits, various modes of transportation also bring externalities to our environment. Fossil fuel-burning vehicles emit greenhouse gas (GHG) and pollutants that degrade the air quality and contribute to climate change. Roadway, rail, maritime, and air traffic also create noise pollution that impacts wildlife and communities. Stormwater runoff, oil spill incidents, and disturbance to fish passages are some other examples of the transportation system's environmental impacts in Washington.

With the continuous growth in demand for transportation, the environmental externalities are expected to grow, accelerating the effects of climate change and bringing even more impacts to the transportation infrastructure and operations. WSDOT and other state agencies have been working at the forefront of reducing pollutant emissions and increasing the resiliency of the transportation infrastructure. This chapter reviews the environmental impacts of the transportation system in Washington and provides a foundation for determining freight emissions and alternative fuels assessment in future planning efforts.
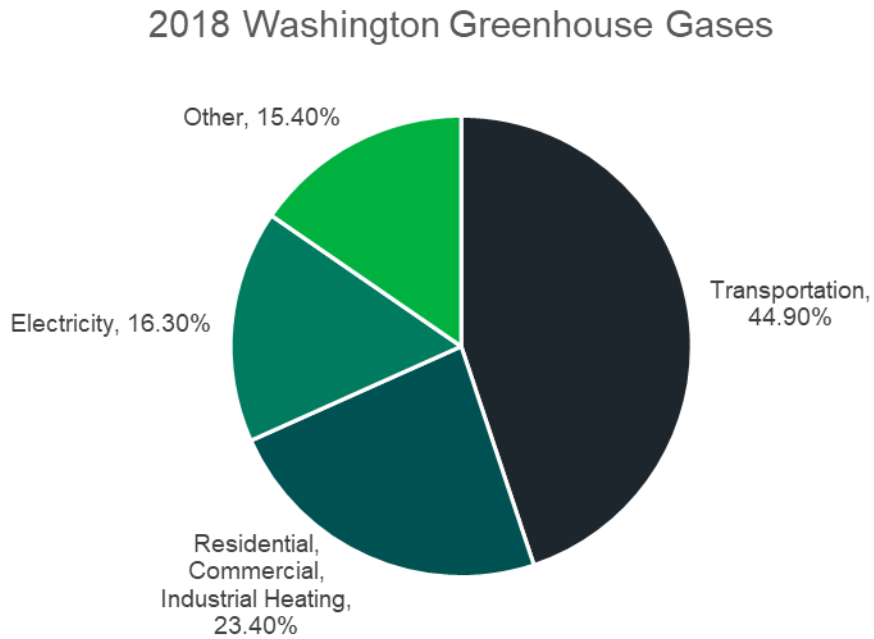
Greenhouse gas emissions

According to the 2018 Washington Greenhouse Gas (GHG) Inventory, transportation was the largest GHG generator and created 44.73 million metric tons of CO_2, accounting for 45 percent of the total GHG emissions in the state. Among the different transportation modes, personal cars and trucks made up over half of the emissions in Washington.[36] Besides carbon dioxide, the transportation sector also emits relatively small amounts of methane, nitrous oxide, and hydrofluorocarbon (from mobile air conditions and refrigerated transport).[37]

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[36] 2018 Greenhouse gas inventory, Washington State Department of Ecology, 2018. https://ecology.wa.gov/Air-Climate/Climate-change/Tracking-greenhouse-gases/GHG-inventories/2018-GHG-inventory
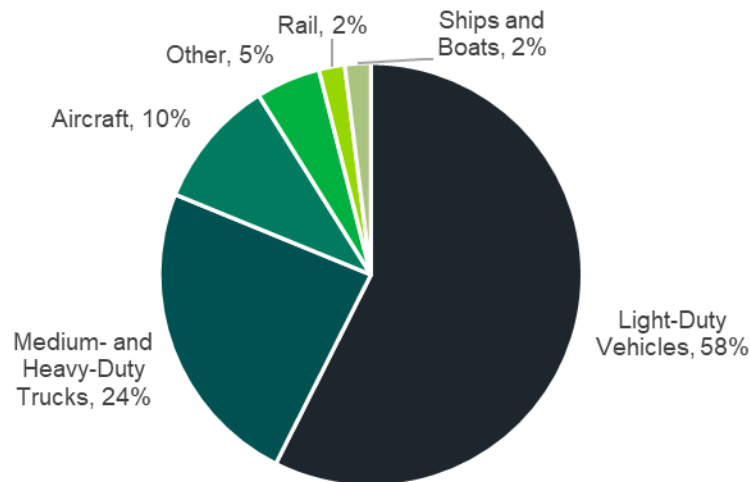
[37] Sources of Greenhouse Gas Emissions, U.S. EPA, 2020. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation

Figure 43: Sources of Washington greenhouse gases, 2018

2018 Washington Greenhouse Gases

Other, 15.40%

Electricity, 16.30%

Transportation, 44.90%

Residential, Commercial, Industrial Heating, 23.40%

Source: Washington Department of Ecology, 2022.

Figure 44: U.S. transportation sector GHG emissions by source, 2019

Rail, 2%

Ships and Boats, 2%

Other, 5%

Aircraft, 10%

Light-Duty Vehicles, 58%

Medium- and Heavy-Duty Trucks, 24%

Source: EPA, 2022.

Environmental health disparities

The Washington Environmental Health Disparities Map incorporates 19 indicators to evaluate the environmental impacts across the communities in Washington. The 19 indices are grouped into the following four themes:

- **Environmental Exposures** consist of a series of air quality indicators, including NOx-diesel emissions, ozone concentration, and PM2.5 concentration, population near heavy traffic roadways, and toxic release from facilities (RSEI model).

- **Environmental Effects** encompass lead risk from housing, proximity to hazardous waste treatment, storage, and disposal facilities, proximity to National Priorities List sites (Superfund Sites), proximity to Risk Management Plan facilities, and wastewater discharge.

- **Sensitive Populations** look at the death from cardiovascular disease and populations with low birth weight.

- **Socioeconomic Factors** capture vulnerable populations by measuring English proficiency, high school diploma attainment, poverty, race, transportation expense, unaffordable housing, and unemployment rates.

Although the only theme that is directly related to transportation operations is the Environmental Exposures, factoring the other three categories provides a holistic picture of the level of impacts on local communities caused by transportation-induced pollutants and toxins.

### *Transportation-specific environmental impacts*

The Washington Environmental Health Disparities are calculated using the four themes noted above based on the formula demonstrated in Figure 45. The results show that the communities with high Environmental Health Disparities are clustered in major urban areas, such as the Puget Sound region and Spokane. Communities are also disproportionally impacted along the I-5 corridor, Yakima Indian Reservation, and southeast Washington. NOx-Diesel Emissions reveal that the impact on the vulnerable population is especially disproportionate along the FGTS T-1 and T-2 corridors. As depicted in Figure 46, the communities along Puget Sound, Centralia, Longview I-5 corridor, I-90 corridor from Moses Lake to Spokane, and I-82 between Yakima and Kennewick are impacted the most by the diesel pollution.

Figure 45: Washington environmental health disparities calculation

Threat	Vulnerability	Risk
Environmental Exposures + Environmental Effects	✕ Socioeconomic Factors + Sensitive Populations	= Environmental Health Disparities

Source: Washington State Department of Health, 2022.

