SEATTLE HARBOR
NAVIGATION IMPROVEMENT PROJECT

APPENDIX A

Economics

Draft Integrated Feasibility Report and Environmental Assessment

US Army Corps of Engineers®
Seattle District

Port of Seattle®

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List of Acronyms

Acronym	Definition
AAEQ	Average Annual Equivalent
AAPA	American Association of Port Authorities
ARRA	American Recovery and Reinvestment Act
BLS	Bureau of Labor Statistics
BLT	Bulk Loading Tool
BNSF	Burlington Northern Sante Fe
CAGR	Compound Annual Growth Rate
CDF	Cumulative Distribution Function
CLT	Container Loading Tool
CSPS	Container Shipping Planning Service
DC	Distribution Centers
DWT	Deadweight Tonnes
EGM	Economic Guidance Memorandum
EJ	Environmental Justice
ETTC	Estimated Total Trip Cargo
EW	East Waterway
FCC	Fully Cellular Container
FE	Far East
FUSRAP	Formally Utilized Sites Remedial Action Program
FY	Fiscal Year
GDP	Gross Domestic Product
Gen	Generation
GI	Global Insight
GRP	Gross Regional Product
HMST	HarborSym Modeling Suite of Tools
IANA	Intermodal Association of North America
IDC	Interest During Construction
ILWU	International Longshore and Warehouse Union
ISIC	International Standard Industrial Classification
IWR	Institute for Water Resources
LFA	Load Factor Analysis
LOA	Length Overall
LPP	Locally Preferred Plan
LR	Lloyd's Register
MED	Mediterranean
MLLW	Mean Lower Low Water
MSA	Metropolitan Statistical Area
MSI	Maritime Strategies, Inc.
MXSLLD	Maximum Summer Loadline Draught
NAAQS	National Ambient Air Quality Standards
NAICS	North American Industry Classification System
NAVD	North American Vertical Datum
NED	National Economic Development
NOAA	National Oceanic and Atmospheric Administration
NWSA	Northwest Seaport Alliance
O&M	Operations & Maintenance
OD	Origin-to-Destination

OMRR&R	Operations, Maintenace, Rehabilitation, Repair & Replacement
P&G	Principles & Guidelines
PIANC	Permanent International Association of Navigation Congresses
PNW	Pacific Northwest
PPX	Post-Panamax
PPX Gen I	Post-Panamax Generation I
PPX Gen II	Post-Panamax Generation II
PPX Gen III	Post-Panamax Generation III
PPX Gen IV	Post-Panamax Generation IV
PSP	Puget Sound Pilots
PX	Panamax
RECONS	Regional Economic System
RED	Regional Economic Development
RHA	Rivers and Harbors Act
SPX	Sub-Panamax
T-115	Terminal 115
T-18	Terminal 18
T-30	Terminal 30
T-46	Terminal 46
T-5	Terminal 5
TEU	Twenty-Foot Equivalent Unit
TPI	Tons Per Inch Immersion
TSP	Tentatively Selected Plan
UKC	Underkeel Clearance
UPRR	Union Pacific Railroad
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VOC	Vessel Operating Costs
WCUS	West Coast United States
WRDA	Water Resources Development Act
WTM	World Trade Model
WW	West Waterway
XB	Extreme Breadth

1 Introduction

This document presents the economic evaluations performed for the Seattle Harbor deepening and widening project, also known as the Seattle Harbor. The current federally authorized channel depth of Seattle Harbor is -34 feet mean lower low water (MLLW) feet in the West Waterway and -34-51 MLLW in the East Waterway, with authorized channel widths of 500 feet in both waterways. In September 2014, the U.S. Army Corps of Engineers (USACE) Seattle District was approved by the Office of Management and Budget to begin the multi-year feasibility study to determine if deepening Seattle Harbor is both economically beneficial and environmentally acceptable to the nation. The USACE Seattle District together with the Deep Draft Navigation Planning Center of Expertise performed the economic analyses contained within this document in support of the feasibility study.

1.1 Study Purpose and Scope

The purpose of this study is to evaluate problems and opportunities for improved navigation in Seattle Harbor and identify the plan that best satisfies the environmental, economic, and engineering criteria. The scope of this feasibility study involves analysis of existing conditions and requirements, identifying opportunities for improvement, preparing economic analyses of alternatives, identifying environmental impacts, and analyzing the National Economic Development (NED) plan.

Potential navigation improvements include deepening and widening of navigation channels, including entrance channels. The purpose of these potential improvements is to increase the efficiency of cargo vessel operations on Post-Panamax containerships, which are already calling on the Port of Seattle and are projected to call on the port with increased frequency in the future. This study identifies and evaluates alternatives that will:

- Accommodate recent and anticipated future growth of containerized cargo and containership traffic;
- Improve the efficiency of operations for containerships within the East and West Waterways of Seattle Harbor; and
- Allow larger and more efficient containerships to use the Port.

1.2 Document Layout

Section 2 details the existing conditions at Seattle Harbor. Section 3 examines future without and with project conditions and includes an evaluation and description of forecast trade, terminal upgrades, and the vessel fleet and operations at the harbor. Section 4 presents the transportation cost savings benefit analysis. In Section 5, sensitivities to the forecast are explored. Section 6 examines the multiport analysis while Section 7 describes the socioeconomics of Seattle and the surrounding region.

2 Existing Conditions

The existing conditions are defined in this report as the project conditions that exist today (2014) plus any changes that are expected to occur prior to project year one, anticipated in 2024, which is referred to as the base year for comparison of alternatives to the without project condition and among proposed alternatives. It is the year the project is expected to be operational and accrue benefits.

2.1 Economic Study Area (Hinterland) and Regional Distribution Centers

The federally authorized Seattle Harbor navigation project, consisting of the East, West, and Duwamish Waterways, is located in Puget Sound's Elliott Bay at Seattle, Washington (Figure 2-1). The authorized project is located from Elliott Bay upstream approximately five miles to the head of the Federal navigation channel which lies in the lower Duwamish River. The authorized project consists of the East Waterway, -34 to -51 MLLW; the West Waterway, -34 feet MLLW; the Duwamish Waterway, -30 feet MLLW for 2.6 miles, -20 feet MLLW for 0.8 miles, and -15 feet MLLW for 1.8 miles to the head of navigation. These three waterways provide over 7 miles of deep draft navigation accessible from Elliott Bay, Puget Sound, and the Pacific Ocean. While the study area includes the East, West, and Duwamish Waterways, the project area for the Reconnaissance and Feasibility phases will include only the East and West Waterways, as they have been identified by the Corps and Port of Seattle as the areas of critical importance for navigation improvements. Multiple ports, including West Coast Canadian ports, are competing for the same hinterland. More information on the study area can be found in Section 1.4, Location and Description of the Study Area, of the main feasibility report.

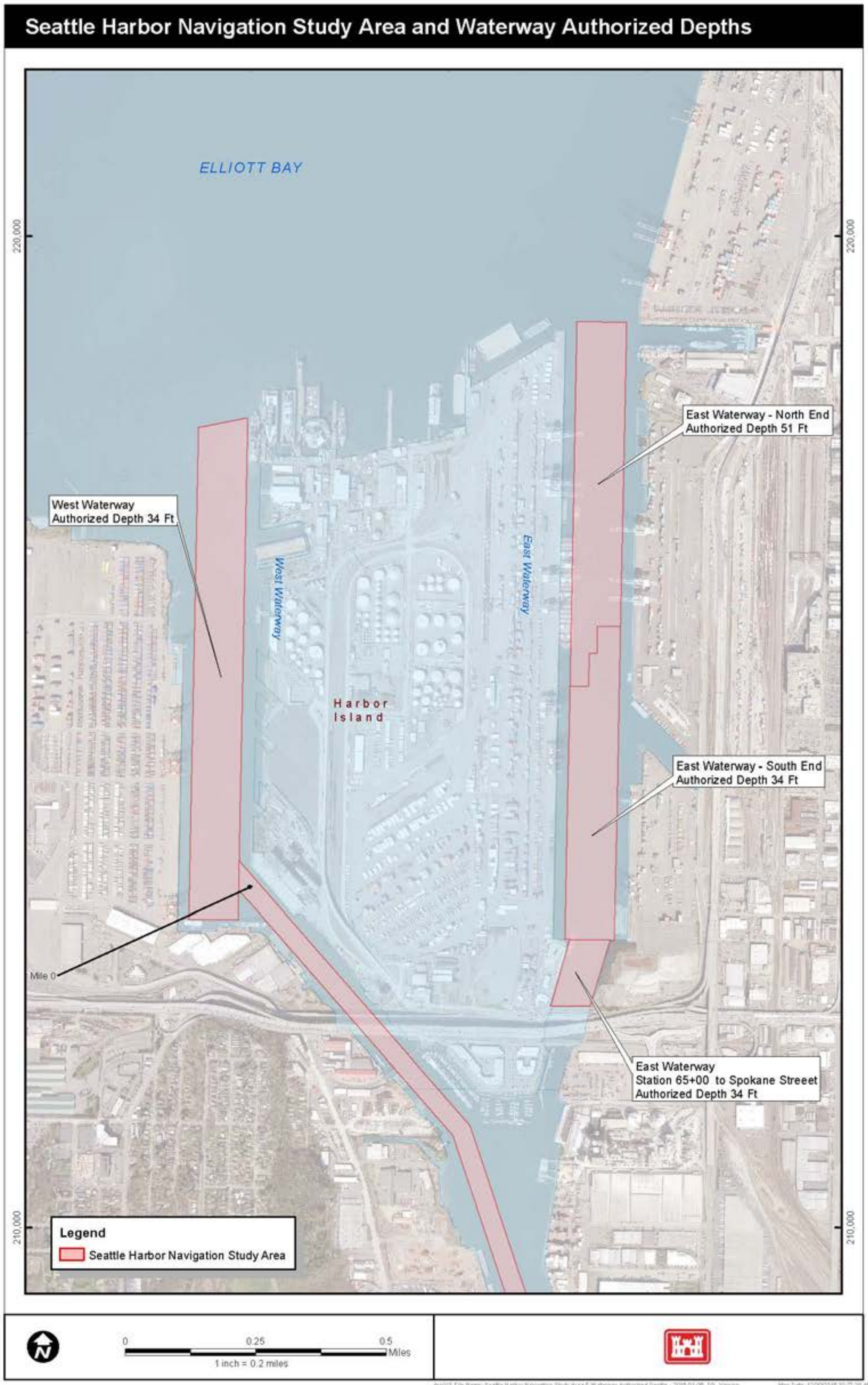

Figure 2-1. Federally Authorized Navigation Channel (East and West Waterways)

The authorized purpose of the Seattle Harbor is navigation. A number of legislative authorities apply to the existing project including the East Waterway and West Waterways, as summarized in Table 2-1 below. However, this table contains only authorizing language relating to the East and West Waterways, as they are the focus of this feasibility analysis. There are several other authorizations that relate solely to the Duwamish Waterway and are not included in this table.

Table 2-1. East and West Waterway Authorizing Language

Document	Date	Citation	Authorizing Language
Senate Doc 313	15 Dec 1918	S.D. 313, 65th Cong. 3d Sess.	…the United States take over and assume the maintenance of these portions of the East and West Waterways for distances of 6,500 feet and 5,200 feet, respectively, from the pierhead line at Elliott Bay …maintaining the East and West Waterways to a depth of 34 feet
River and Harbor Act (RHA) 1919	2 Mar 1919	40 Stat. 1285	Construction, completion, repair, and preservation of the works hereinafter named: …maintenance of East and West Waterways, Seattle Harbor, in accordance with the report in Senate Document numbered 313, Sixty-fifth Congress, third session, and subject to the conditions set forth in said document
House Doc 211 Examination and Survey of East Waterway, Seattle, Washington	6 Jan 1932	H.D. 211, 72nd Cong. 1st Sess.	…in addition to the work now authorized, for the maintenance of East Waterway north of Spokane Street, 700 feet long and 400 feet wide, to a depth of 34 feet
RHA 1935	30 Aug 1935	74 Pub. L. 409	That the following works of improvement of rivers, harbors, and other waterways are hereby adopted and authorized, to be prosecuted under the direction of the Secretary of War and supervision of the Chief of Engineers, in accordance with the plans recommended in the respective reports hereinafter designated and subject to the conditions set forth in such documents; Seattle Harbor, Washington; House Document Numbered 211, Seventy-second Congress
WRDA 1986	17 Nov 1986	99 Pub. L. 662	Sec. 202 GENERAL CARGO AND SHALLOW HARBOR PROJECTS (a) AUTHORIZATION FOR CONSTRUCTION. - The following projects for harbors are authorized to be prosecuted by the Secretary substantially in accordance with the plans and subject to the conditions recommended in the respective reports designated in this subsection, except as otherwise provided in this subsection: EAST, WEST, AND DUWAMISH WATERWAYS, WASHINGTON The project for navigation, East, West, and Duwamish Waterways Navigation Improvement Study, Seattle Harbor, Washington: Report of the Chief of Engineers, dated May 31 1985, at a total cost of $60,200,000 Sec. 1001 (a) Any project authorized for construction by this Act shall not be authorized after the last day of the 5-year period beginning on the date of enactment of this Act unless during such period funds have been obligated for

Document	Date	Citation	Authorizing Language
			construction, including planning and designing, of such project. Sec. 1002 The following projects … are not authorized after the date of enactment of this Act, except with respect to any portion of such a project which portion has been completed before such date or is under construction on such date: The feature of the project for navigation, Seattle Harbor, King County, Washington, authorized by the Act of July 3, 1930, Public Law 520, Seventy-first Congress, which feature consists of a settling basin located at the upper end of the existing Duwamish Waterway navigation project about 1.4 miles above the 14th Avenue South Bridge.
WRDA 1996	12 Oct 1996	104 Pub. L. 303	Sec. 356 EAST WATERWAY, WASHINGTON The project for navigation, East and West Waterways, Seattle Harbor, Washington, authorized by the 1st section of the Act entitled "An Act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes", approved March 2, 1919 (40 Stat. 1285), is modified to direct the Secretary- To expedite review of potential deepening of the channel in the East Waterway from Elliott Bay to Terminal 25 to a depth of up to 51 feet; and If determined to be feasible, to implement such deepening as part of project maintenance. In carrying out work authorized by this section, the Secretary shall coordinate with the Port of Seattle regarding use of Slip 27 as a dredged material disposal area.

Below is a summary of current authorized boundaries for each waterway:

West Waterway: from the pierhead line at Elliott Bay, 5,200 feet long, effective width of 500 feet wide, and depth of -34 MLLW. Note: Existing depths in this waterway range from 50 to 60 feet due to historical overdredge of the waterway.

East Waterway: from the pierhead line at Elliott bay, 6,500 feet long, effective width of 500 wide; from that point an additional 700 feet long and effective width of 500 feet wide and terminating at Spokane Street. In the area defined as "Stage I" in the East Waterway Channel Deepening Stage I Project Report, the authorized depth is -51 MLLW. In all other areas of the East Waterway, the authorized depth is -34 MLLW. Note: Existing depths in this waterway range from 34 to 53 feet.

2.1.1 Hinterland

The Port of Seattle is a natural gateway to move import cargo, primarily Transpacific cargo from Asia, to the large population centers in the Midwest and Northeast as shown in Figure 2-2. Seattle is directly served by BNSF Railway and Union Pacific Railroad. Corridor investments such as double tracking, new track, facility expansion, and equipment upgrades have been made to increase the velocity between the gateway and key markets. Nearly 70 percent of international intermodal containers that move through the Puget Sound market are destined for the Midwest and Northeast, with 30 percent of the cargo remaining in the Pacific Northwest (PNW, which includes Washington and Oregon) area. Figure 2-3 shows intact intermodal container traffic between major US regions and the PNW.