Figure 46: Diesel pollution and disproportionate impact
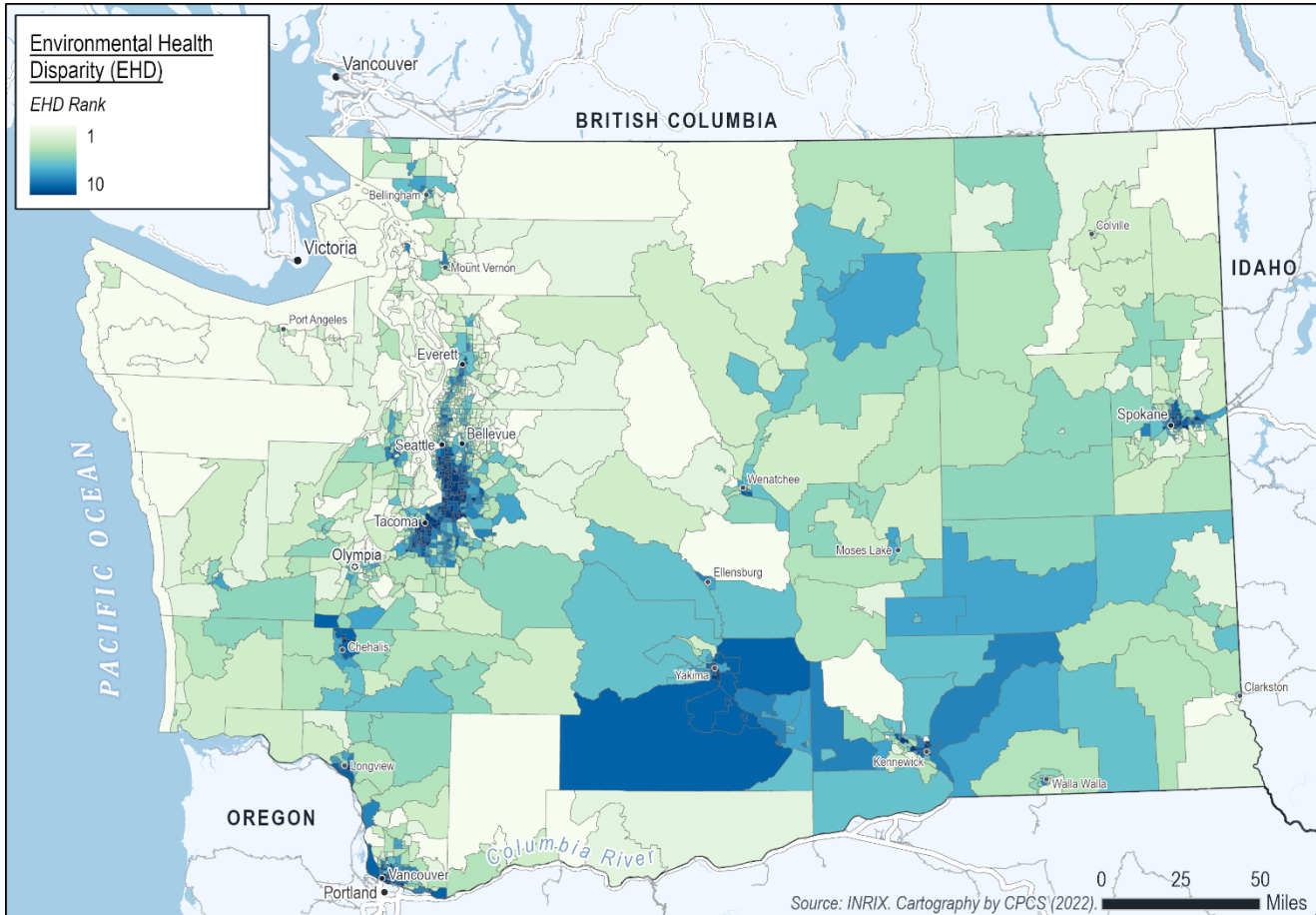
Source: Washington State Department of Health, 2022.

Hazardous material spills to water

A hazardous material spill refers to the accidental leak of any toxic element into the environment. The most common type of spill involves petroleum products, although other materials may be spilled as well, including sewage, pesticides, paint, firefighting foam, and other chemicals. Not only do such spills threaten the health of wildlife and the natural environment, but they also risk polluting critical human water resources.

Figure 47 provides a snapshot of hazardous material spills to water in Washington between 2016 and 2021. According to data from the Washington Department of Ecology, during this period, there were over 2,700 spills, or about 452 spills per year on average. These spills released nearly 95,000 gallons of hazardous material into water in the environment, or over 15,800 gallons per year on average. That's almost 200 bathtubs worth of hazardous waste released annually. King County saw the most spills between 2016 and 2021 with 1,060.[38]

It is important to note that the Washington Department of Ecology data does not differentiate between freight-related spills and non-freight-related spills. The data here should be viewed as an approximate proxy for the frequency of freight-related hazardous spills.

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[38] Spills maps, State of Washington Department of Ecology, 2022.
https://apps.ecology.wa.gov/coastalatlas/storymaps/spills/spills_sm.html

Figure 47: Hazardous material spills to water snapshot, 2016-2021

| **About 452 spills**	**Almost 16k gallons**	**King County**
Average number of hazardous spills per year	Average volume of hazardous materials spilled per year	County with the most hazardous spills

Source: CPCS analysis of Washington Department of Ecology Reported Spills data, 2022.
Note that the data provided by the Washington Department of Ecology only captures reported spills of one gallon or more. Small spills are excluded, as are spills that go unreported.

Figure 48 maps the location and quantity of reported hazardous spills to water in Washington between 2016 and 2021 as well as the state's oil spill response equipment. Hazardous spills are concentrated along water resources like the Pacific Ocean, the Puget Sound, and the Columbia-Snake River system. Spills are most common in and around Puget Sound and along the I-5 corridor.

Figure 48: Reported hazmat spills to water and locations of oil spill equipment in Washington

Source: WA Ecology, WSDOT. Cartography by CPCS (2022).
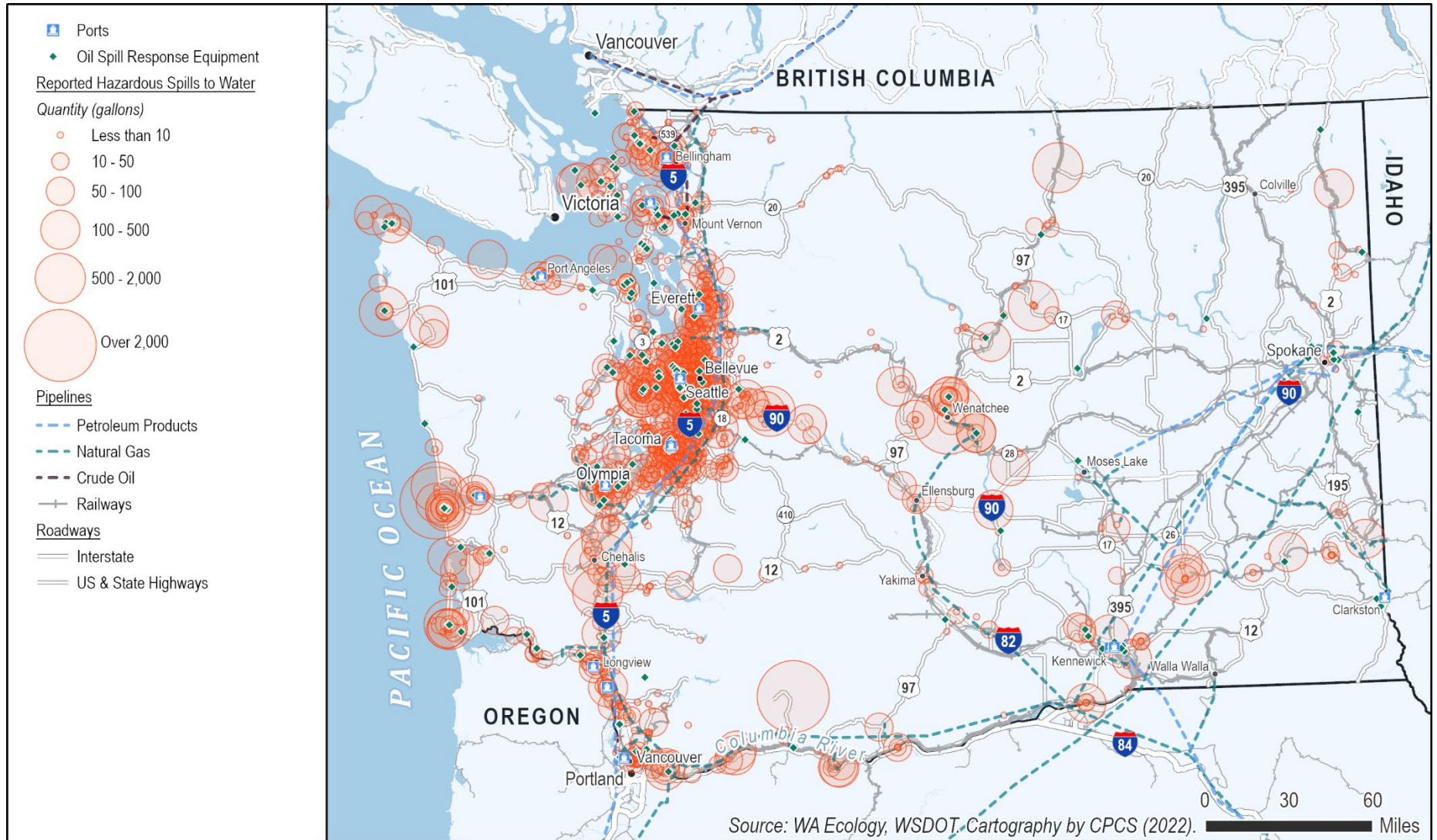
Reference Chapter A: Truck mobility analysis methodology

Truck Travel Time Reliability (TTTR) Index

FHWA's recommended method for calculating the TTTR Index is used for the purpose of this freight planning effort.[39] In this method, truck speed information is collected from the National Performance Management Research Data Set (NPMRDS). The NPMRDS data is developed based on field observations of vehicle travel time and speed data, collected anonymously from probe vehicles (both passenger vehicles and trucks). The time and location data collected by the probe vehicles is translated into speed and travel time information and aggregated in 10-minute, 15-minute, or 1-hour intervals.

NPMRDS data is available at the Traffic Message Channel (TMC) link-level along the National Highway System (NHS). A TMC link is a directional road segment. The TMC link lengths are about 0.5 to 1 mile in urban areas and up to 5 to 10 miles in rural areas.[40] A caveat of the NPMRDS data is outliers and missing travel time and/or speed values. This is due to some road segments not being traversed by a probe vehicle during a certain time period or day of the week. This issue is especially encountered when analyzing the speed and travel time profiles of rural, lower-volume roads. Also, the variabilities in the lengths of the TMC links are an issue that can impact the analysis results.

The project team collected NPMRDS data of Washington's NHS network using WSDOT's license with the Regional Integrated Transportation Information System (RITIS) platform.[41] RITIS comes with pre-built analytical tools that enable the DOTs to run analyses, reports, and visualizations without the need for data curation and cleaning. To address the missing data issue, the project team replaced the null fields with the historical average data by month, day of week, and hour. The TMC link size issue is addressed through visualization of the analysis results and grouping the adjacent short links by setting thresholds for the various measures that are calculated using NPMRDS data.

According to FHWA's guidelines for calculating TTTR Index, the NPMRDS data was downloaded for the following five periods of 2021 (January 01 – December 31):

i.   Morning peak (6 am – 10 am, Monday – Friday)

ii. Midday (10 am – 4 pm, Monday – Friday)

iii. Afternoon peak (4 pm – 8 pm, Monday – Friday)

iv. Weekends (6 am – 8 pm, Saturday – Sunday)

v.   Overnight (8 pm – 6 am, all days)

TTTRs for each TMC link and each time period are then calculated using Eq. 1. The largest TTTR values of the five periods are selected as the final TTTR for each TMC link (Figure 49). With this formula, lower values represent a more reliable travel speed, while higher values represent more variable travel speeds. Therefore, a high TTTR value means low reliability.

$$\text{Truck Travel Time Reliability} = \frac{\text{95th Percentile Travel Time}}{\text{50th Percentile Travel Time}} \qquad (Eq. 1)$$

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[39] 23 CFR § 490.611.

[40] The National Performance Management Research Data Set (NPMRDS) and Application for Work Zone Performance Measurement, FHWA, September 2020. https://ops.fhwa.dot.gov/publications/fhwahop20028/fhwahop20028.pdf

[41] RITIS is the leading big data aggregation and dissemination platform for solving challenging and complex transportation problems. The University of Maryland Center for Advanced Transportation Technology Laboratory (CATT Lab) hosts the NPMRDS on RITIS platform,

Figure 49: Statewide truck travel time reliability ratios for five periods, 2021

Truck Travel Time Reliability (TTTR) (Single Segment, Interstate Highway System)		
Monday – Friday	6am – 10am	TTTR = $\frac{80\ sec}{52\ sec}$ = 1.54
	10am – 4pm	TTTR = 1.45
	4pm – 8pm	**TTTR = 1.72 (Maximum)**
Weekends	6am – 8pm	TTTR = 1.35
Overnight	8pm – 6am	TTTR = 1.27

Source: CPCS analysis of NPMRDS data, 2022.

After calculating the TMC-level TTTR Indices, the statewide annual TTTR Index for the NHS is calculated by using Eq. 2. It is also called as statewide Freight Reliability Index. The statewide TTTR Index is the sum of the maximum TTTR for each TMC link, divided by the total system miles.

$$\text{TTTR Index} = \frac{\sum_{i=1}^{T}(SL_i \times maxTTTR_i)}{\sum_{i=1}^{T}(SL_i)} \qquad (Eq.\,2)$$

Where,

i = TMC link or segment.

$max\ TTTR_i$ = the maximum TTTR of all five periods for road segment i.

SL_i = the length of segment i, which accounts for the proportion of the segment that is designated as NHS.

T = the length of all segments.

Figure 50 shows Washington's interstate TTTR Indexes reported to FHWA in 2018 and 2020, calculated based on NPMRDS data of 2017 and 2019. Two-year and four-year TTTR Index targets and 2022 measures calculated based on 2021 NPMRDS data are also included in the table. As shown, Washington achieved its two-year target for the statewide TTTR Index since the 2019 Index was about 9.5 percent (1.5 points) below the two-year target of 1.7. According to WSDOT, this improvement can be associated with various state and regional efforts undertaken to reduce truck congestion and alleviate bottlenecks through the planning process and TIP and STIP investments, including but not limited to mobility, operational and system management improvements, and pavement preservation.[42] The TTTR Index for the NHS network in Washington was 1.49 in 2021. Therefore, the state has achieved its four-year target of 1.75.

Figure 50: Washington's TTTR Index and targets

Measure	2017	2019	2021	2-year Target	4-year Target
TTTR Index on Interstates	1.63	1.54	1.72	1.7	1.75

Source: CPCS analysis of NPMRDS data, 2022; FHWA State Biennial Reports, 2018 & 2020.

The TTTR ratios calculated for highway segments (TMC links) are used (along with other factors) to determine what parts of the system have the greatest reliability and are identified as roadway bottlenecks.

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[42] CPCS review of Washington DOT's biennial transportation performance report submittals to FHWA, 2018 and 2020.

Truck Delay Per Mile (DPM)

Travel time delay is usually calculated from the difference between free-flow travel time and observed travel time for road segments, multiplied by the peak hour or non-peak hour traffic volume. Many states use the truck travel time delay as their preferred measure for decision-making regarding freight mobility issues since it captures the mobility performance of the roadway segments (travel time and speed) while taking traffic volumes into account.