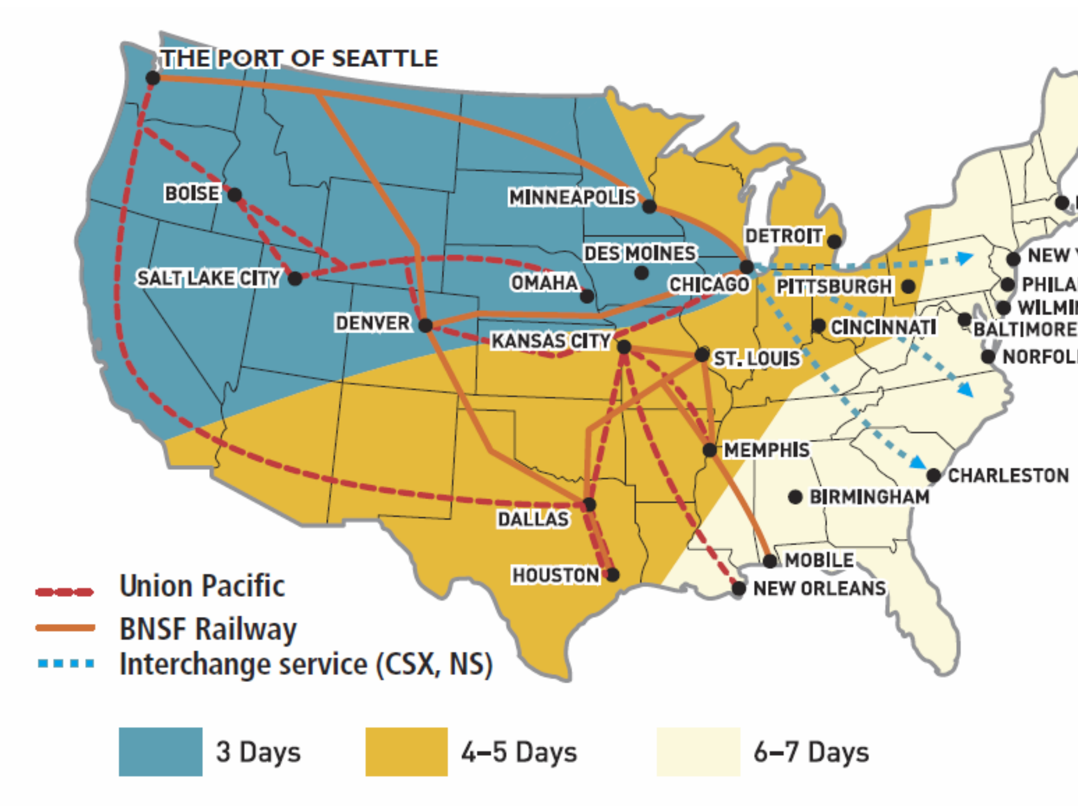

Figure 2-2. Port of Seattle Hinterland

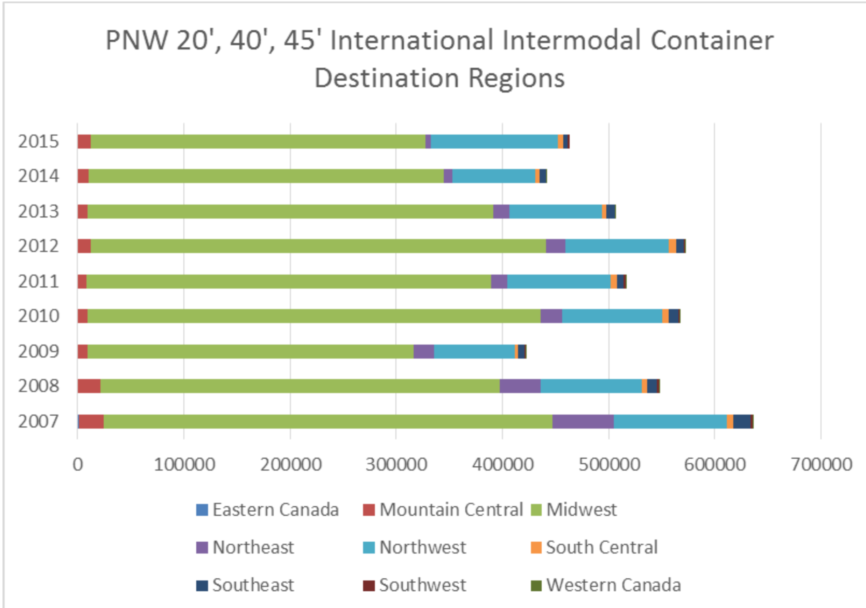

Figure 2-3. Pacific Northwest International Intermodal Container Destinations
Source: Intermodal Association of North America data

Import intermodal activity is also reflected in a growing eastbound transload business in the Puget Sound Area. Transloading is the transfer of cargo from smaller international shipping containers (twenty-foot equivalent units or 20-foot containers, 40-foot containers, 45-foot containers) into larger 53-foot containers or trailers near the Port. This allows more efficient and economical movement of cargo inland since fewer containers must be transported, and it offers importers the shipper the flexibility to deconsolidate cargo near the port and distribute to multiple destinations throughout the country. The growth of transloaded cargo is illustrated in Figure 2-4, showing a 69 percent increase from 2007 compared to 2015.

A recent study identified 55 commercial facilities within 35 miles of the Port of Seattle that offer transloading services. All of the major retailers have a transload operations in the PNW to serve distribution centers across the US. The Kent/Auburn Valley is the fourth-largest warehouse and distribution center in the U.S. and the second largest manufacturing center on the West Coast.

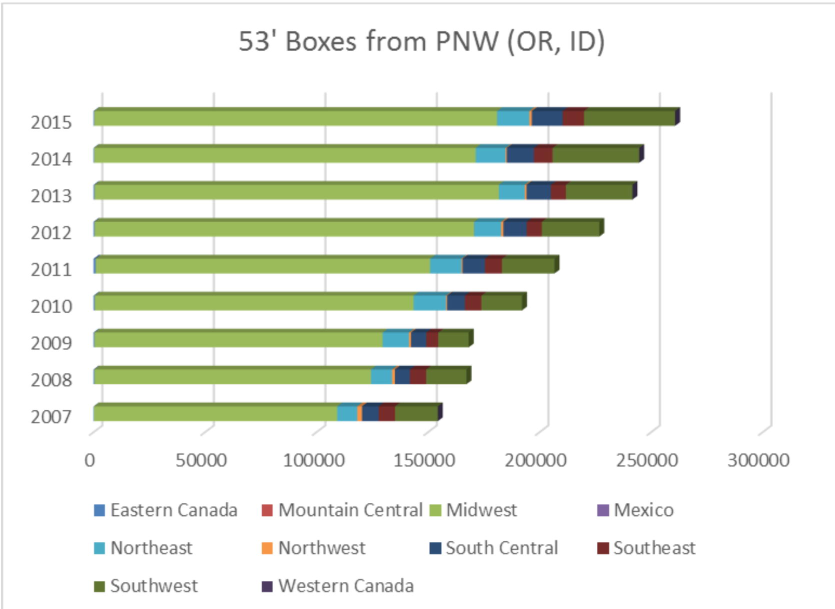

Figure 2-4. Rail Moves of -53 MLLW Containers from PNW to Inland Regions

Source: Intermodal Association of North America (IANA)

The Port of Seattle is also a critical transportation link for export of containerized agricultural products from the Pacific Northwest and the U.S. heartland. Nearly $20.7 billion of food and agricultural products were exported from the Pacific Northwest states of Oregon, Idaho and Washington in 2014, over 70% of which originated in the State of Washington – the third largest exporter of food and agriculture commodities in the nation. The Port of Seattle's strategic location, in close geographic proximity to Washington's agricultural heartland via Interstate 90, and on the Pacific Rim, make it a natural gateway for agricultural exports from the region destined for Asian export markets. Additionally, export commodities (mostly Washington agricultural products including apples) typically weigh substantially more than imports and are more expensive to transport longer distances due to additional fuel costs, making them less competitive in the international market the further they are shipped from the point of origin. Seattle also sees a large volume of heavy forest products. The heavy weight of export commodities loaded in Seattle means that ships can depart very close to full draft. Export and import commodities are discussed in greater detail in Section 2.1.4, Cargo Profile.

The discontinuation of major international container service at the Port of Portland in the spring of 2015 has further increased demand for shipping services at the Port of Seattle, as Oregon exports have sought alternative gateways to get their product to market. Geographically, Puget Sound ports are the shortest distance from where the majority of Oregon exports are produced. Exporters in Oregon also have access to multiple modes of transportation for delivery to Puget Sound ports – over the road transportation via Interstate 5 or by rail via regularly scheduled port-to-port service from Portland to Seattle.

The Port of Seattle and Northwest Seaport Alliance (see Section 2.8) continue to invest in local port infrastructure, including railways ($4.3 billion for regional rail and Class 1 corridor investments to increase velocity between Seattle/Tacoma and the Midwest via BNSF and Union Pacific railways), roads ($9.2 billion locally), and dockside and harbor improvements ($800 million, including Terminal 5 Modernization improvements described in Section 3.1).[1] In the past decade, the Port has invested $62 million in various regional transportation infrastructure projects with other jurisdictions which total $795 million.

2.1.2 Distribution Centers Development

Transload warehouse and distribution centers (DCs) are an integral component of the international supply chain. The concentration, capabilities and location of warehouse and distribution centers in relation to a port can influence importers', exporters', and container shipping lines' cargo routing and port selection decisions.

Warehouse and distribution centers not only provide storage for goods received from and/or delivered to the Port, but also add much needed flexibility for importers using what is commonly referred to as a "four-corner" national distribution strategy. The four-corner approach has become widely accepted as a means of diversifying or mitigating supply chain risk from labor disruptions, natural disasters and other events that could impact the integrity of the supply chain at a single gateway. Using this model, a major port in each quadrant of the country (Pacific Northwest, Pacific Southwest, Northeast, Southeast) serves as the primary import gateway for the region. Upon arrival, goods are transported from the terminal to nearby warehouses or distribution centers, where they are stored or consolidated, cross-docked, or transloaded (removing contents of international marine containers and repackaged in 53-foot domestic containers) for delivery to local or regional DCs or directly to retail stores. Additionally, these facilities provide value-added services such as labeling, re-packaging, order pick-and-pack fulfillment and computerized inventory control to supplement the regular or just-in time delivery needs of the importer.

Transload facilities are important for exporters as well. Commodities such as soybeans, wheat, meat and poultry are shipped in railcars to facilities near the port, where they are deconsolidated into marine shipping containers for export. This allows for more efficient inland transportation and flexibility for exporters.

For Seattle, the warehousing and distribution cluster is well-positioned to support the growing needs of shippers using Seattle Harbor. A number of transloaders operate adjacent to the Port of Seattle. Additionally, the Kent/Puyallup Valley (extending from Renton in King County to Puyallup in Pierce County along State Route 167), is home to the second largest concentration of warehousing and distribution on the West Coast. Currently, there is over 260 million square feet of active industrial space is available in the area, much of it designated for warehousing and distribution activities, with an additional 3.2 million square feet currently under-construction or about to become available. These distribution center complexes are easily accessible via Interstates 5 and 90, two main interstate arteries serving the Port. All of the country's major retailers have a transload and distribution operation in the PNW.

[1] Source: Northwest Seaport Alliance Infrastructure Investment Highlights, 2015.

2.1.3 Maritime Businesses

A database of major port users and port service providers was obtained from the Port. The role that these companies play in the supply chain varies - from trucking companies that physically transport goods from the factory or facility to and from the port, to integrated logistics service providers that can manage all aspects of the transportation from origin to final destination. These firms are engaged in providing services such as freight forwarding, shipping agent services and customs house brokering. There are hundreds of transportation and logistics companies that facilitate trade at the Port of Seattle. These businesses include the Port itself; steamship lines; stevedores and longshoreman; truck lines; Class I and shortline railroads; intermodal marketing companies, tug companies; customs house brokers and freight forwarders; docking and harbor pilots; marine survey and fumigation; and hundreds of other firms.

2.1.4 Cargo Profile

In 2014, the East and West Waterway Terminals at the Port of Seattle received 755 vessel calls. These facilities handled 1 million TEUs weighing a total of 9.5 million metric tons, down 18 percent from 2013. Non-containerized tonnage totaled over 1 million metric tons, up 24 percent from 2013. It should be noted that tonnage declined in 2014 and 2015 due in part to a West Coast port slowdown described later in this section. Although tonnage did not increase in 2015 over 2014, overall TEUs did increase. Since 2007, the Port of Seattle has been a net exporter of containerized goods, with net exports averaging over 1 million metric tons. Table 2-2 gives international containerized import and export metric tons by year. Note that all tonnage presented in this appendix is reported in metric tons.

Table 2-2. International Containerized Commodity Tonnage (Metric Tons), 2005-2015[2]

Year	Imports	Exports	Total Metric Tonnage
2005	5,509,229	5,648,347	11,157,575
2006	5,178,706	5,142,885	10,321,591
2007	5,199,088	5,995,362	11,194,451
2008	4,167,711	5,164,947	9,332,658
2009	3,916,095	5,428,958	9,345,053
2010	5,962,703	6,530,781	12,493,484
2011	5,298,850	7,182,822	12,481,672
2012	5,128,422	6,214,577	11,342,999
2013	3,849,557	5,517,610	9,367,167
2014	3,229,130	4,566,536	7,795,666
2015	4,347,077	4,998,129	9,345,206

Containerized Imports are primarily furniture and fixtures (420 thousand metric tons), parts of motor vehicles (331 thousand metric tons), iron and steel (146 thousand metric tons), non-metallic products (144 thousand metric tons), and machinery and equipment (143 thousand metric tons). The above

[2] PIERS data for years 2005-2014. Obtained from Port of Seattle and IHS Commodity Forecast (2015). Marine Transportation Information System (MTIS) data obtained from Port of Seattle for 2015 data only, 26 April 2016.

imports are all expected to see absolute growth over the study period following strengthening construction and consumer demand.

Seattle's market share of West Coast containerized imports is largely the result of rail delays during harsh winter conditions in 2013/2014, increased cargo traffic at neighboring ports in Canada, and labor disputes associated with the International Longshore and Warehouse Union (ILWU) contract negotiations in 2014. The effects of these short-term factors are expected to lessen, leading to absolute growth beginning 2015-2016. Preliminary numbers collected by the Port in 2015 support positive growth in 2015 over 2014, both for the Port of Seattle and the Northwest Seaport Alliance between the Ports of Seattle and Tacoma. Figure 2-5 shows Seattle's historic market share of imports (IHS 2015).

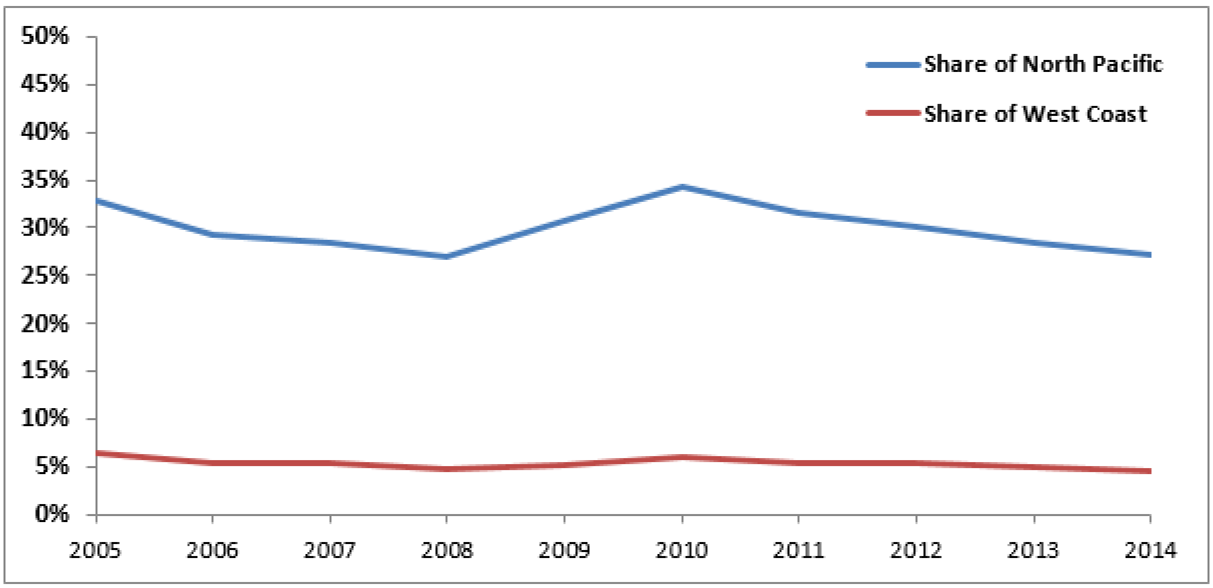

Figure 2-5. Port of Seattle shares of North Pacific and U.S. West Coast import tonnage, 2005-2014
Source: IHS Commodity Forecasts for the Port of Seattle, 2015

As is discussed later in this report, Seattle will continue to be a natural gateway for East Asian imports from China, South Korea, and Japan. Figure 2-6 displays historic import TEUs from 2005 to 2014.

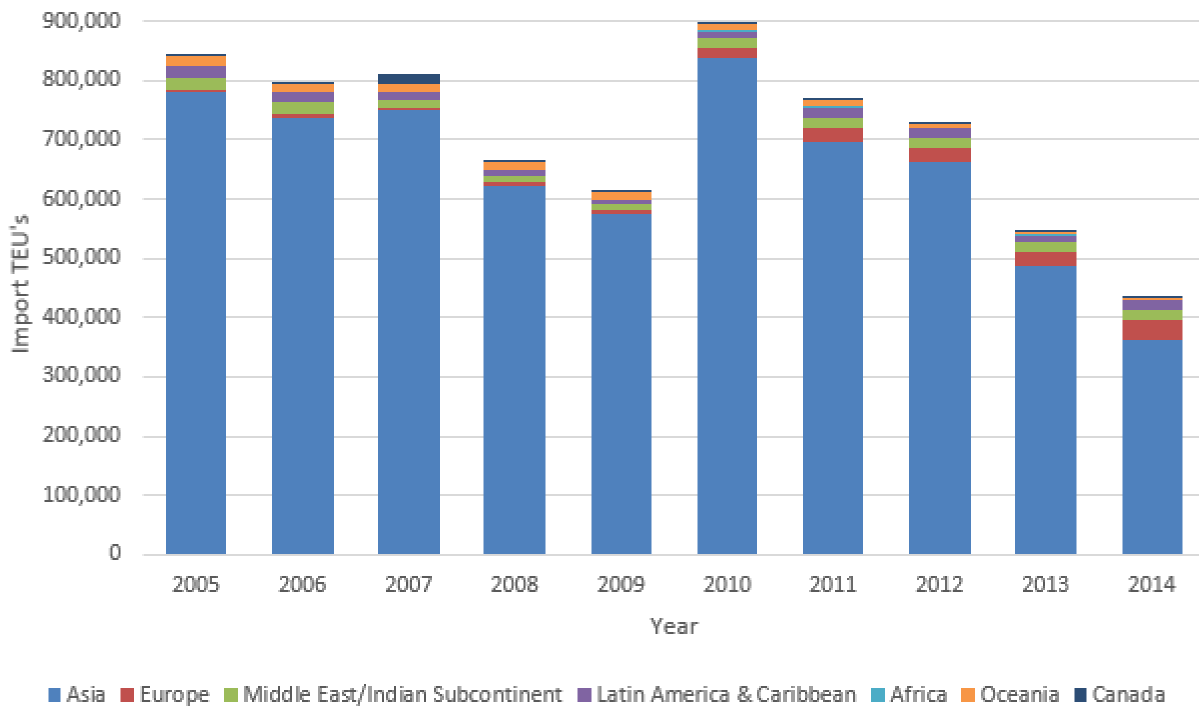

Figure 2-6. Port of Seattle Historic Import TEUs, Loaded, 2005-2014
Source: IHS Commodity Forecasts for the Port of Seattle, 2015

Containerized exports primarily consist of animal feed (1,320 thousand tons), fruits and vegetables (704 thousand tons), and paper products (556 thousand tons). Seattle exports are generally considered more volatile, evidenced by the declines in total tonnage in 2013 and 2014. The increasing average ship size is also shifting growth to ports like Los Angeles/Long Beach, Vancouver, and Prince Rupert. Seattle is not expected to regain previous highs of 50.9 percent and 12 percent market share of containerized exports from the West Coast and Pacific Northwest, respectively. Leading container export destinations include China, Japan, South Korea, India, Hong Kong, and Indonesia. Figure 2-7 shows Seattle's historic market share of imports (IHS 2015).

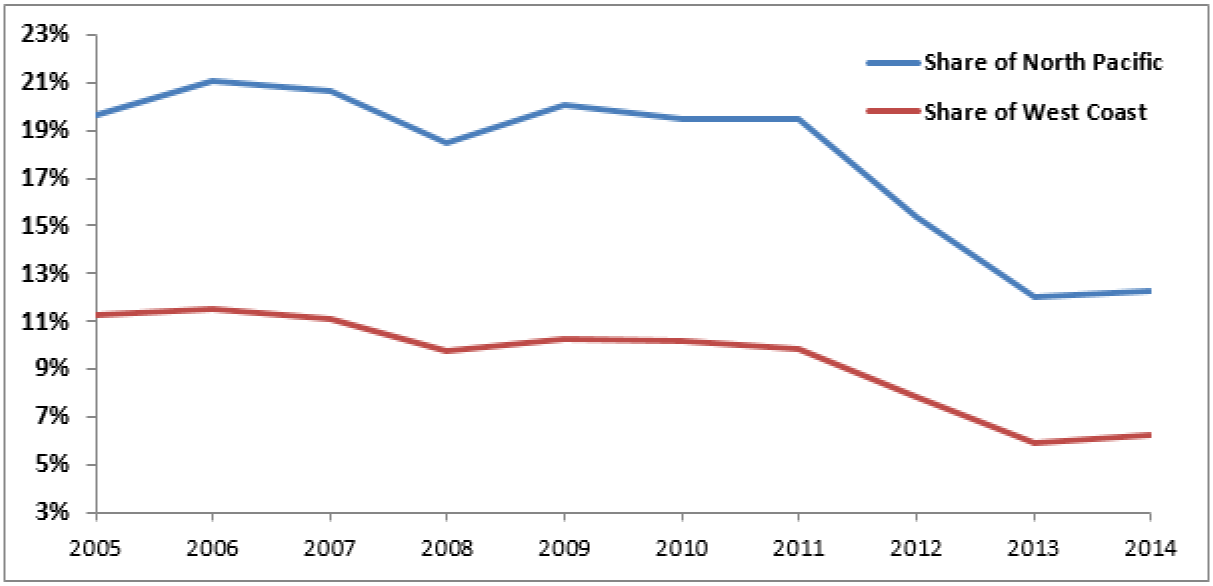

Figure 2-7. Port of Seattle shares of North Pacific and U.S. West Coast export tonnage, 2005-2014
Source: IHS Commodity Forecasts for the Port of Seattle, 2015

Figure 2-8 displays historic export TEUs from 2005 to 2014.

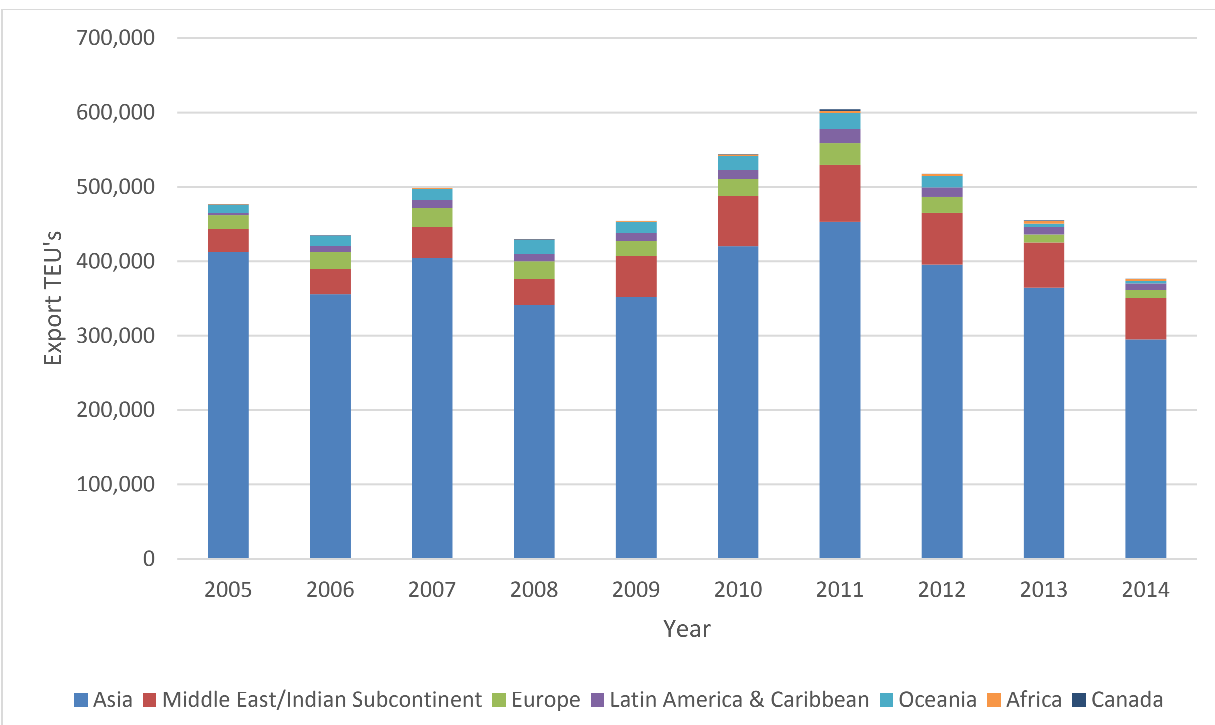

Figure 2-8. Port of Seattle Historic Export TEUs, Loaded, 2005-2014
Source: IHS Commodity Forecasts for the Port of Seattle, 2015

2.1.5 Cargo Value

As shown in Table 2-3, Port of Seattle ranks as the 24th largest U.S. port in terms of total tonnage, and 13th in terms of cargo value. Cargo value is expected to grow for both imports and exports over the study period. Imports are expected to grow from $15.4 billion in 2015 to $30.7 billion in 2030. Exports are expected to grow from $6.9 billion in 2015 to $14.8 billion in 2030 based on IHS commodity forecasts developed for this study.

Table 2-3. Port of Seattle Ranking by Foreign Trade Volume and Value, 2013

Total Trade		U.S. Exports		U.S. Imports	
Rank	Total Trade	Rank	Total Exports	Rank	Total Imports
24	14,914,000 metric tons	21	7,941,000 metric tons	27	6,973,000 metric tons
13	$28,541,000,000	19	$7,374,000,000	14	$21,167,000,000

Source: American Association of Port Authorities (AAPA), U.S. Foreign Waterborne Trade Calendar Year 2013, accessed online 17 Sep 2015

2.2 Facilities and Infrastructure

The Port of Seattle's seaport is one of the most diverse in the United States. It is home to a wide range of maritime activities that brings trade to the region. The Seaport is made up of 1,543 acres of waterfront land and nearby properties including container terminals, general purpose/cargo terminals, break-bulk cargo and refrigerated cargo and storage. There are four container terminals in the Port of Seattle, as well as a number of other facilities. The Port of Seattle's four container terminals, shown in Figure 2-9 are:

- Terminal 5 (T-5)
- Terminal 18 (T-18)
- Terminal 30 (T-30)
- Terminal 46 (T-46)

Figure 2-9. Seattle Harbor Map[3]

2.2.1 West Waterway – Terminal 5

Terminal 5 is a container terminal located along the West Waterway at the mouth of the Duwamish River. The terminal size is 197 acres. Currently, acreage is leased on an interim basis while modernization of this terminal to accommodate ultra-large containerships is underway. This terminal includes two berths with an overall length of 2,900 feet. Berths currently vary in depth from -45 to -50 feet MLLW, and will be deepening to -56 feet MLLW as part of the modernization. Cranes are being sold or surplused as of October 2015 and are no longer operational. Refer to Section 3.1 on modernization of Terminal 5 to accommodate ultra large containerships. This terminal has an on-dock intermodal yard with loading capacity of 54 five-platform doublestack railcars equivalent to two full trains. There is an adjacent storage facility for an equivalent capacity. The intermodal yard is 30 acres with six loading tracks and six storage tracks. Full trains can be assembled within the terminal and are allowed direct access to two Class I railroads. Additionally, this terminal has refrigerated capacity with 600 reefer plugs.

2.2.2 East Waterway – Terminal 18

Terminal 18 is a multipurpose terminal located along the west side of East Waterway on Harbor Island. The terminal size is 196 acres (79 hectares). This terminal includes four berths with an overall length of 4,400 feet, one used for breakbulk and three used for containerships. Berths currently vary in depth from -40 feet MLLW for breakbulk berths to -50 feet MLLW for containerships at the north end of the terminal. Currently there are plans to deepen container berths to accommodate ultra large containerships in the near future. This terminal includes ten cranes, seven of which are located furthest north and can accommodate ultra large containerships with an outreach 23 to 24 boxes wide (203 to 210 feet). Refer to Section 3.1 on future improvements to Terminal 18 to accommodate ultra large containerships. This terminal has an on-dock intermodal yard with loading capacity of 54 five-platform doublestack railcars equivalent to two full trains for both Union Pacific and Burlington Northern-Sante Fe railroads. There is an adjacent storage facility for an equivalent capacity. Additionally, this terminal has refrigerated capacity with 1,227 reefer plugs.

2.2.3 East Waterway – Terminal 30

Terminal 30 is a container terminal located along the east side of the East Waterway. The terminal size is 70 acres (28.3 hectares). This terminal includes two non-continuguous berths with an overall length of 2,700 feet. Berths are currently -50 feet MLLW. This terminal includes six cranes, three of which are can accommodate ultra large containerships with an outreach 23 boxes wide (203 feet). This terminal has near-dock yards with access to Union Pacific and Burlington Northern Sante Fe railroads within two miles of the terminal. Additionally, this terminal has refrigerated capacity with 451 reefer plugs.

2.2.4 Other Container Terminals

Terminal 46 is a container terminal located outside of the East and West Waterways near downtown Seattle. This terminal has two berths that are 50 feet deep, varied crane sizes, and near dock rail.

[3] Source: Northwest Seaport Alliance, nwseaportalliance.com, accessed 23 September 2015.

Terminal 115 is located along the Duwamish River upstream of the West Waterway entrance. This terminal is used for domestic shipping to Alaska by barge service.

Summary information for all Seattle Harbor container terminals is shown in Table 2-4.

Table 2-4. Seattle Harbor Container Terminals[4]

	T-5*	T-18	T-30	T-46	T-115
LAND AREA	185 acres 75 ha	196 acres 79 ha	70 acres 28 ha	82 acres 33 ha	70 acres 28 ha
SHIP BERTHS	2 2900 ft 884 m	3 4,440 ft 1,353 m	2 2,700 ft 823 m	2 2,300 ft 701 m	4 1,600 ft 487 m
BERTH DEPTH	50 ft 15.2 m	50 ft 15.2 m	50 ft 15.2 m	50 ft 15.2 m	30 ft 9.2 m
CRANES	Terminal undergoing modernization	10 6 x 24-wide 1 x 23-wide 3 x 19-wide	6 3 x 24-wide 3 x 18-wide	5 3 x 22-wide 2 x 16-wide	Barge Operation
TRUCK LANES	6/2/4 Inbound / outbound / reversible	16/8 Inbound / outbound	13	9/8/2 Inbound / outbound / by pass	8/6/4 to gate / to warehouse / to outlanes
SCALES	8	18 10 at gate one, 8 at gate four	11	7	5
REEFER PLUGS	600	1,227	451	538	400
SHIPPING LINES	Terminal undergoing modernization	ANL-US Lines, APL, CMA-CGM, CSCL, Hamburg Süd, Hapag-Lloyd, Hyundai, Matson, MOL, NYK Line, OOCL, PIL, UASC, ZIM	ANL-US Lines, CMA-CGM, CSCL, Hamburg Süd, PIL, UASC	COSCO, Evergreen, Hanjin, "K" Line, Maersk, MSC, Safmarine, Yang Ming	Alaska Marine Lines, Aloha Marine Lines
RAIL RAMPS	On-dock / Near-dock	On-dock / Near-dock	Near-dock	Near-dock	Near-dock

*Terminal 5 is being modernized for container-handling, in the interim period it is being used as a non-container terminal

2.2.5 Other Port Facilities

There are two properties owned by Port of Seattle in the West Waterway that handle liquid bulk commodities. At the north end of T-18, petroleum barges and small tankers and handled, moving fuel to/from an adjacent tank farm. At the south end, acreage is leased to private company handling molasses moving to/from barges and small tanker vessels to adjacent tanks.