To assist with truck DPM calculations, the Peak Hour Excessive Delay (PHED) for trucks is calculated at the TMC link level and for every 15-minute bin. This measure improves truck DPM analysis by adding a threshold for when travel time delays should begin to be accounted. According to FHWA guidance,[43] PHED is calculated using the following steps:

Step 1: Calculating a threshold speed as the larger of 20 mph or 60 percent of the reference speed limit during peak hours (6 am – 10 am and 4 pm – 8 pm, Monday – Friday) (Eq. 3). The reference speed is extracted from Washington's NPMRDS data of 2021 as the 95th percentile of the speeds between 10 pm and 5 am:

$$Threshold\ Speed = \ Max \begin{cases} 20\ mph \\ \\ Reference\ Speed\ \times 0.60 \end{cases} \qquad (Eq.3)$$

Step 2: Excessive Delay Threshold Travel Time (EDTTT) is calculated using the threshold speed from the previous step and Eq. 4. EDTTT indicates the travel time for each road segment (TMC link) above for which delays would be incurred:

$$Excessive\ Delay\ Threshold\ Travel\ Time\ (EDTTT) = \frac{Road\ Segment\ Legnth}{Threshold\ Speed} \qquad (Eq.4)$$

Step 3: Travel Time Segment Delay (RSD) is calculated using EDTTT from the previous step and Eq. 5. The average travel time in the formula is calculated as the average travel time for all the trucks traveling along each segment (TMC link) and for each 15-minute time bin:

$$Travel\ Time\ Segment\ Delay\ (RSD) = Average\ Travel\ Time - EDTTT \qquad (Eq.5)$$

Step 4: Excessive Delay (ED) time for each road segment (TMC link) is calculated using RSD calculated in the previous step and Eq. 6:

$$Excessive\ Delay\ (ED) = \begin{cases} \dfrac{RSD}{3600}\ when\ RSD \geq 0 \\ \\ 0\ when\ RSD < 0 \end{cases} \qquad (Eq.6)$$

Step 5: EDs calculated for each segment are multiplied by Annual Average Daily Truck Traffic (AADTT) during peak hours and the percent of reporting segment length that is on the NHS to calculate annual hours of Peak Hour Excessive Delay (PHED) on NHS (Eq. 7). The AADTT data is provided in the 2019

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[43] MAP-21 Measures for Congestion, Reliability, and Freight Step-by-Step Metric Calculation Procedures, FHWA, June 2018.
https://www.fhwa.dot.gov/tpm/guidance/hif18040.pdf

Highway Performance Monitoring System (HPMS) database,[44] which also includes data of highway functional classes and NHS network designation at the road segment (TMC link) level:

$$Peak\ Hour\ Excessive\ Delay\ (PHED) = \ ED\ \times Peak\ Hour\ Truck\ AADT \times NHS\ Percent \quad (Eq.\ 7)$$

Step 6: The delay times for all road segments are divided by the length of each road segment (Eq. 8) to result in the PHED per mile. Next, the annual average daily Delay per Mile (DPM) for each segment (TMC link) is calculated by using Eq. 9. Finally, the Total Delay per Mile (TDPM) can be calculated using the following formula of Eq. 10:

$$PHED\ per\ Mile\ = \frac{PHED}{Road\ Segment\ Length\ (miles)} \qquad (Eq.\ 8)$$

$$Delay\ per\ Mile\ (DPM) = \ PHED\ per\ Mile\ \times \frac{Total\ Truck\ AADT}{Peak\ Hour\ Truck\ AADT} \quad (Eq.\ 9)$$

$$Total\ Delay\ per\ Mile\ (TDPM) = \ Delay\ per\ Mile\ (DPM) \times 365 \qquad (Eq.\ 10)$$

The steps above result in TDPM values for each segment of the NHS network. TDPM is the annual hours of delay per mile for each segment.

Combining travel time delay and reliability measures to identify truck bottleneck locations

According to the FHWA, a bottleneck may cause congestion, but congestion is not always the result of a bottleneck. Hence, a two-lens approach is used to identify bottlenecks that are not mere traffic congestion locations (that suffer from excessive delays) but reflect the extent by which the delays are expected. In this approach the TTTR values are multiplied by TDPM values for each segment (TMC link to calculate the TTTR-TDPM Index values for each road segment (*Eq. 10*). These TTTR-TDPM Index values are then used to identify and rank the major bottlenecks in Washington.

$$TTTR - TDPM\ Index = \ TTTR\ \times\ TDPM \qquad (Eq.\ 10)$$

TTTR-TDPM Index represents both the travel time delays and the reliability challenges along the road segments and is a combined measure to identify and rank truck bottlenecks.

The following table and maps show the top five truck bottlenecks identified for each of the six transportation administrative areas in Washington or the WSDOT regions. The road segments shown in the maps are color-coded based on the TTTR-TDPM Index values so that the segments with the highest index values (top 10 percent) are highlighted as orange.

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[44] 2019 HPMS data is used since 2021 data has not been published yet.

Figure 51: Top five truck bottlenecks in each of the WSDOT region

Road Name	Intersection	Total Delay Hours (Per Mile)	TTTR	TTTR-Delay	Region Name	Bottleneck Rank
N CENTER PKWY	W GAGE BLVD	135.48	2.28	309.05	South Central Region	1
WA-24	I-82/US 12/US 97	35.58	3.57	127.20	South Central Region	2
MAIN ST	VALLEY MALL BLVD	31.14	3.64	113.23	South Central Region	3
WA-240	WA-240 BUS/JADWIN AVE/STEVENS DR	56.46	1.88	106.20	South Central Region	4
GAGE BLVD	KEENE RD	26.30	3.80	99.94	South Central Region	5
3RD AVE	I-90/E 2ND AVE/S FREYA ST	296.49	2.02	600.12	Eastern Region	1
N ARGONNE RD	WA-290/E TRENT AVE	109.33	2.44	266.23	Eastern Region	2
NE STADIUM WAY	WA-27/N GRAND AVE	61.01	4.14	252.59	Eastern Region	3
E BROADWAY AVE	I-90	68.22	3.62	247.15	Eastern Region	4
EVERGREEN RD	I-90	43.22	5.32	230.05	Eastern Region	5
N STRATFORD RD	I-90-BL/E BROADWAY AVE	61.40	4.71	289.47	North Central Region	1
GRANT RD	WA-28	52.45	4.73	247.92	North Central Region	2
9TH ST NE	WA-28/SUNSET HWY	51.70	3.93	202.97	North Central Region	3
WA-28	US 2/US 97	33.52	5.10	170.93	North Central Region	4
I-90-BL	N STRATFORD RD	15.79	4.65	73.46	North Central Region	5
I-5	I-705/WA-7/EXIT 133	211.19	6.60	1,393.84	Olympic Region	1
E 27TH ST	I-5/PORTLAND AVE	422.01	3.12	1,315.09	Olympic Region	2
S TACOMA WAY	WA-512	210.48	4.00	842.76	Olympic Region	3
2ND AVE SW	I-5/US 101/DESOTO AVE/DESOTO ST SW	223.01	3.60	802.82	Olympic Region	4
E 28TH ST	I-5/PORTLAND AVE	137.33	5.75	789.65	Olympic Region	5
5TH AVE NE	I-5/NE 44TH ST	345.86	5.13	1,773.92	Northwest Region	1
WEST SEATTLE BRG	DELRIDGE WAY	120.18	7.17	862.12	Northwest Region	2
WEST SEATTLE BRG	WA-99/ALASKAN WAY VIA	173.93	4.76	828.74	Northwest Region	3
I-5 HOV LN	I-5 (SOUTH)	170.73	4.49	766.40	Northwest Region	4
HARVARD AVE E	WA-520/E ROANOKE ST	300.06	4.60	1,380.26	Northwest Region	5

Road Name	Intersection	Total Delay Hours (Per Mile)	TTTR	TTTR-Delay	Region Name	Bottleneck Rank
ATLANTIC ST	WA-503/LEWIS RIVER RD	208.86	11.50	2,401.88	Southwest Region	1
CHKALOV DR	SE MCGILLIVRAY BLVD	169.37	3.28	555.14	Southwest Region	2
NW 78TH ST	I-5	106.72	3.66	390.09	Southwest Region	3
WA-14	WA-140/15TH ST	58.05	4.95	287.35	Southwest Region	4
164TH AVE	WA-14/LEWIS AND CLARK HWY	88.86	2.98	264.69	Southwest Region	5

Source: CPCS analysis of Highway Performance Monitoring System data, 2022.