2.3 Container Services

2.3.1 Existing Container Terminals and Capabilities

The majority of Port of Seattle's container traffic is handled at Terminal 18 and Terminal 5. Annual throughput capacity at all terminals is over 4 million TEUs. Ongoing expansion projects at Terminal 5 should add to this capacity with dock strengthening and landside infrastructure improvements which are projected to be completed by 2020 and are described in Section 3.1.1. Given forecasted container growth during the study period, Port of Seattle is not expected to exceed capacity with estimates of

[4] Source: Northwest Seaport Alliance, nwseaportalliance.com, accessed 23 September 2015

approximately 3.9 million TEUs at the end of the study period. Figure 2-10 gives terminal specifications and capacity estimates for Port of Seattle container terminals.

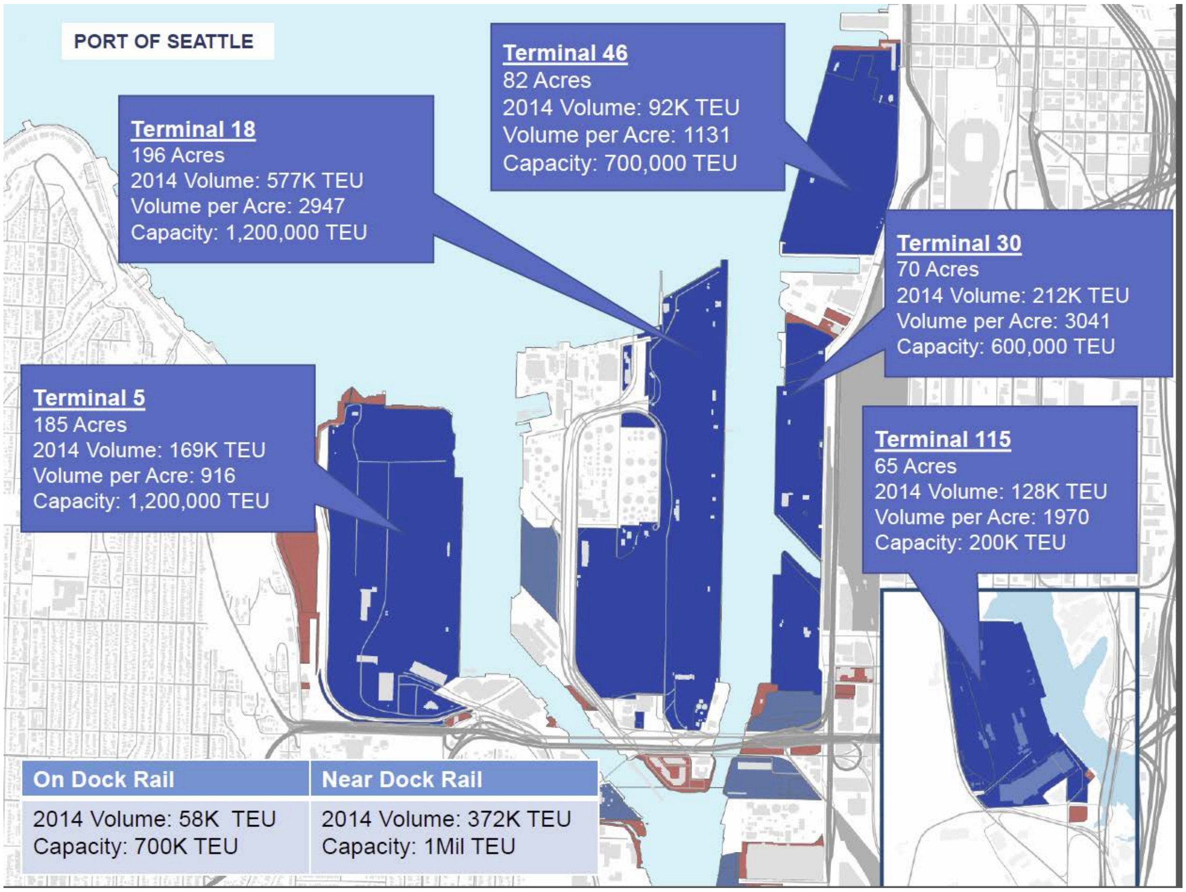

Figure 2-10. Seattle Harbor Container Capacity by Terminal[5]

2.3.2 Carriers and Trade Lanes

According to the Port in summer 2015, there were ten weekly container services at the Port. Historically, more services have called but formation of shipping alliances has reduced the number or routes as well as temporary closure of Terminal 5 in 2014. Several of these services call may call one of two terminals. Table 2-5 summarizes services that were considered for the economic evaluation, including the terminal, carrier(s), service name, vessel rotation, number of ships, and ship sizes at that time. Most services call from Asia via trans-Pacific routes. Major lines include Cosco, Hanjin, CMA CGM, OOCL, Hyundai, MSC, and Maersk, and nine of the top 10 call the Port of Seattle.

[5] Source: Capacity current as of Spring 2015, produced by Moffatt & Nichol and Mercator for the Northwest Seaport Alliance Strategic Business Plan, 6 May 2015, accessed online 23 Sep 2015, nwseaportalliance.com. https://www.nwseaportalliance.com/sites/default/files/NWSeaportAllianceStrategicBusinessPlan.pdf.

Table 2-5. Seattle Carriers Services by Terminal (2015)

Terminal	Carrier(s)	Service Name	Vessel Rotation	First	Last	# of Ships	Ship Sizes
T-18	**Cosco, K-Line, Yang Ming, Hanjin**	MD1	SE Asia – S China – N Asia – US West Coast – N Asia – S China	No	Yes	16	10,000
	APL, MOL, Hyundai, Hapag Lloyd, NYK, OOCL, ZIM	NP1	SE Asia – S China – West Coast Canada – US West Coast – N Asia – S China – SE Asia	No	Yes	7	8,050-10,000
	APL, MOL, Hyundai, Hamburg Sud, Hapag Lloyd, NYK, OOCL, ZIM	NP2	S China – N Asia – US West Coast – West Coast Canada – N Asia – S China	No	No	6	7,900-8,600
	China Shipping, CMA CGM, UASC, PIL, Hamburg Sud, ANL-US Lines	ANW1/ AWN1/ Columbus PNW	SE Asia – S China – N Asia – US West Coast – West Coast Canada – N Asia – S China – SE Asia	Yes	No	12	8,500
T-30	**China Shipping, CMA CGM, UASC, PIL, Hamburg Sud, ANL-US Lines**	ANW1/ AWN1/ Columbus PNW	SE Asia – S China – N Asia – US West Coast – West Coast Canada – N Asia – S China – SE Asia	Yes	No	12	8,500
T-46	**Cosco, Yang Ming, Hanjin**	PNH	N Asia – West Coast Canada – US West Coast – West Coast Canada – N Asia	No	No	6	4,500-5,500
	Cosco, K-Line, Yang Ming, Hanjin	MD1	SE Asia – S China – N Asia – US West Coast – N Asia – S China	No	Yes	16	10,000
	Maersk, MSC, Safmarine	TP9	SE Asia – S China – N Asia – West Coast Canada – US West Coast – N Asia – S China – SE Asia	No	Yes	15	5,000
	MSC	CAX	Med – Panama – US West Coast – West Coast Canada – US West Coast – Panama - Med	No	No	10	5,000

2.3.3 TEU Weight by Container

PIERS data was obtained from the Port of Seattle and confirmed with IHS historical commodity data to determine weight per TEU. Data was obtained at a country and region level, and were grouped in to world regions and two route groups (Asia and Mediterranean). This methodology is further described in Section 3.3.2. Table 2-6 presents loaded TEU weights, including the box weight of approximately 2 metric tons per box, for each world region. Table 2-7 presents loaded TEU weights by route group. Generally, export TEUs are heavier than import TEUs primarily due to heavier Northwest agriculture exports. Overall average loaded TEU weights are 9.2 metric tons for import and 14.1 metric tons for export, or 9.3 metric tons overall including box weight.

Table 2-6. Seattle Average Weight per Loaded TEU, Import and Export

World Region	Import – Average Weight per Loaded TEU (MT)	Export – Average Weight per Loaded TEU (MT)	Imports and Exports – Average Weight per Loaded TEU (MT)
Africa	11.4	12.9	12.1
Asia	8.9	14.0	11.1
Europe	9.0	13.7	9.9
Latin America & Caribbean	11.7	13.7	12.4
Middle East/Indian Subcontinent	11.7	14.2	13.8
Oceania	9.1	13.6	13.1

*Includes average box weight of 2 tons per TEU

Table 2-7. Average Weight per Loaded TEU by Trade Lane

Route Group	Import - Average Weight per Loaded TEU (MT)[6]	Export - Average Weight per Loaded TEU (MT)	Imports and Exports - Average Weight per Loaded TEU (MT)
Route 1: Asia, Oceania, and Middle East/Indian Subcontinent	9.0	14.2	11.2
Route 2: Europe, Latin America, Africa, and Middle East/Indian Subcontinent	10.7	13.7	12.3
Overall Average Weight per Loaded TEU	9.2	14.1	9.3

*Includes average box weight of 2 tons per TEU

2.4 Historical Commerce

The Port of Seattle is a nationally significant port and a critical regional and national export gateway. The Port of Seattle is the 10th largest U.S. port in terms of Twenty-Foot Equivalent Unit containers (TEUs) and the 14th largest North American port terms of TEUs[7]. The Port of Seattle exports more cargo than it imports by metric tons, but imports more TEUs than it exports, and is a last port of call for several of the Asian – West Coast routes. The Port's inland markets extend to Chicago, Memphis, and St. Louis, making it an ideal gateway for import and export of goods moving between Asia and the U.S. Midwest. The Midwest makes up nearly two-thirds of the Port's hinterlands[8] (i.e., the inland area served by a port). The Port's top three trading partners for both imports and exports include China, Japan, and South Korea. Machinery, toys and sports equipment, furniture and bedding, clothing, footwear, plastic, and iron/steel products were among the greatest value of imported commodities in 2013. High value

[6] Based on 2012-2014 average weight per loaded TEU.
[7] Seaport Statistics. Port of Seattle. 2013. Accessed online at http://www.portseattle.org/About/Publications/Statistics/Seaport/Pages/default.aspx on 2 June 2014.
[8] Data Source: IANA (Intermodal Association of North America), 2013.

export commodities included a variety of food products (grain, fish and seafood, preserved food, meat, fruit, dairy, vegetables, cereals, etc.), paper products, and wood products. The Port of Seattle is also a natural gateway for exports that originate in Washington State. The State is a top national producer of apples, pears, potatoes, onions, red raspberries, hay, and hops.

Imports and exports were valued at $21.2 billion and $7.4 billion, respectively, and over half of the trade value is with China alone[9]. Washington's exports are heavier than imports and are sensitive to vessel size and depth limitations.

Vessels currently calling at the Port of Seattle include 48-foot draft vessels in the East Waterway, including 8,500 TEU capacity CMA CGM Opera class vessels and 49 foot draft 10,000 TEU capacity ZIM vessels. The 11,300 TEU capacity *CMA CGM Callisto* and *CMA CGM Cassiopeia* made calls to T-18 in September 2015. In February 2016, the 18,000 *CMA CGM Benjamin Franklin* called T-18. In the West Waterway 48-foot draft vessels have already called, including 8,600 TEU capacity Hyundai vessels. The large Hyundai ships began calling in November 2013, but were restricted in load in the West Waterway due to pilotage requirements for 10% under keel. Annual vessel calls average around 559 calls in the East Waterway and 224 calls in the West Waterway for 2007 to 2013, as shown in Figure 2-11. Associated average TEUs from 2007 to 2013 for the East and West Waterways is 789,000 and 501,000 TEUs, respectively. Total TEUs averaged 1.3 million over this time period. TEUs by waterway from 2007 to 2013 is shown in Figure 2-12. Non-containerized cargo and bulk also call at the East and West Waterway and included 48,000 metric tons of molasses and 788,000 metric tons of petroleum in the East Waterway in 2013.

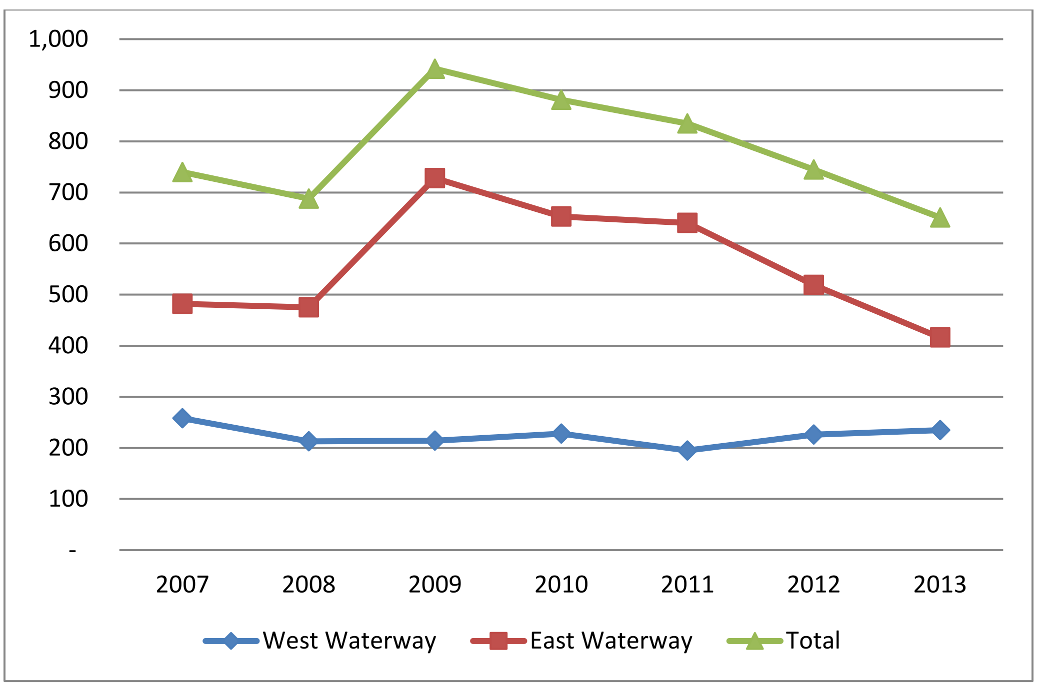

Figure 2-11. Vessel Calls by Waterway, 2007-2013

[9] Port of Seattle. "2013 Port of Seattle Foreign Waterborne Trade Report". 2013.

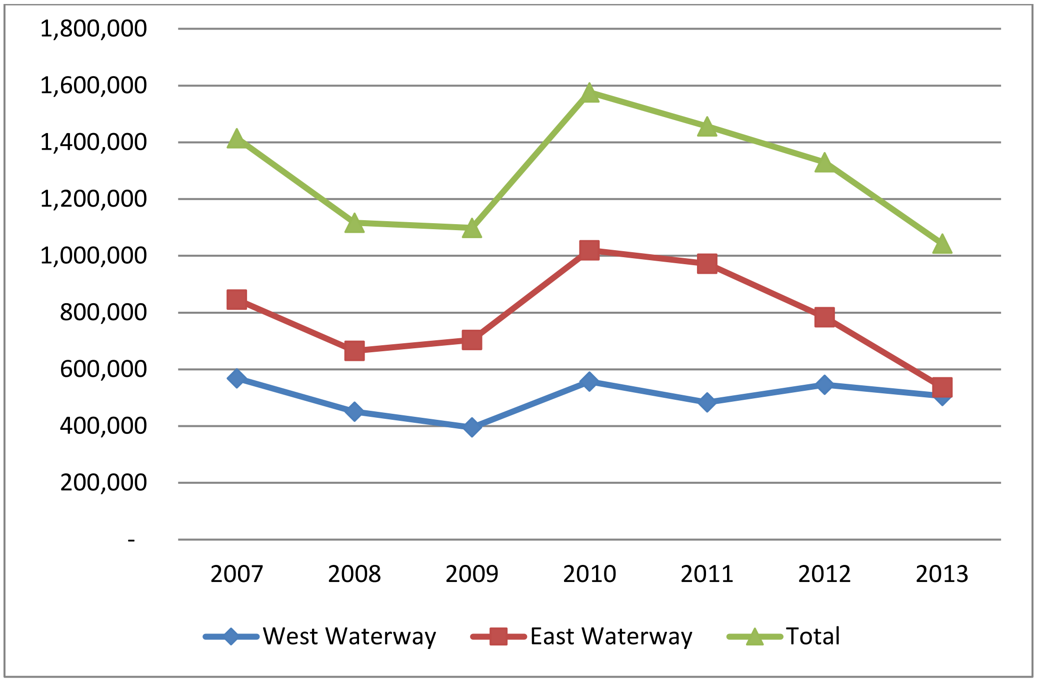

Figure 2-12. Containerize Cargo in TEUs by Year, 2007-2013

Containerized traffic declined after 2007, with declines continuing in 2008 and 2009. This decline in container traffic is likely related to global economic recession that impacted commerce in many sectors of the economy, both nationally and internationally. Container traffic increased again in 2010 to its peak of 2.1 million TEUs (1.6 million TEUs in the East and West Waterways), and has been on the decline to present day. This decline is partly due to new container operations at the Port of Prince Rupert (British Columbia, Canada) starting in 2007. Additional discussion about the Port of Prince Rupert is included in the following paragraphs.

Seattle's average share of the West Coast trade volumes from 2007 to 2013 is approximately 8.1 percent and has declined from its high of 9.3 percent in 2010 to 6.6 percent in 2013. During this same period, the share at the Port of Prince Rupert has increased from 1.5 percent in 2010 to 2.2 percent in 2013. Figure 2-13 shows the share of West Coast port trade volumes by port between 2007 and 2013.

Los Angeles, Long Beach, Tacoma, Vancouver (British Columbia, Canada), and Prince Rupert (British Columbia, Canada) all have ports with channels and berths as deep or deeper than the Port of Seattle. Prince Rupert has a natural depth of -60 feet MLLW, has grown quickly and plans major expansion that would allow that port to handle 2.5 million TEUs by 2020 and 4 to 5 million TEUs in subsequent years[10,11], more than the current combined volumes of the ports of Seattle, Tacoma, and Portland (3.7 million TEUs in 2013 for these three ports). Prince Rupert is one of the deepest ports in North America, giving it a competitive advantage. It has shown positive growth since 2008 and may capture more of the West Coast market share because of having no depth limitations.

The naturally deep waterways of Prince Rupert provide an advantage to vessels working under very tight Asian market shipping schedules. Because shipping line vessel deployments are closely scheduled to meet berthing windows in all of the ports of call in a rotation, any delay in Seattle, whether heading to a Canadian port or an Asian port, would increase cost for a shipping line by creating a need for them to speed up the ship and burn more fuel to catch up their long term schedule. Shipping lines are extremely focused on cost reduction, especially in managing fuel consumption (they have implemented slow steaming on all of their routes). Continued delay at any port creates a need to speed up and burn more fuel to regain a schedule. Delays due to tidal restrictions at Seattle Harbor create an incentive for shipping lines to look for ways to avoid that port in order to meet tight schedules; ultimately, these shipping lines may potentially call more often at naturally deeper ports like Prince Rupert. As described later in the economic evaluation, market share for Seattle is based on an average historic share of West Coast trade and is the basis for the commodity and vessel fleet projections. Although there has been shifts in market share at the Port of Seattle, the analysis accounts for the change in share resulting from Prince Rupert and other port developments and does not support a claim that Seattle market share would change in the future both with and without a proposed deepening project considered in this evaluation.

Other West Coast ports with positive growth trends from 2007 to 2013 include Oakland and Vancouver. Long Beach had the most significant decline of 0.3 percent per year, followed by Los Angeles, Tacoma, and Seattle.

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[10] Prince Rupert Port Authority. "A Vision for the Future". Accessed online at http://www.rupertport.com/trade/vision on 23 Jun 2014.

[11] U.S. Department of Transportation Maritime Administration. "Panama Canal Expansion Study, Phase 1 Report: Developments in Trade and National and Global Economies. November 2013.

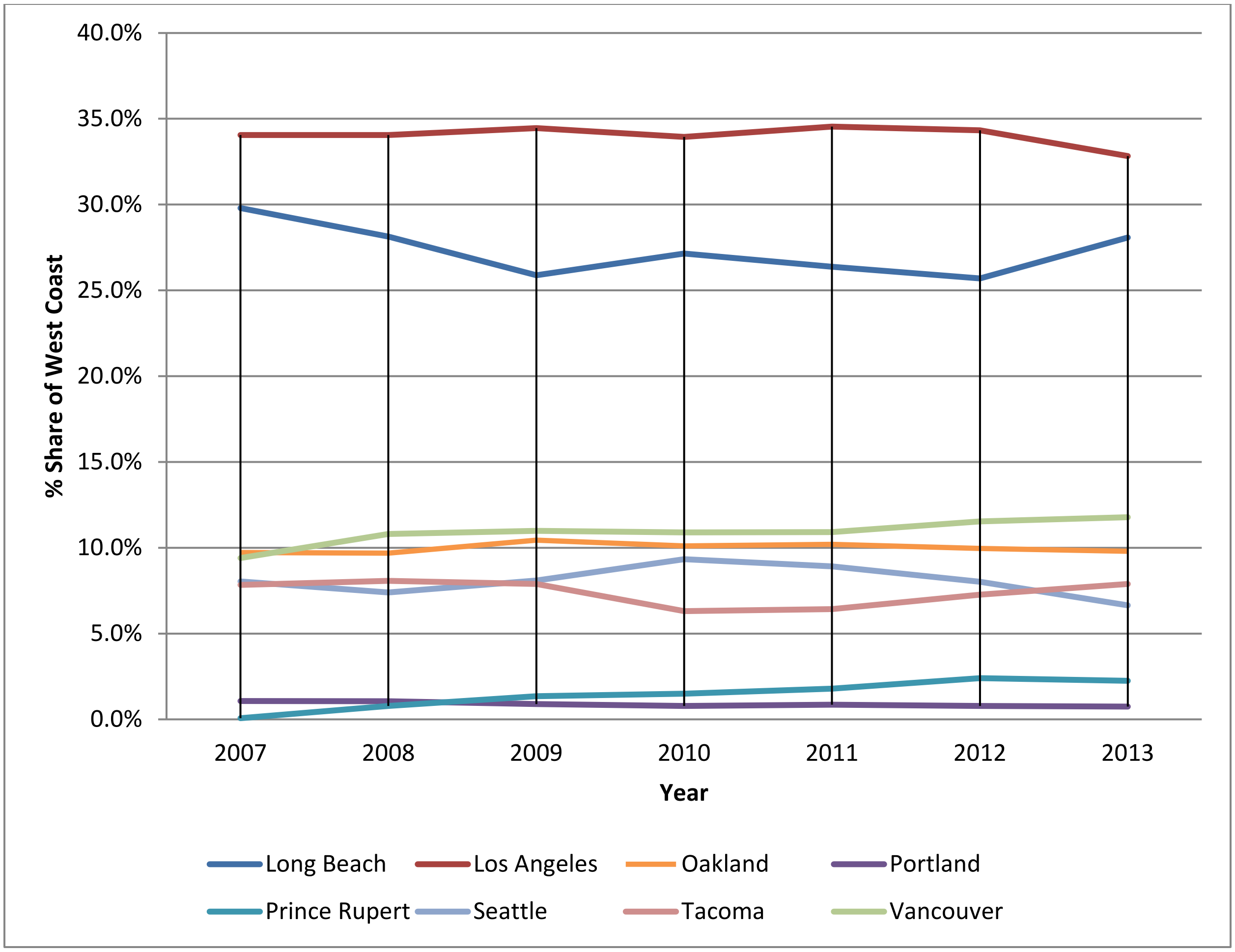
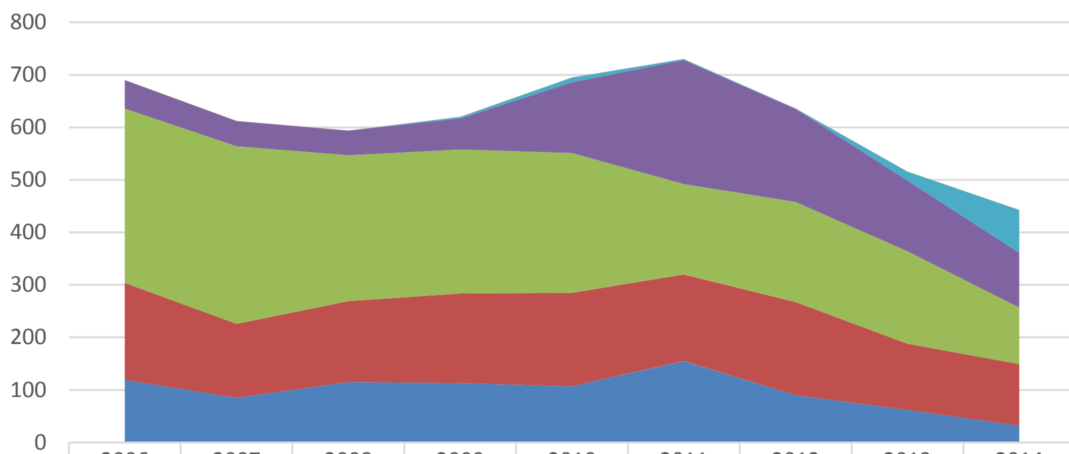


Figure 2-13. Select Ports Share of West Coast Volumes, 2007-2013

2.5 Existing Fleet

Data for the container fleet was obtained from the Puget Sounds Pilot's log and the Sea-web database. From 2006 to 2014 a variety of different container ships called to the Port of Seattle. These ships are classified as sub-Panamax, Panamax, Post-Panamax Generation 1 (PPX Gen I), Post-Panamax Generation II (PPX Gen II), and Post-Panamax Generation III (PPX Gen III) depending on their capacity. The vessels are distinguished based on physical and operation characteristics, including lengths overall (LOA), design draft, beam, speed, and TEU capacity. It is common practice to separate the containership fleet in TEU bands or classes to analyze supply within the industry. However, due to the evolution of vessel design over time, these TEU bands do not correspond to a breakdown of the fleet by dimensions such as beam or draft. Accordingly, breakdowns in terms of beam and draft straddle different classes. For instance, within the 3,900 to 5,200 TEU band, which is generally regarded as the Panamax range, a number of ships fall within that category yet have beams that are too large to pass safely through the current Panama Canal, despite what their name suggests. Conversely, there are many Panamax vessels in the world fleet that fit easily through the Panamax Canal while carrying large volumes of TEUs. To minimize the overlap, the beam band or range was used to distinguish container vessels into six vessel classes as shown in Table 3-17.

Figure 2-14 shows vessel calls at the Port of Seattle from 2006-2014, broken down by vessel class. Figure 2-15 shows vessels in the world fleet from 1980 to 2014 based on this vessel classification based on information obtained from the Maritime Strategies Inc. (MSI) vessel fleet forecast described in Section 3.4. Finally, Figure 2-16 shows the progression of containerships calling the Port of Seattle from 2000 to present day. It should be noted that the 18,000 nominal TEU capacity ship CMA CGM Benjamin Franklin called the Port of Seattle on February 29, 2016 as part of a trail deployment of these ultra-large containerships to U.S. West Coast ports from Asia.



	2006	2007	2008	2009	2010	2011	2012	2013	2014
PPX Gen IV	0	0	0	0	0	0	0	0	0
PPX Gen III				3	9	2	1	17	82
PPX Gen II	54	48	47	59	135	236	177	135	104
PPX Gen I	332	338	278	274	266	172	191	176	108
Panamax	185	141	154	171	178	165	177	126	117
Sub-Panamax	119	85	115	113	107	155	90	62	32

Figure 2-14. Seattle Vessel Calls by Class, 2006-2014

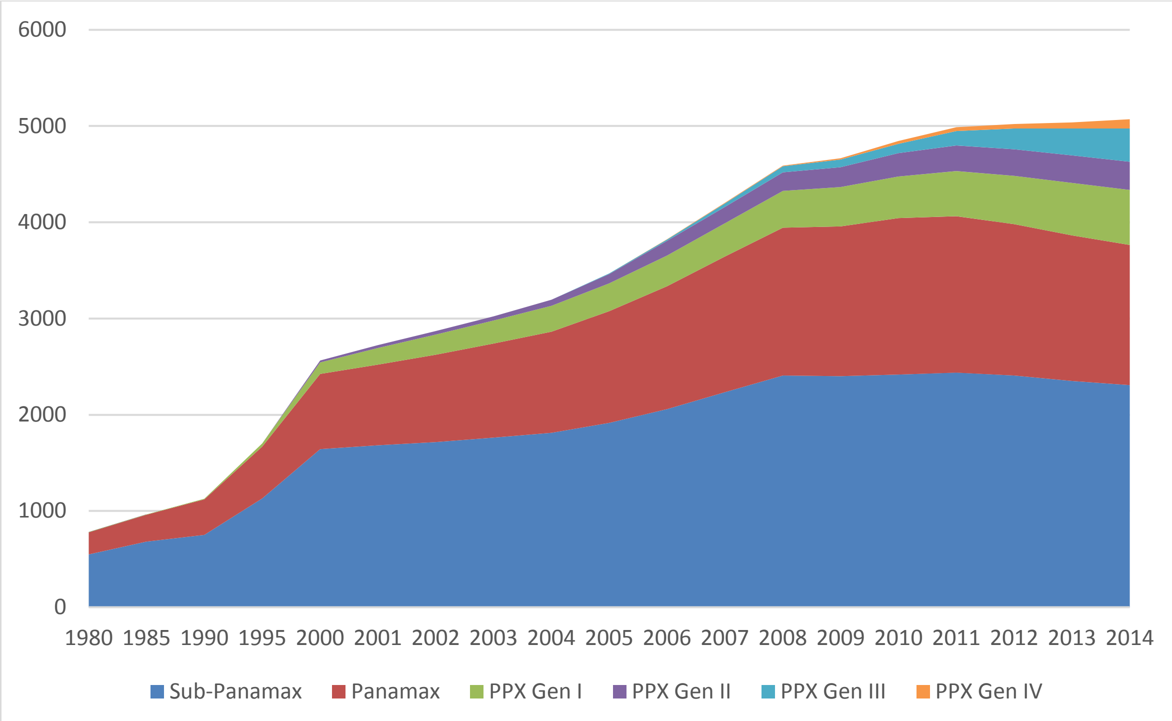


Figure 2-15. Vessels in World Fleet, 1980-2014

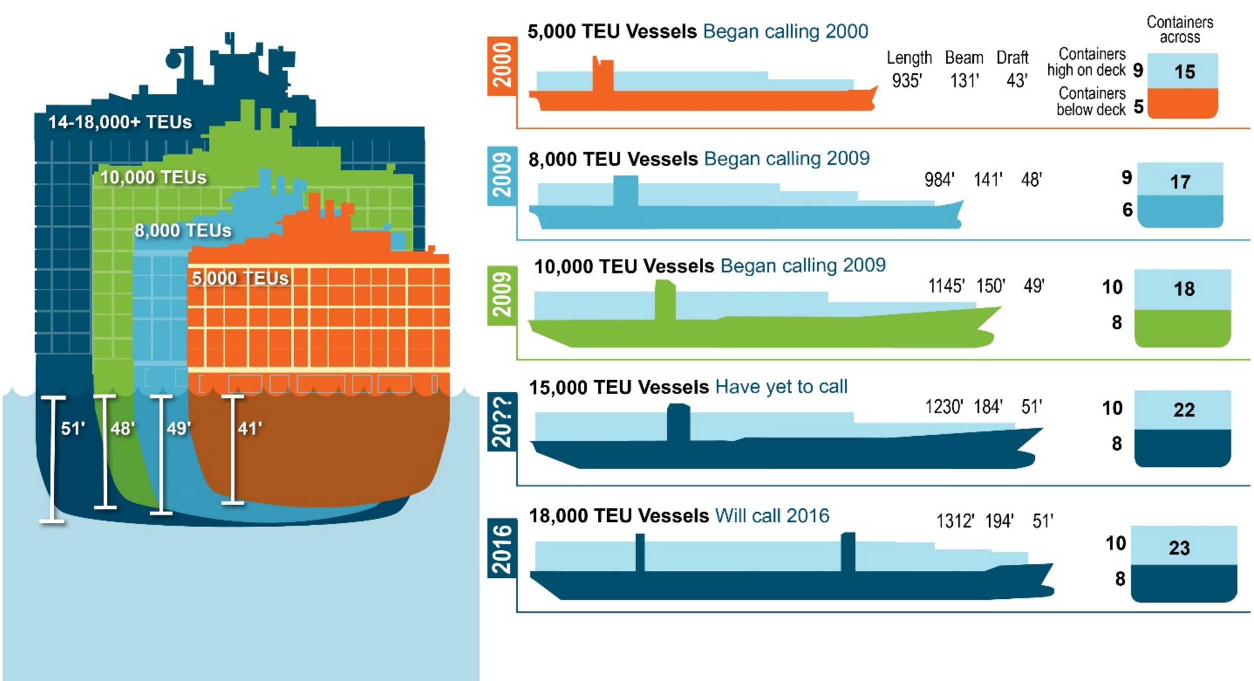


Figure 2-16. Containership Growth at Port of Seattle, 2000-2016

In 2011, the average vessel size per call at U.S. ports was 53,832 deadweight tons (DWT), up 6.3 percent from five years before. The average size of containerships increased by 13.3 percent in terms of TEU capacity (9.9 percent in terms of DWT) as carriers expanded the deployment of post-Panamax (5,000+ TEU) containerships in U.S. trades. These post-Panamax vessels generally require drafts of -43 feet MLLW or greater, with the largest vessel classes requiring -53 feet MLLW. Over the last five years, calls by containerships of 5,000 TEU or greater, which are largely Post-Panamax class and generally require drafts of -43 feet MLLW or greater, increased by 78.2 percent. Additionally, the number of 5,000+ TEU containerships deployed in U.S. trades increased by 60.4 percent; these ships generally require drafts of -48 feet MLLS or greater.