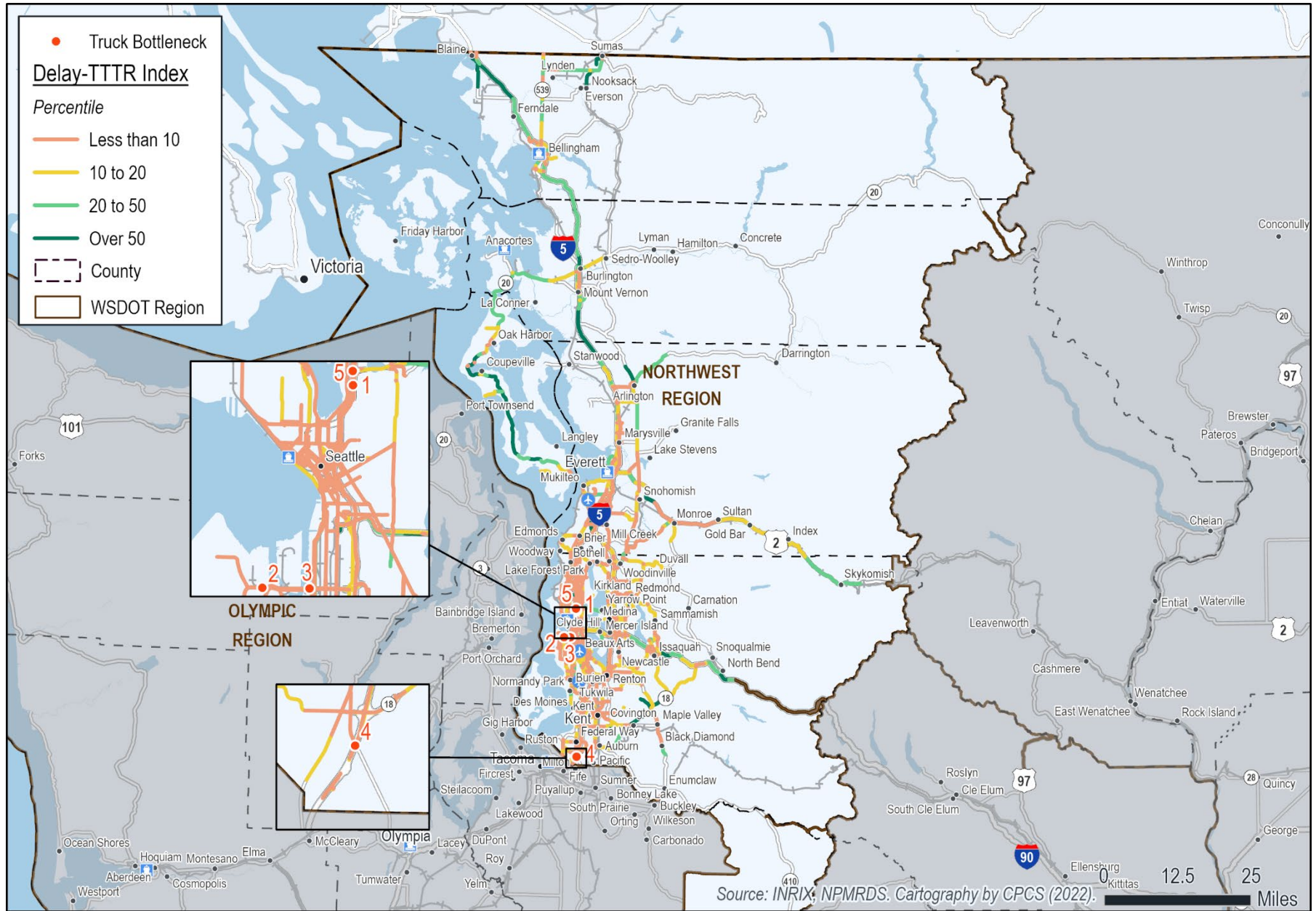**Figure 52: Top five truck bottlenecks in the WSDOT northwest region**