Seattle Pilots records show that the average containership size in the Port of Seattle has grown by 16 percent through the previous 6 years, from 2010 through 2015. As shown in Table 2-8 below, the average ship for Seattle Harbor in 2010 was about 56,753 gross tons, and in 2015 the average ship had increased to 65,775 gross tons. This represents a 2.5 percent compound annual growth rate. This rate of growth in the typical ship, if sustained, would indicate the average ship gross tonnage for base year 2024 to be 82,000—typically classified as a Generation II Post-Panamax containership.

Table 2-8. Average Ship Gross Tonnage by Year, 2010-2015

Year	Average Gross Tonnage
2010	56,753
2011	55,976
2012	55,042
2013	55,621
2014	62,383
2015	65,775

As vessel gross tonnage grows, so does vessel design draft, length, beam, and height (air draft). Each of these vessel characteristics is critical to navigation safety and port capability. Figure 2-17 presents average gross tonnage per ship from 2010 to 2014.

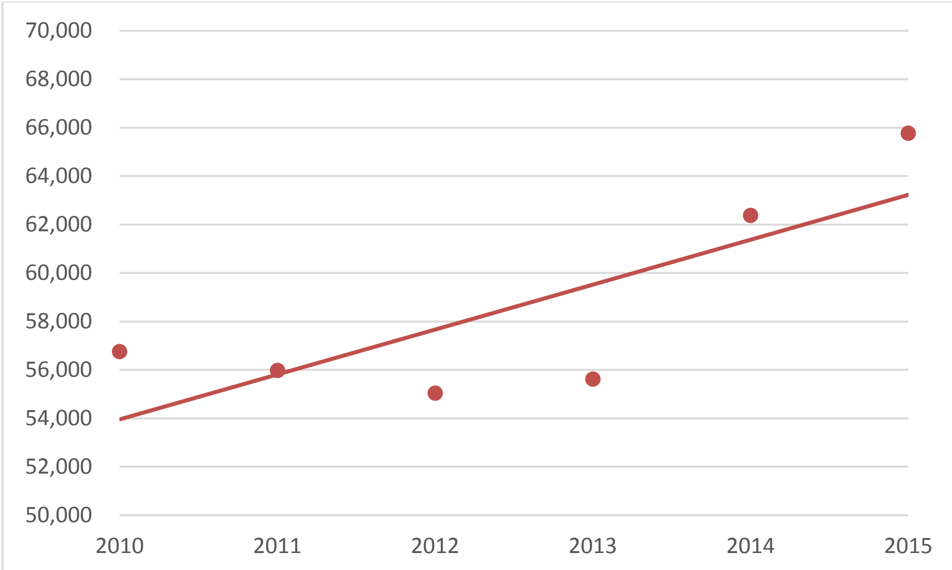


Figure 2-17. Port of Seattle Average Gross Tonnage per Vessel

Seattle is already handling a significant number of Post-Panamax ships. From 2010 through 2015, about 52 percent of all calls were Post-Panamax calls. Of all containership calls in this same period, 1,099 inbound or outbound transits were deeper than current Panamax draft, which represents 23 percent of all containership transits over that period.

Table 2-9 and Figure 2-18 display percent cargo by vessel class for years 2010 to 2014. Total cargo movements on PPX Generation II or larger containerships grew from 32 percent in 2010 to 71 percent in 2014.

Table 2-9. Percent Cargo by Vessel Class, 2010-2014

	2010	2011	2012	2013	2014
Import					
SubPanamax	7%	10%	11%	10%	6%
Panamax	23%	21%	17%	14%	14%
Gen I Post-Panamax	36%	23%	33%	35%	7%
Gen II Post-Panamax	25%	40%	38%	38%	49%
Gen III Post-Panamax	9%	7%	1%	3%	24%
Export					
SubPanamax	9%	11%	12%	10%	8%
Panamax	22%	24%	18%	14%	16%
Gen I Post-Panamax	39%	23%	31%	31%	7%
Gen II Post-Panamax	22%	36%	37%	41%	44%
Gen III Post-Panamax	8%	6%	1%	4%	25%
Total					
SubPanamax	8%	10%	12%	10%	7%
Panamax	22%	22%	18%	14%	15%
Gen I Post-Panamax	38%	23%	32%	33%	7%
Gen II Post-Panamax	23%	38%	38%	40%	46%
Gen III Post-Panamax	9%	6%	1%	4%	25%

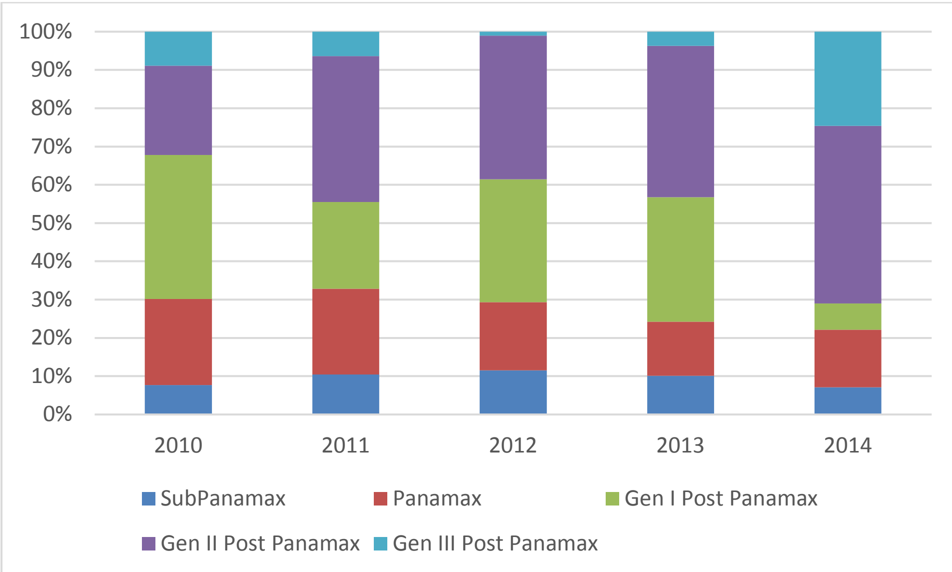


Figure 2-18. Total Tonnage by Vessel Class, 2010-2014

2.6 Shipping Operations

2.6.1 Underkeel Clearance

Vessel transit guidelines are documented for the Puget Sound Pilots[12]. Below are general guidelines for underkeel clearance which apply to all vessel types, including containerships. These guidelines are not expected to change as a result of a deepening project. Underkeel requirements for the economic analysis utilized evaluation was obtained from recent Corps evaluations and expertise as shown in Table 4-7.

UNDERKEEL CLEARANCE IN ALL PORTS and WATERWAYS

1. Vessels exceeding 400 feet in length transiting restricted waterways and channels will be dispatched to maintain a minimum under-keel clearance of three (3) feet or 10 percent of draft (for example, a containership with a design draft of 48 feet would have a minimum underkeel clearance of 10 percent, or 4.8 feet), whichever is greater, during the transit, provided that vessels may have less under-keel clearance when berthing, un-berthing and alongside the dock. Vessels shall remain afloat at all times.

2. While the above guideline is general in nature, it is noted that the determination of an appropriate minimum under-keel clearance for a specific vessel transiting a specific waterway or channel must take into account many factors in addition to vessel draft and least depth, including but not limited to: vessel size, configuration, speed, trim, and list; the shape, size and hydrography of the waterway; and variations from predicted tide levels.

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[12]Puget Sound Pilots. "General Guidelines for Vessels Transiting Restricted Waterways or Ports". Revised January 27, 2015.

2.6.2 Tidal Range

Tides in Puget Sound are mixed semidiurnal in type. The mean tidal range published by NOAA for Seattle, Washington is 7.66 feet. The great diurnal tidal range is 11.36 feet. Tidal data for Seattle, Washington are listed in Table 2-10. The strongest and most frequent winds at Seattle are oriented from the north and south due to the geometry of the Central Puget Sound basin as shown in the wind rose in Figure 2-19. However, due to the orientation of Elliott Bay, Seattle Harbor is predominantly sheltered from southerly winds and wind-generated waves.

Table 2-10. Tidal Data at Seattle NOS/CO-OPS station 9447130 (1983-2001 tidal epoch)

Datum	Value (feet)	Description
MHHW	11.36	Mean Higher-High Water
MHW	10.49	Mean High Water
MTL	6.66	Mean Tide Level
MSL	6.64	Mean Sea Level
MLW	2.83	Mean Low Water
MLLW	0	Mean Lower-Low Water
NAVD	2.34	North American Vertical Datum
Maximum	14.48	Highest Observed Water Level
Minimum	-5.04	Lowest Observed Water Level

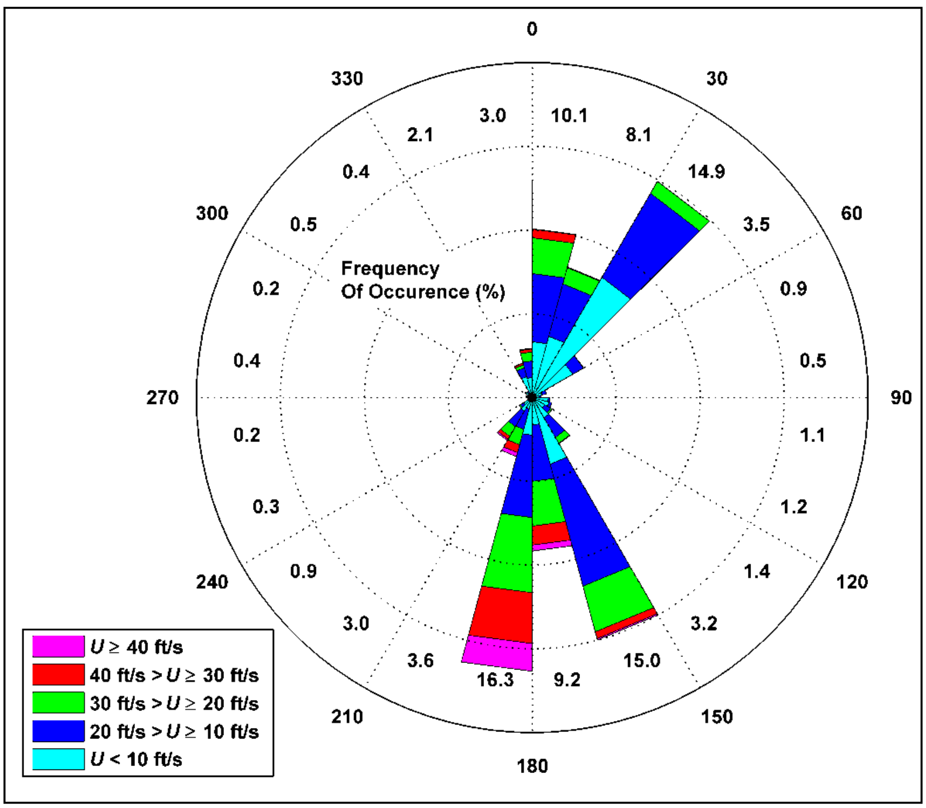

Figure 2-19. Wind Rose at West Point Coastal-Marine Automated Network (C-MAN) station (1984-2007). Wind speeds are shown in feet per second, and directions are in degrees from true north (0°)

Drainage from the Green/Duwamish River basin is the primary sediment source in the Duwamish, East, and West Waterways. The Green/Duwamish River is regulated by Howard A. Hanson Dam, operated by the Corps, located at river mile (RM) 64.5. Below the dam at about river mile 59, the Green River enters the Puget Sound lowlands. The remaining 48-mile reach of the Green River drains the Puget Sound lowlands and flows through a region of increasingly intensive agricultural and urban land use. At RM 11, the Green becomes the Duwamish River, which flows through a heavily industrialized area of Seattle and then enters Elliott Bay. The average daily discharge reported at the USGS 12113000 Green River gauge at Auburn is 1,345 ft^3/s. A peak regulated discharge of 12,400 ft^3/s was observed on February 8, 1996. An annual average suspended sediment load of 270,000 tons per year (as measured from 1996 to 1998) is transported into Puget Sound through the Green/Duwamish[13].

Tidal Delays

The June 2014 condition survey indicates the controlling depth for the East Waterway is on the channel sideslope at Station 25+00 near Terminal 30. The controlling depth in the West Waterway is near Station 18+00 near the entrance to the Waterway. Table 2-11 summarizes the tidal limitations on vessel drafts for the East and West Waterways at Seattle Harbor. As an example, a vessel drafting 48 feet with a minimum 3 feet of underkeel clearance can only transit into or out of the West Waterway two hours per day given tidal restrictions at the approach to that waterway.

Table 2-11. Tidal Limitations on Port of Seattle Vessel Draft

East Waterway		West Waterway	
Hours/Day available for transit[1]	Vessel Draft (feet)	Hours/Day available for transit[1]	Vessel Draft (feet)
24	40	19	40
24	41	18	41
24	42	17	42
24	43	16	43
24	44	11	44
24	45	8	45
24	46	5	46
23	47	3	47
21	48	2	48
20	49	0	49
19	50	0	50
18	51	0	51
17	52	0	52
16	53	0	53
11	54	0	54
8	55	0	55

[1] Based on depths observed in the June 2014 condition survey and an assumed 3 foot underkeel clearance requirement.

[13] Embry and Frans, 2003; USGS WRIR 02-4190.

2.6.3 Sailing Practices

Vessel transit guidelines are documented for the Puget Sound Pilots[14]. Below are general guidelines, as well as specific guidelines for the East and West Waterways of Seattle Harbor. These guidelines are not expected to change as a result of a deepening project.

VESSEL SPACING

It is recommended that all final berthing positions provide for a minimum clearance of 30 meters between vessels or between vessels and shoal areas.

HORIZONTAL CLEARANCE

There should be net horizontal clearance available at all times to a transiting/maneuvering vessel of at least 140 feet, meaning a minimum of 70 feet clearance on each side when the vessel is in the center of the available waterway.

VESSEL & TERMINAL GANTRY CRANE SAFETY

It is recommended that all terminal operators with gantry cranes adopt the following Best Practices:

1. When vessels are berthing or unberthing at the terminal:

a. Prior to a vessel's arrival or departure from a berth, gantry cranes at the berth should be boomed up and positioned close together near the midships section of the vessel (avoiding the vessel's bow and stern flair).

b. Gantry cranes should not be moved when a vessel is berthing or unberthing.

c. It is recommended no person be allowed aloft on a gantry crane during berthing or unberthing operations.

2. When vessels using the waterway are passing the terminal:

a. Gantry crane booms should be topped up over empty berths when a vessel is transiting/maneuvering past. If a boom cannot be topped up, advance notice should be given to PSP.

b. There should be net horizontal clearance available at all times to a transiting/maneuvering vessel of at least 140 feet, meaning a minimum of 70 feet clearance on each side when the vessel is in the center of the available waterway.

c. Gantry cranes over working berths can remain boomed down provided the net clearance conditions above are met.

INCLEMENT WEATHER and WIND

[1414] Puget Sound Pilots. "General Guidelines for Vessels Transiting Restricted Waterways or Ports". Revised January 27, 2015.

1. Decisions relating to vessel movements requiring more than 50 tons of force to hold the vessel against a wind from any direction will be made on a case by case basis by the pilot depending on direction and force of wind and the type and characteristic of the vessel.

2. Wind on the beam is one of the factors used in evaluating the counter force necessary for tugs and or thrusters on a particular transit. The formula below calculates the approximate static tons of beam wind exerted upon a vessel based on its sail area. Agents and operators ordering pilots are encouraged to provide to the dispatcher the specific sail area of a vessel when ordering a pilot.

Static Metric Tons of Wind on the Beam = [(V^2/18) x Sail Area] / 1000

Where:

Sail Area = Square meters determined by Length (m) x Height (m) (Height is freeboard plus highest container row)

V = Wind velocity in meters per second (Knots of wind ÷ 1.944)

SEATTLE - EAST WATERWAY

1. Vessels with a LOA of 900 feet or greater than 55,000 Gross Tons will be dispatched with a minimum of two T-5 class tugs except that one T-5 class tug may be dispatched to a vessel with a 4% Bow Thruster Departing T-18 berths 1 or 2 if berth 1 and Kinder Morgan are unoccupied and no cranes are down north of the vessel.

2. All other vessels will be dispatched with a minimum of two tugs except that one tug may be dispatched to: 1) a vessel that will not pass moored vessels on both sides of the waterway and that has a 4% Bow Thruster and a draft of less than 36.2 feet, or; 2) a vessel with a bow thruster departing Terminal 18 berths 1 or 2 if berth 1 and Kinder Morgan are unoccupied.

3. Vessels greater than 115,000 Gross Tons will be dispatched with a minimum of three T-5 class tugs or two T6 class tugs.

SEATTLE - WEST WATERWAY

1. All vessels with a LOA of 900 feet or greater or more than 55,000 Gross Tons should be dispatched with a minimum of two T-5 class tugs.

2. All other vessels should be dispatched with a minimum of two tugs except that one tug may be dispatched to a vessel with a 4% Bow Thruster.

3. Vessels greater than 115,000 Gross Tons should be dispatched with a minimum of three T-5 class tugs or two T6 class tugs.

2.7 Design Vessel

"For deep-draft projects, the design ship or ships is/are selected on the basis of economic studies of the types and sizes of the ship fleet expected to use the proposed channel over the project life. The design ship is chosen as the maximum or near maximum size ship in the forecasted fleet" (USACE 1984, 1995, 1999).

For the East and West Waterways, the economics and coastal hydraulics team, in consultation with the Corps' IWR, recommended consideration of two containerized carrier design vessels given flexibility for evaluation of marginal or incremental costs, and differing specifications combined with potential differentials in timing for inception and frequency of service over the planning horizon. Historically, new vessels are first deployed on the Trans-Mediterranean lines, followed by the Pacific including the West Coast three to seven years later, followed by the Atlantic including the East Coast three to five years later, and finally calling the Gulf Coast a few years after the East Coast deployments. The specifications for the recommended design vessels are as follows:

Post-Panamax Generation III

- 168 foot beam (extreme breadth (XB))
- 1,200 to 1,220 feet length over all (LOA)
- 51.2 foot maximum summer loadline draught (MXSLLD)
- Nominal TEU intake of 12,800 to nearly 14,000 TEUs
- Deadweight rating of approximately 154,000 to 165,000 metric tones
- Air draft of approximately 175 feet or less above the immersed waterline (at MXSLLD)

Post-Panamax Generation IV

- 185 to 190 feet in beam (extreme breadth (XB))
- 1,300 to 1,315 feet length over all (LOA)
- Approximately 51.4 to 52.6 foot maximum summer loadline draught (MXSLLD)
- Nominal TEU intake of approximately 14,200 to 15,800 TEUs
- Deadweight rating of 157,000 metric tones
- 198 to 203 feet for air draft above the immersed waterline (at MXSLLD)

Having reviewed vessel specifications and capacity, recommendations for the East and West Waterways of Seattle Harbor are tentatively for two aggregate designs for fully cellular containerized carriers as described herein with anticipation for refinement of evaluation as studies progress with potential to select either vessel based on preliminary cost evaluations and timing of service as better determined with undertaking of fleet service forecasts. It should be noted that the future fleet of containerships which may call Seattle may exceed the dimensions of the two design vessels. As of March 2016, a ship larger than the PPX Generation IV design vessel has called at Terminal 18 on the East Waterway. CMA CGM announced in March 2016 that it would deploy a fleet of six 18,000 nominal TEU capacity containerships on a service between Asia and the U.S. West Coast, though it will not call Seattle as part of this initial rotation. It is anticipated that 14,000 to 16,000 nominal TEU capacity containerships will call in the near future as part of regular services between Seattle and Asian ports.

The selection of vessel specifications for fleet service forecasts and waterway engineering evaluations sometimes poses unique concerns given requirements to evaluate design and improvements for waterway systems over time. Generally, waterway improvements should be designed to be optimized across the entire fleet forecast regime or structure. Typically, it may include service by several sizes and types of vessels (i.e., bulk carriers, containerships, tankers, etc.). Where vessel designs are relatively mature (tankers and dry bulk carriers), the task is comparatively straightforward. However, where consideration is to include fully cellular containership services, associated hull designs are still evolving. On a world fleet basis, containership designs continue to change with respect to size and cargo carrying capacity, and have not reached an absolute limiting threshold for rated carrying capacity as measured by weight (deadweight tonnage) or nominal intake for standard-unit slot capacity (i.e., nominal TEUs).

Studies for Seattle Harbor are primarily based on the anticipated service regime for future containerized movements with consideration of Sub-Panamax, Panamax, current Post-Panamax and new Panamax, and new Post-Panamax hull designs or specifications. In this context it should be understood that current Panamax standards for vessel dimensions allow for vessel beam or breadths less than or up to 105.9 feet and lengths of up to 960 feet in length overall (LOA) via the existing lock system while the new Panamax standard associated with capacity of the new lock system will formally allow for vessels up to 160 feet in breadth and 1,200 feet in length. As with established practice for the existing lock system it is anticipated that there will exist a margin for slightly larger vessels in terms of breadth and LOA (perhaps as much as 168 feet in breadth and up to 1,220 feet LOA) with compensating adjustment to transit draft to allow for required hydraulic flow needed to move the vessel into and out of respective lock chambers.

With respect to current and projected fleet service for deep-draft harbors such as Seattle, post and new Panamax designs are divided into three (3) general groupings, largely separated by beam or extreme breadth and capacity for nominal TEU intake. Building trends for the first two groupings (Generation I and Generation II, with beams typically less than 150 to 152 feet) are reasonably well established with respect to typical physical dimensions and size relative to displacement, associated deadweight capacity, and typical homogeneous and nominal TEU ratings. What can be termed the Generation III class of containership (beams exceeding 150 feet through 168 feet) has only recently become better defined in terms of typical dimensions that a project analyst would expect to encounter due in large part to announcement of the specifications for maximum hull size to be accommodated by the new locks currently nearing completion of construction for the Panama Canal. This class has dimensions designed with an emphasis of consideration for specifications of the new locks under construction for the Panama Canal expansion. The length and beam limitations of the new locks for the Panama Canal are now known and these parameters are considered fixed. Conversely, while the specification for draft typically does have a limit, as with employment of the existing lock system, actual immersed draft can be adjusted or allowed to vary based on variability in cargo density, loading, and utilization of weight carrying capacity of the hull.

In addition to new or evolving Panamax specification, fleet service for harbors on the west of the United States such as Seattle have the potential to be serviced by the new Post-Panamax class(es) of ships, especially where concerns for depth and limitation on air draft of little concern. The primary issue for these carriers is a matter of timing or when they will initiate service, frequency of service, and applicable load factor specifications applicable to the trades involved. These vessels fall within the classification of what could be called Generation IV (and above) Post-Panamax (with the definition of Post-Panamax based on the original or lock specifications of the Canal) or new Post-Panamax based on the new locks expected to be placed into service by 2015. The Generation IV Post-Panamax class of containership have beams exceeding 168 feet through 185 to nearly 190 feet and accordingly this class of ship represent hulls that are considered to clearly exceed the margins for accommodation of the new lock system of the Panama canal and as previously described fall into the realm of what may be considered to the “new” Post-Panamax standard once the new lock system is commissioned into service.

Studies for Seattle Harbor involve the assessment and projection of fleet service to multiple terminals located in separate reaches of the harbor. These include containerized cargo handling facilities located along the East and West Waterways of Seattle Harbor. No bridges exist that impose air draft limitations for these containerized cargo handling facilities within the harbor. Both the East and West Waterways are designed to allow only one-way traffic and no turning basins are included as part of the project with sufficient area and depth to turn vessels in Elliott Bay just outside of the two waterways.

An analysis of the projected needs for Seattle Harbor has determined that both the East and West Waterways will likely support the largest containerships that will serve the harbor via Pacific crossing routes from Asia. The East and West Waterways will need to be designed to support Post-Panamax Generation I-III range vessels projected to serve the U.S. West Coast over the next several years with the potential to eventually support Generation IV or analogous vessels subject to timing and frequency. Terminals 18 and 30 on the East Waterway include Post-Panamax cranes that can handle containerships up to 25 containers wide, whereas the Terminal 5 on the West Waterway is currently undergoing upgrades which will likely include similar cranes to accommodate Post-Panamax Generation IV vessels. Seattle Harbor currently sees frequent calls from Generation II and Generation III containerships, which make up a greater proportion of total calls. The authorized width of the two waterways is 500 feet and this falls within the recommended width to accommodate these existing vessel calls and associated hull designs. Larger containerships (Generations III and IV) would require up to an additional 25 to 75 feet of channel width than the currently authorized channel width, but both channels could be modified to meet this need subject to economic evaluation.

Review of the world fleet indicates that as of July 2012 there were about 200 Generation III ships (i.e., approximately 152 to nearly 168 feet in breadth) in service, under construction, or on order with TEU intake averaging nearly 12,400 nominal TEUs. Of that, about 68 percent were identified as the smaller sub-grouping (between 152 to nearly 160 feet in XB) of Generation III ships. There are about 140 in service, under construction, or on order to be delivered in five years or less with corresponding nominal TEU intake capacities averaging nearly 11,800 TEUS. The upper 50 percent of this sub-group (as measured by TEU capacity) averaged about 13,060 nominal TEUs, 1,200 feet LOA, nearly 1,150 feet lower boundary point (LBP), 158 feet XB, and 51.1 feet in MXSLLD. For ships in the upper bound of the

Generation III class range (with breadths of 160 to nearly 168 feet), review of statistics indicates the larger sub-group of Generation III averaged about 13,740 TEUs, 1,200 feet LOA, 1,047 feet LBP, 168 feet XB, and 51.3 feet in reported MXSLLD. The corresponding upper 50 percent of the sub-group averages approximately 14,000 nominal TEUs, 1,200 feet LOA, 168 feet in XB, and 51.7 feet in reported MXSLLD.

A review of new builds for containerized carriers as supported by the statistics reveal that for containerized carriers, the fixed dimensions of length, breadth, and draught largely converge toward the physical limits of the new locks presently under construction for expansion of the Panama Canal. Further, general evaluation indicates that more recent builds tend to have a greater proportion of nominal TEU capacity per rated deadweight tonnes (DWT) with efforts to more fully support repositioning or prepositioning of empty containers and where possible, better utilize DWT capacity given lashing and line of sight requirements, and typical cargo weights in containerized trade. The upper bound of 50 percent was assessed for sub-groupings as described and past experience has indicated physical dimensions and characteristics in the upper half of a sub-grouping for containerized carriers seem to provide a reasonable estimation for the general trends in characteristics for DWT and nominal TEU capacity for the foreseeable future. To develop parameters for specifications of the future fleet representative of interim to long-term building trends for studies related to Seattle Harbor, the upper 50 percent of fleet groupings or sub-groupings operating and on order as of mid-2012 was selected as the basis for compilation of aggregate statistics representative of the trend toward increased TEUs relative to DWT. Additionally, general review of information for pending or publicized designs indicates the approach as generally described is reasonable for fleet forecast of physical parameters for hull design.

One issue for review of statistics is the specification for MXSLLD. The reported measures of length and breadth currently and historically available are often comparatively accurate across the reporting history of the world fleet database(s). However, the MXSLLD and requisite capacity based on related displacement is sometimes (initially) overstated because of confusion with initial reporting of draft for new builds of either MXSLLD or scantling draft without clarification as to which measure is actually reported or publicized followed by subsequent correction in the fleet characteristics database(s). The publicly stated capacity of the new locks under construction for expansion of the Panama Canal by physical dimension(s) is for a vessel not to exceed the following limits: 160 feet in XB, 50 feet in immersed draft TFW, approximately equal to 49.0 to 48.6 SLL immersion (depending on hull shape and characteristics of displacement), 1,200 feet for LOA, and 190 feet for air draft above the immersed waterline. Research and review of MXSLLD indicates that with increasing breadths very few designs are being developed with MXSLLDs exceeding 50.0 to nearly 51.0 feet. While traditionally it was not uncommon to see Panamax ships with MXSLLDs exceeding canal draught allowances by a notable margin (i.e., typically a world fleet average of 42.0 to 43.0 feet versus the less than 40-foot immersed draft in the saline condition), the threshold of 50.0 to nearly 51.0 feet appears to largely be driven by practical needs as a whole for port and berth depths as well as hydrologic considerations of the canal. With time, it is possible that the trend for increasing port depths will continue beyond limitations of the improved canal but will likely occur several years after canal improvements similar to the way Panamax carriers changed over time after the original locks were constructed and utilized. Accordingly, review of

MXSLLD measurements for Generation II and lesser size carriers (which have been in existence and service comparatively longer than most Generation III hulls) indicate draft measurements are accurately or reasonably reported. However, some degree of adjustment may need to be applied to sub-groupings of Generation III carriers (i.e., hulls between approximately 150 and 158 feet in XB) with adjustment to 50.0 feet MXSLLD and relative capacity based on holding other dimensions and corresponding block coefficient(s) constant for estimation of change in associated displacement and DWT capacity as may be applicable to economic evaluations.

2.8 The Northwest Seaport Alliance

The Northwest Seaport Alliance (NWSA) is the first of this kind in North America. The ports of Seattle and Tacoma joined forces in August 2015 to unify management of marine cargo facilities and cargo business to strengthen the Puget Sound gateway and attract more marine cargo and jobs for the region. The Northwest Seaport Alliance offers shorter U.S.-to-Asia transits, and is the gateway for Alaska.

The NWSA is a port development authority governed by the two ports as equal members, with each port acting through its elected commissioners. Assets are assigned to The Northwest Seaport Alliance on a roughly 50/50 basis by both home ports. These assets, primarily the marine cargo terminals of both ports, are managed by The Northwest Seaport Alliance CEO and staff. Investments in infrastructure will be made with approval of the managing 10 commissioners. The chief executive officer, in carrying out the policies, leads employees and oversees alliance investment programs, business development, and other strategic initiatives.

The boundaries of the alliance include King and Pierce counties.

NWSA terminals made up the third-largest container gateway in 2014 for containerized cargo shipping between Asia and major distribution points in the Midwest, Ohio Valley and the East Coast. It is also a major center for bulk, breakbulk, project/heavy-lift cargoes, automobiles and trucks. It is located adjacent to the second-largest concentration of distribution centers on the West Coast.

Top international trading partners include: China/Hong Kong, Japan, Republic of Korea, Taiwan, Vietnam, Thailand, Canada, Malaysia, and Indonesia.

The value of this two-way international trade totaled more than $73 billion in 2014. Imports were $55 billion and exports were $18 billion of that total.

The Puget Sound is also a major gateway for domestic trade to Alaska. More than 80 percent of the total trade volume between Alaska and the lower 48 states moves through Seattle and Tacoma. Trade with Alaska was estimated at $5.4 billion in 2015. If it were ranked with our international trading partners, Alaska would be fourth. The NWSA also provide connections to Hawaii.