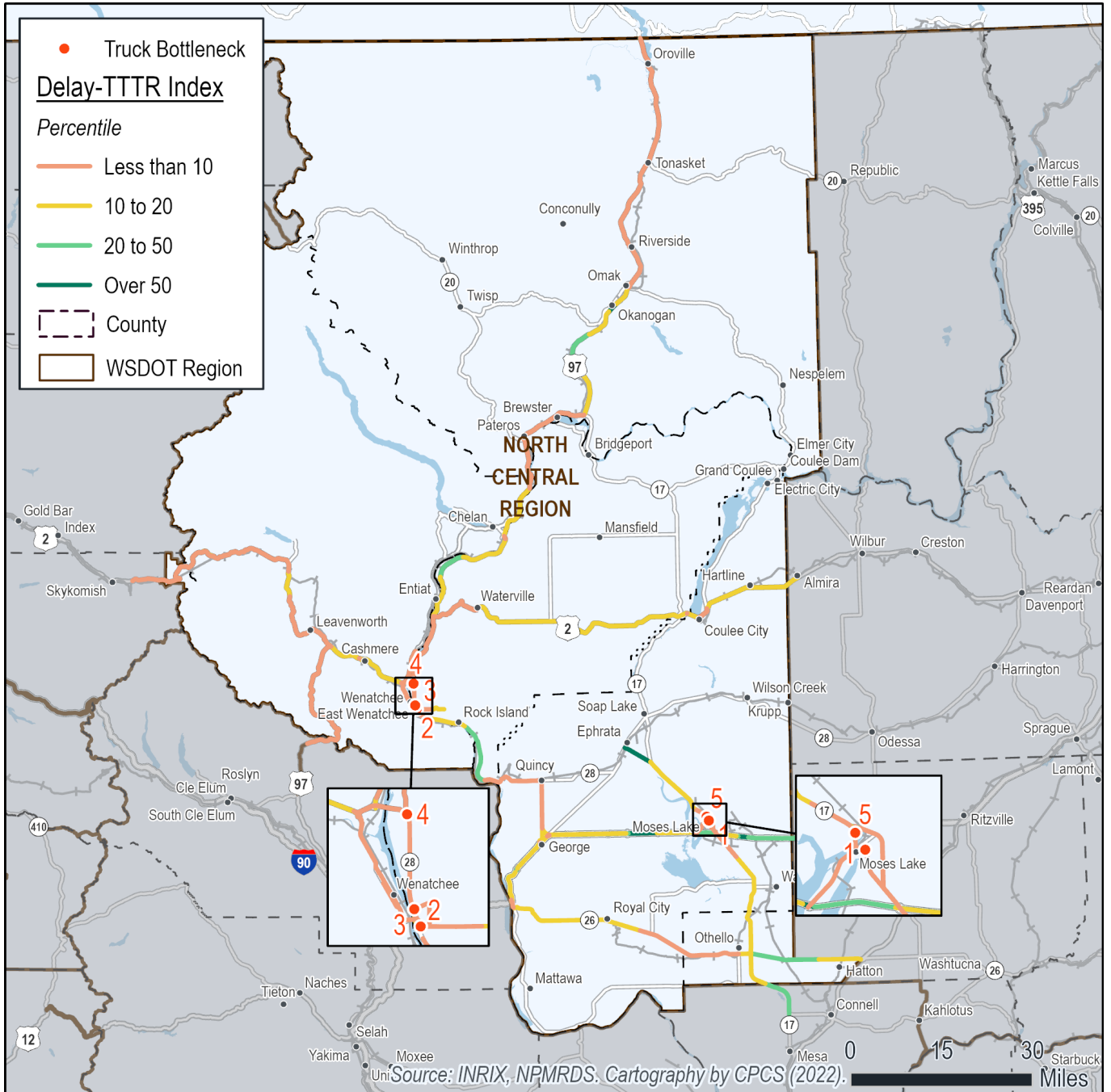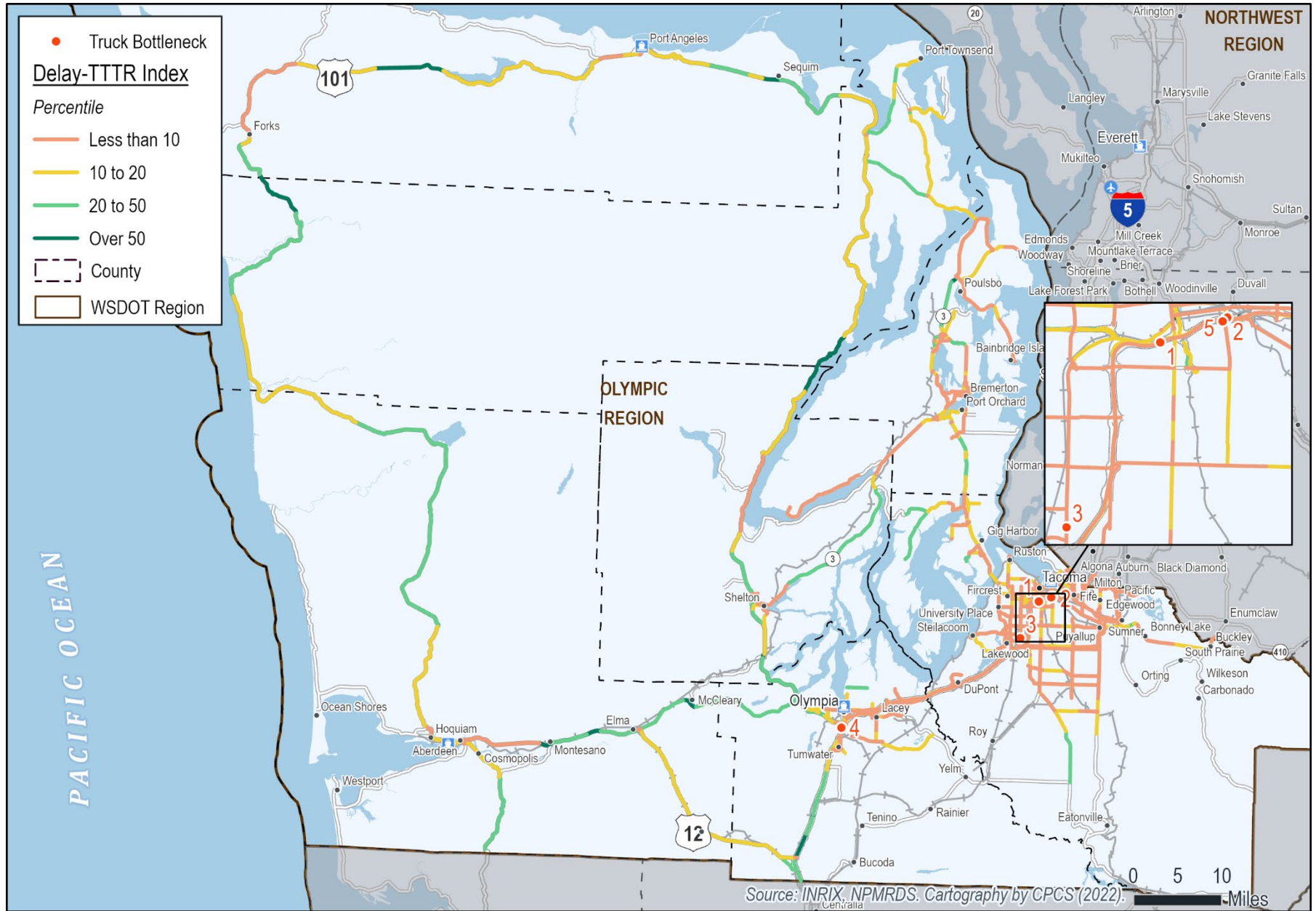**Figure 53: Top five truck bottlenecks in the WSDOT north central region**

Source: INRIX, NPMRDS. Cartography by CPCS (2022).

Figure 54: Top five truck bottlenecks in the WSDOT Olympic region

Source: INRIX, NPMRDS. Cartography by CPCS (2022).

Figure 55: Top five truck bottlenecks in the WSDOT southwest region

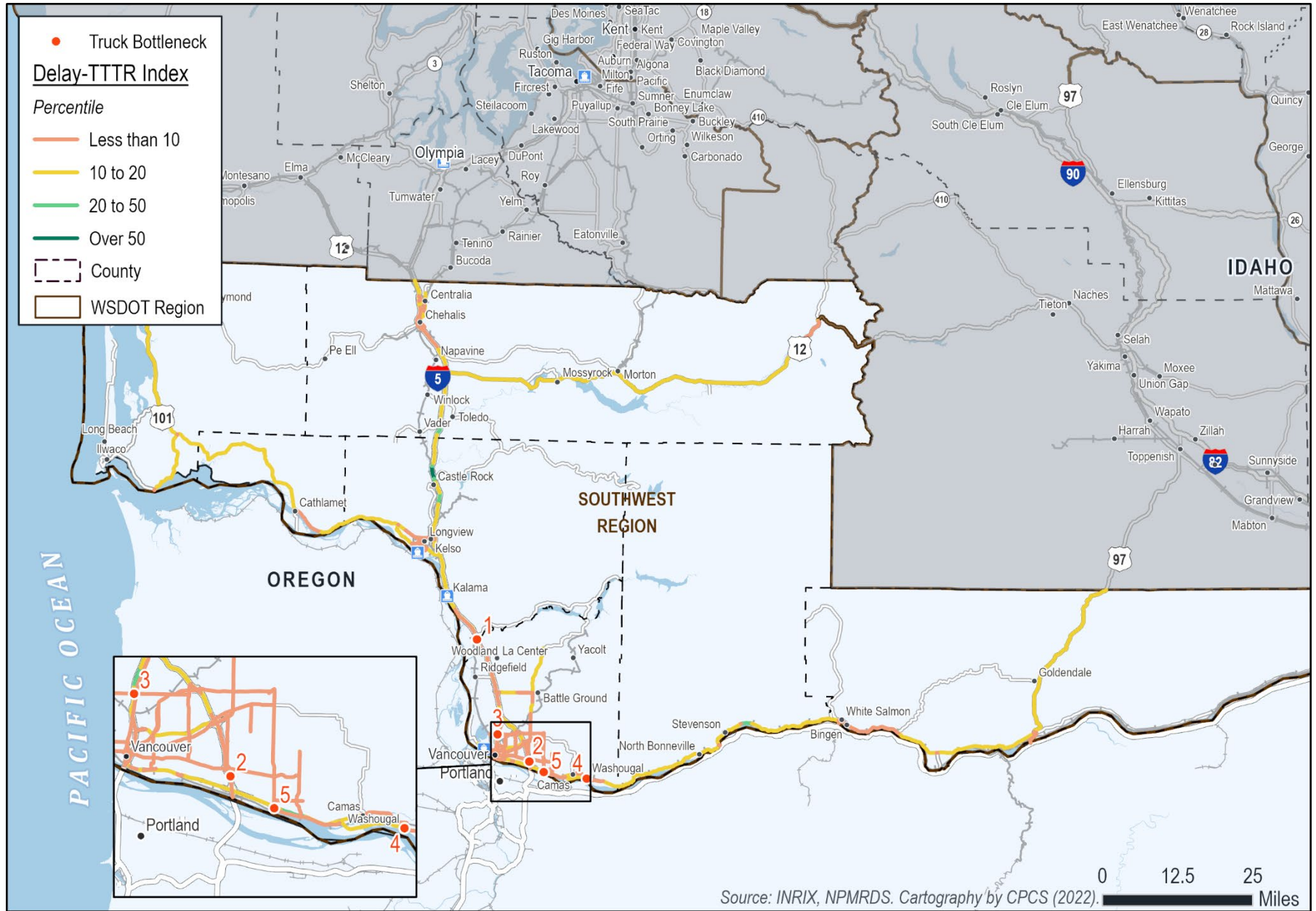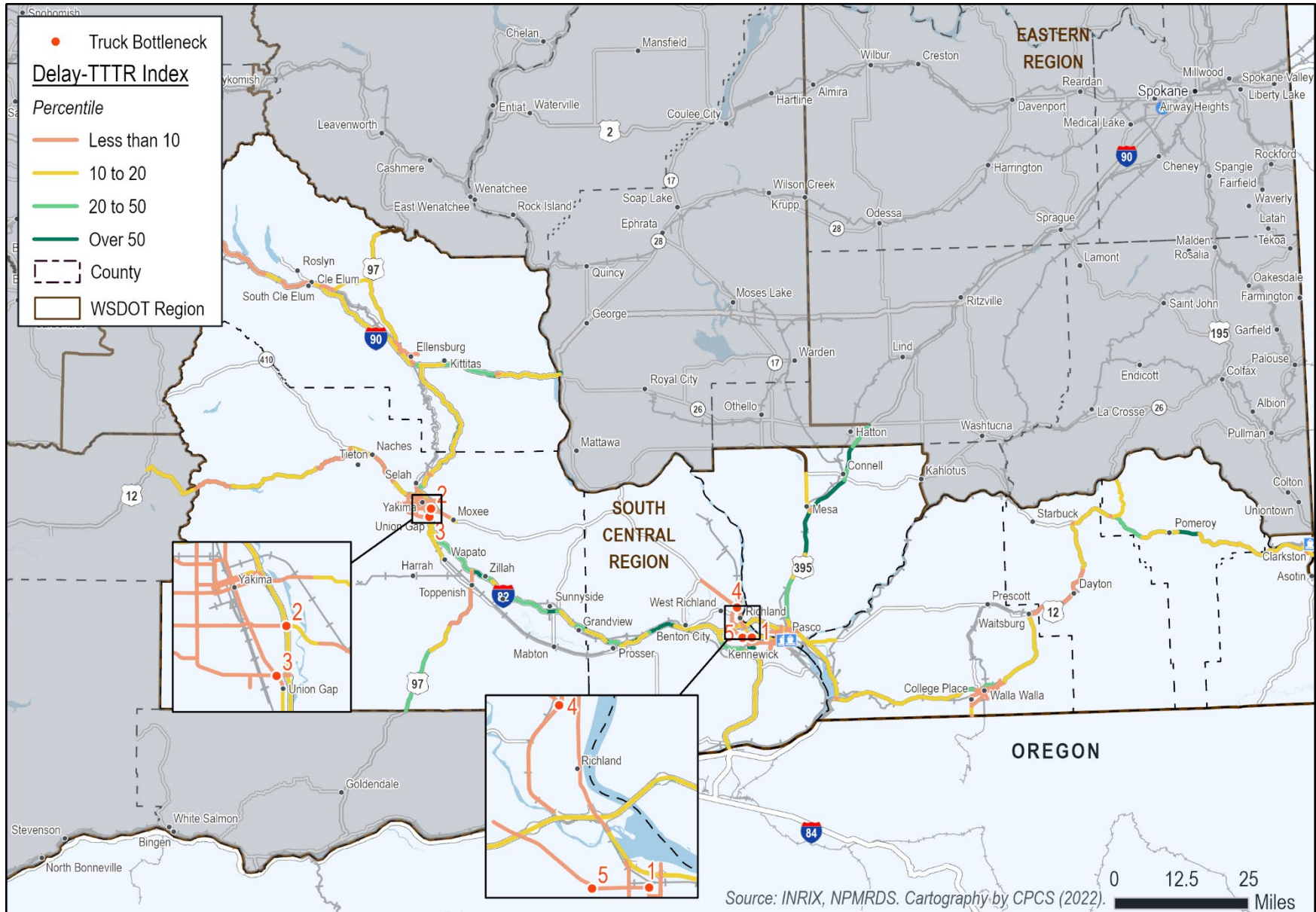*Source: INRIX, NPMRDS. Cartography by CPCS (2022).*

Figure 56: Top five truck bottlenecks in the WSDOT south central region

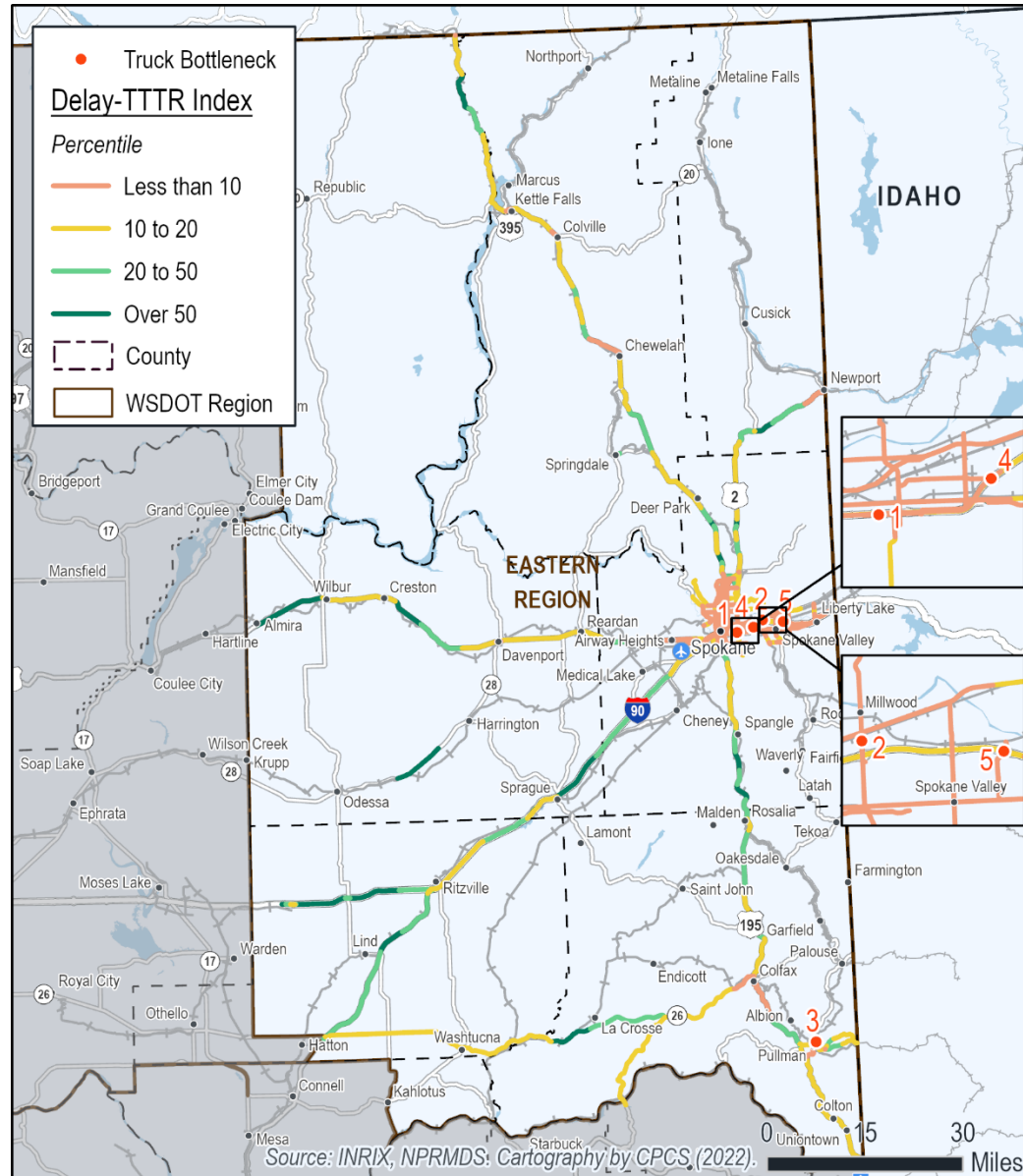**Figure 57: Top five truck bottlenecks in the WSDOT eastern region**

Source: INRIX, NPRMDS. Cartography by CPCS (2022).

Reference Chapter B: Major freight facilities in Washington

The following is a list of major multimodal freight facilities in Washington. These facilities connect truck mode with one or more other modes, including rail, water, and air cargo, and are selected based on the volume of cargo they handle annually.

Figure 58: Major freight facilities In Washington

Facility Name	Facility Type
Sea-Tac International Airport	Air Cargo - over 1,000 annual tonnage
King County International Airport	Air Cargo - over 1,000 annual tonnage
Spokane International Airport	Air Cargo - over 1,000 annual tonnage
Paine Field Airport	Air Cargo - over 1,000 annual tonnage
Yakima Air Terminal	Air Cargo - over 1,000 annual tonnage
Tri-Cities Airport	Air Cargo - over 1,000 annual tonnage
Bellingham International Airport	Air Cargo - over 1,000 annual tonnage
Grant County International Airport	Air Cargo - over 1,000 annual tonnage
Friday Harbor Airport	Air Cargo - over 1,000 annual tonnage
Anacortes	Port Facility
Port Angeles	Port Facility
Bellingham	Port Facility
Bremerton	Port Facility
Everett	Port Facility
Olympia	Port Facility
Seattle	Port Facility
Shelton	Port Facility
Tacoma	Port Facility
Port of Grays Harbor	Port Facility
Vancouver	Port Facility
Kalama	Port Facility
Longview	Port Facility
Cold Connect Facility	Rail Terminal
Ritzville Shuttle Train Loading Facility	Rail Terminal
Quincy Intermodal Terminal	Rail Terminal
Tacoma (South Yard)	Rail Terminal
Tacoma (North Yard)	Rail Terminal
South Seattle Intermodal Facility	Rail Terminal
Seattle International Gateway (SIG) Intermodal facility	Rail Terminal
Spokane (Inland Empire)	Rail Terminal

Source: National Transportation Atlas Database; Washington State Rail Plan 2019; Joint Transportation Committee Air Cargo Study 2018.

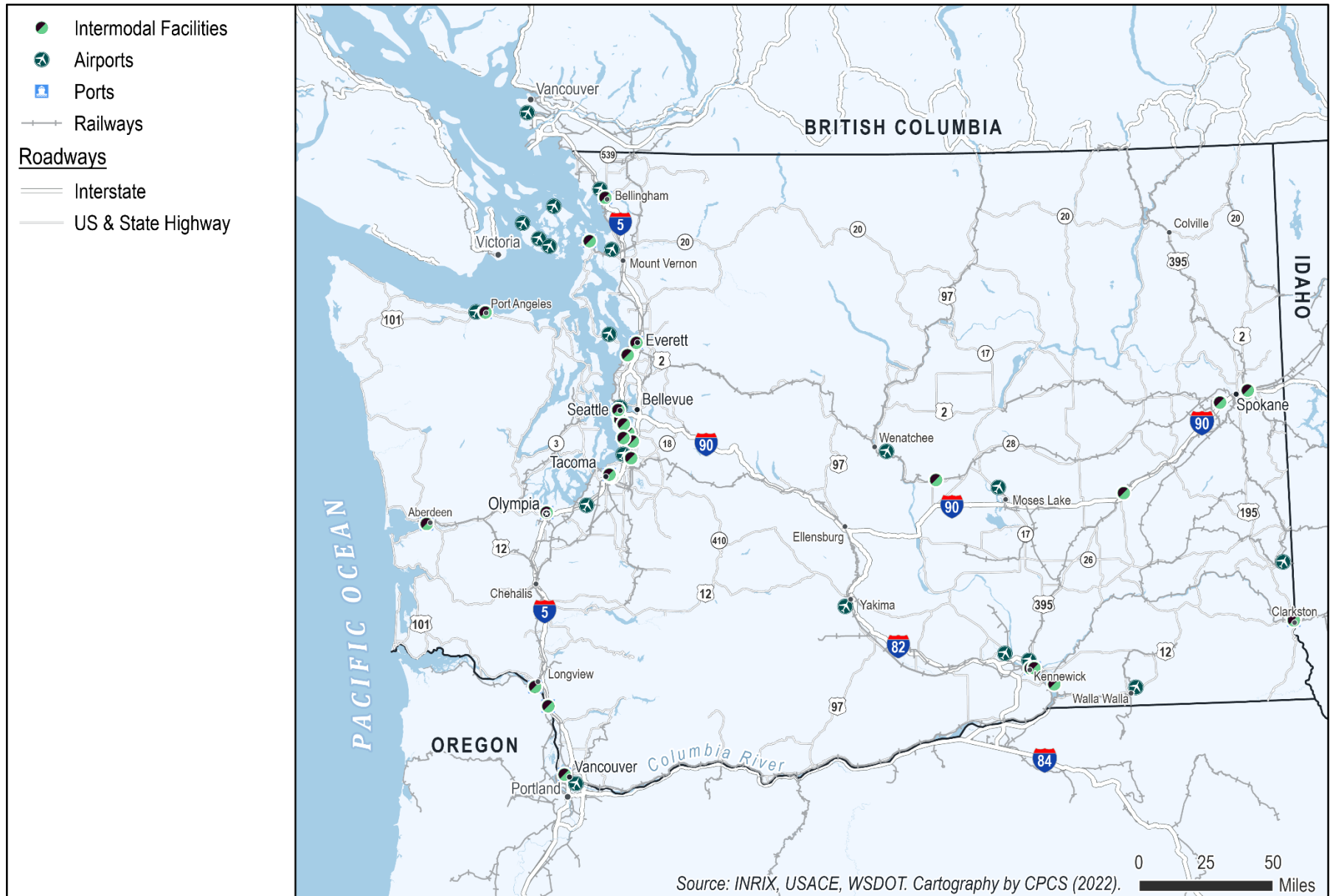**Figure 59: Major freight facilities In Washington**

Figure 60: Non-NHS connector routes analyzed in terms of truck delays