The Northwest Seaport Alliance is a marine cargo operating partnership of the ports of Seattle and Tacoma. Combined, the ports are the third-largest container gateway in North America. Regional marine cargo facilities also are a major center for bulk, breakbulk, project/heavy-lift cargoes, automobiles and trucks.

3 Future Conditions

3.1 Terminal Expansions

The Northwest Seaport Alliance created a 10-year strategic business plan in 2015. The cornerstone of the plan is investment in strategic terminals that have the berth length, water depth, storage acreage and on-dock rail facilities to position them to handle the current and future generations of large containerships most efficiently. Two terminals were identified for strategic investment: Terminal 5 in the Seattle harbor and the General Central Peninsula development in the Tacoma harbor. Terminal 18 already has the cranes and acreage for large ships and berth deepening is anticipated. To better manage terminal utilization and capacity, some smaller, less efficient container terminals in both harbors may be repurposed over time to other maritime uses like breakbulk, autos, bulk or project cargo.

3.1.1 Existing Container Terminal Facilities and Infrastructure

Terminal 5 is undergoing an infrastructure development project to upgrade the berthing area to handle ultra large containerships. The dock infrastructure including crane rail beams is being strengthened to handle up to 12 dual hoist, super post-Panamax container gantry cranes. The power infrastructure is being increased to accommodate new cranes. Slope stabilization and a new toe wall will be constructed to allow deepening to --55 MLLW, and finally dredging will be conducted to bring 2900' of berth to --55 MLLW. Combined with upland improvements and investments in equipment expected to be made by a new tenant, this will create a state of the art terminal with a capacity of over 1 million TEUs.

Terminals 18, 30 and 46 have already undergone dock improvement projects that were finished in 2009. Investments were made in 10 super post-Panamax cranes at that time. Six of the cranes at T-18 have a height and outreach to accommodate an 18,000 TEU ship. Berth deepening of one to two berths at Terminal 18 to better accommodate large ships is in conceptual design at this time.

There are plans underway to lengthen the crane rail beams at Terminal 46 to accommodate two large ships at one time. Two new super post-Panamax cranes will also be purchased by the NWSA.

Significant investments have been made by the Port, City, State and Federal government in the harbor area to facilitate an increased flow of freight traffic. These include grade separations at East Marginal Way and Atlantic Street to separate truck and rail traffic, meaning all terminals are now fully accessible at all times of the day. The North Argo Access project created a dedicated truck entrance to UPRR's intermodal yard. The Spokane Street viaduct project widened the upper structure to accommodate more traffic, reconfigured exits and improved the at grade road surface for heavy vehicles. The City of Seattle has approved a Heavy Haul Corridor for the Seattle harbor area, to which the Port will contribute up to $20 million in road structure improvements for heavy vehicle traffic, benefiting exporters of heavy agricultural and other products like forest products, paper, and metals.

3.2 Operations

3.2.1 Container Terminal Use Plan

As ships get larger, terminal operators throughout North America and globally are continually looking for ways to handle higher densities of cargo most efficiently and cost effectively. Automation is one form of efficiency that is increasingly being implemented. Two terminals on the West Coast of the US and two on the East Coast have been automated. It is expected that the buildout at Prince Rupert and the new Terminal 2 project at Deltaport in Vancouver will employ some form of automation. Prospective terminal operating tenants of Terminal 5 may also consider automation as a way to provide higher levels of efficiencies to their customers.

3.3 Commodity Forecast

3.3.1 Baseline

An essential step when evaluating navigation improvements is to analyze the types and volumes of cargo moving through the port. Trends in cargo history can offer insights into a port's long-term trade forecasts and thus the estimated cargo volume upon which future vessel calls are based. Under future without and future with project conditions, the same volume of cargo is assumed to move through Seattle Harbor. However, a deepening project will allow shippers to load their vessels more efficiently or take advantage of larger vessels. This efficiency translates to savings and is the main driver of National Economic Development (NED).

To minimize the impact of potential anomalies in trade volumes on long-term forecasts, ten years of data were employed to establish the baseline for the commodity forecast. Empirical data from 2010 to 2014 were used to develop a baseline, allowing the forecast to capture both economic prosperity and downturn which occurred over that timeframe. However, given the port slowdown in 2015 and closure of Terminal 5 for upgrades in 2014, the three year period from 2012 to 2014 was considered in the development of the baseline condition. Because the 2014 containerized commodities were lower than the 2012 to 2014 average and the 2015 values, 2014 was used as the basis for developing the baseline forecast and 2013 traffic was used to represent the existing condition.

3.3.1.1 Containerized Imports

Table 3-1 illustrates historical containerized imports moved through the Port of Seattle from 2010 to 2014. Since 2010, overall international imports have declined from nearly 6 million to 3.2 million in 2014. It should be noted that imports did increase in 2015 over 2014, both in terms of weight and TEUs. Trade with the Far East, including China, North Asia, and Southeast Asia, dominates Seattle's market, accounting for nearly 89 percent of import tonnage. The top containerized imports based on 2014 tonnages is non-metallic products; furniture and fixtures; machinery and equipment; motor vehicle parts; and iron and steel. A high percentage of Seattle imports are either consumer goods or raw or intermediate goods that will become consumer goods after going through a manufacturing process. Average imports from all World regions were estimated to total 4.1 million metric tons. Because this import tonnage is higher (at least for the Asia trade routes) than 2014 tonnage, the 2014 tonnages were used to represent the baseline from which forecasted commerce was conducted. However, the weight per loaded TEU by route group presented in Section 2.3.3 was applied for loading vessels with the container loading tool (CLT) Section 4.1.2, which is based on the average weight per loaded TEU from 2012 to 2014.

Table 3-1. Historical Containerized Imports (Metric Tons)

Route Group	2010	2011	2012	2013	2014	Average, 2012-2014
Route 1: Asia, Oceania, and Middle East/Indian Subcontinent	5,657,086	4,854,812	4,689,865	3,450,544	2,717,803	3,619,404
Route 2: Europe, Latin America, Africa, and Middle East/Indian Subcontinent	305,617	444,038	438,557	399,013	511,327	449,632
Total	5,962,703	5,298,850	5,128,422	3,849,557	3,229,130	4,069,036

3.3.1.2 Containerized Exports

Table 3-2 displays historical containerized exports moved through the Port of Seattle from 2010 to 2014. Since 2010, overall international exports have declined from 6.5 million in 2010 to 4.6 million in 2014. It should be noted that exports did increase in 2015 over 2014, in terms of weight but not TEUs. Trade with the Far East accounts for nearly 87 percent of export tonnage. The top containerized exports based on 2014 tonnages is animal feed; fruits and vegetables preserved or dried; paper and newspaper; and fresh apples, pears and plums. Average exports from all World regions were estimated to total 5.4 million metric tons. Because this average export tonnage is higher than 2014 tonnage, the 2014 tonnages were used to represent the baseline from which forecasted commerce was conducted. However, the weight per loaded TEU by route group presented in Section 2.3.3 was applied for loading vessels with the container loading tool (CLT) Section 4.1.2, which is based on the average weight per loaded TEU from 2012 to 2014.

Table 3-2. Historical Containerized Exports (Metric Tons)

Route Group	2010	2011	2012	2013	2014	Average, 2012-2014
Route 1: Asia, Oceania, and Middle East/Indian Subcontinent	5,720,120	6,169,024	5,395,046	4,867,120	3,967,765	4,743,310
Route 2: Europe, Latin America, Africa, and Middle East/Indian Subcontinent	810,661	1,013,798	819,531	650,490	598,771	689,597
Total	6,530,781	7,182,822	6,214,577	5,517,610	4,566,536	5,432,908

Table 3-3 summarizes the baseline for both imports and exports by World region and service route.

Table 3-3. Seattle Harbor Baseline Commodity Forecast (Metric Tons)

Route Group	Imports	Exports	Total
Route 1: Asia, Oceania, and Middle East/Indian Subcontinent	2,717,803	3,967,765	6,685,568
Route 2: Europe, Latin America, Africa, and Middle East/Indian Subcontinent	511,327	598,771	1,110,098
Total	3,229,130	4,566,536	7,795,666

3.3.2 Trade Forecast

The preceding section describes the methodology that was used to develop the import and export baseline. The following sections discuss the methodology employed to develop the import and export long-term trade forecasts.

The long-term trade forecast for the Seattle Harbor study combined data obtained from IHS Global, Inc. and empirical data obtained from the Port of Seattle. Since 1959, IHS has been serving customers ranging from governments and multi-national companies to smaller businesses and technical professionals in more than 180 countries.

First, a baseline was established from historical trade information as discussed in Section 3.3.1. Next, a long-term trade forecast for the U.S. North Pacific, U.S. West Coast and Seattle Harbor was obtained from IHS Global Insight. The IHS Global Insight forecast was obtained in summer 2015. The forecast was developed by applying the growth rates calculated from the commodity forecast for each world region to the baseline tonnage for each trade lane calling on the harbor. This methodology is consistent with the approach that has been used to perform long-term commodity forecasts for other Corps deep draft analyses. In the following sections, the methodology to develop a long-term containerized trade forecast for Seattle Harbor is discussed.

3.3.2.1 IHS Global Insight

In 2015, containerized trade forecasts were obtained from IHS Global Insight, which operates as a research firm to provide economic and financial coverage of countries, regions, and industries. It offers data collection of macro, regional, and global economics; financial markets and securities; survey; U.S. economics; energy; industry; and regional trade.

When making global trade forecasts, IHS Global Insight employs sophisticated macroeconomic models which contain all commodities that have physical volume. The trade forecasts are produced with a system of linked world trade commodity models collectively called the World Trade Model (WTM). The commodities forecast are grouped into IHS Global Insight's own categories derived from the International Standard Industrial Classification (ISIC) and cover 156 ISIC categories. For all trade partners in the world, the WTM has 103 major countries and regions according to their geographic location.

The forecasts of world trade, in both nominal and real commodity value, are converted to physical volume by transportation mode. Primary modes of transportation include air, overland and maritime transport, all measured in metric tons as well as in value. Container trade is measured in twenty-foot equivalent units (TEUs) as well as metric tons.

3.3.2.1.1 IHS Global Insight Trade Data Sources

The primary source of international trade historical data used by IHS Global Insight comes from the United Nations. These commodity trade statistics are collected from member countries' customs agencies. Customs departments have records of both the export side and import side of trade flows. These data cover all UN member countries and non-member economies, such as Taiwan. Because international trade statistics collected by different countries usually have discrepancies and because no one source has complete data, they also use U.S. Customs data and IMF Direction of Trade data to calibrate and supplement historical commodity trade data. Data from different sources are recorded in different classification systems and units of measurements. IHS Global Insight converts data into thousands of current U.S. dollars and then into real commodity value.

IHS Global Insight world trade forecasting models also rely on IHS Global Insight's comprehensive macroeconomic history and forecast databases. Among the data used are population, GDP, GDP deflators, industrial output, foreign exchange rates, and export prices by country. These data are exogenous variables in the trade forecast models. For international commodity prices, IHS Global Insight also obtains data from the U.S. Bureau of Labor Statistics on international import and export prices. Other data, such as foreign direct investment and import tariffs, were also used as determinants of a country's export capacity and import costs.

3.3.2.1.2 IHS Global Insight Model Structure

The basic structure of the IHS Global Insight model for the trade flow of a commodity is that a country's imports from another country are driven by the importing country's demand forces, enabled by the exporting country's capacity of exporting (supplying) the commodity, and affected by the exporting country's price and importing country's import cost for the commodity. A country will import more of a commodity if its demand for this commodity increases. At the same time, the country will import more of this commodity from a particular exporting country if that exporter's capacity to export this commodity is larger and its export price for this commodity is lower than in other exporting countries. Importers will ultimately purchase based on the delivered cost, importing more when the import cost decreases. The distance between two countries is also an important factor in determining the scale of trade between two countries. This model is constructed to capture the dynamics of international trade so that geographic distance as a constant is embedded in determining the scale of the base forecast. Demand forces are commodity specific. Presently, IHS Global Insight groups 156 commodities into two types: (1) those where major demand forces are the importing country's population and income growth; and (2) those where major demand forces are the importing country's production and technology development.

3.3.2.1.3 IHS Global Insight Trade Forecast – 2014

The IHS Global Insight trade forecast for Seattle included 82 countries (e.g. China) or regions (e.g. Other Northeast Asia). First, the data by trade locations were grouped by the world region where they are geographically located, as shown in Table 3-4. The world regions included Asia, Middle East/Indian Subcontinent, Europe, Latin America and Caribbean, Oceania, Africa, and Canada. These world regions were then combined into the two route groups for Seattle Harbor based on historical services calling the Port, broadly defined as Route 1, Asia, and Route 2, Mediterranean as shown in Table 3-5. The Asia route group includes all trade with Asia, Oceania, and approximately half of the trade with the Middle East/Indian Subcontinent. The Mediterranean route group includes as single service which serves Europe, Latin America and Caribbean, Africa, and the remaining half of trade with the Middle East/Indian Subcontinent. Although Canada is a major trading partner with the U.S., most of these cargos are not in the form of ocean transported containers and were therefore not included in the forecasts for these two route groupings. The Middle East/Indian Subcontinent cargo is distributed evenly between the two route groups given no services directly call these regions but cargo is transported to/from these regions to ports directly served on the two route groups. Less than ten percent of overall cargo is associated with this region.

It should be noted that disaggregation of the Asia route group was evaluated, but not pursued, given all of the services call Northeast Asia (China, South Korea, Japan, Taiwan, Hong Kong, Other Northeast Asai) and half of the Asia services also call Southeast Asia (Vietnam, Malaysia, Thailand, Indonesia, Philippines, Singapore, Other Southeast Asia). Much of the cargo imported and exported is from China, South Korea, Japan, Vietnam, and Malaysia. China accounts for nearly three quarters of Asia cargo on average, and Northeast Asia accounts for approximately 90 percent of Asia cargo overall. Given the high proportion of cargo in Northeast Asia and specifically China, disaggregation of the Asia route group is not expected to have a significant impact in the transportation cost savings analysis. Distances for the Asia route group considers the weighting of cargo for each of the assigned services as shown in Section 4.1.1.2.

Table 3-4. Seattle Trade Partner and World Region Groupings

World Region	IHS Global Insight World Trade Regions
Asia	China, Japan, South Korea, Hong Kong, Taiwan, Indonesia, Malaysia, Thailand, Vietnam, Philippines, Singapore, Other Southeast Asia, Other Northeast Asia
Middle East/ Indian Subcontinent	India, United Arab Emirates, Saudi Arabia, Pakistan, Egypt, Russia, Indian Subcontinent Islands, Kuwait, Israel, Bahrain, Qatar, Southern Arabian Peninsula, Other Mediterranean, Other Indian Subcontinent, Other Western Asia
Europe	Ukraine, Germany, Turkey, Spain, Italy, Belgium, United Kingdom, Netherlands, Baltics, Portugal, France, South Caucasus, Greece, Bulgaria, Denmark, Austria, Romania, Switzerland, Slovak Republic, Sweden, Czech Republic, Ireland, Other Europe
Latin America & Caribbean	Chile, Peru, Colombia, Brazil, Greater Antilles, Bahamas and Bermuda, Mexico, Ecuador, Lesser Antilles, Bolivia, Argentina, Central America North, Central America South
Oceania	Australia, New Zealand, Pacific Islands
Africa	Southern Africa, Kenya, Morocco, Nigeria, Libya, Algeria, Ghana, Cote d'Ivoire, Southern African Islands, Central Africa North, East Africa Center, Central Africa South, East Africa North, Other Southern Africa, Other Western Africa East
Canada	Canada

Table 3-5. Seattle Route Groups and World Regions

Route Group	World Regions
Route 1: Asia	Asia, Oceania, and 50% of Middle East/Indian Subcontinent
Route 2: Mediterranean	Europe, Latin America & Caribbean, Africa, and 50% of Middle East/Indian Subcontinent

3.3.2.1.3.1 IHS Global Insight Containerized Imports

The IHS Global Insight database obtained for Seattle Harbor contained over 646,000 rows of cargo-related data. Table 3-6 displays their imports forecast in metric tons for select years occurring over the forecast period using their low growth estimates. The assumption to use low growth estimates is based on comparison of 2015 actual data to IHS Global Insight forecasts for 2015, as well as slowed economic growth in China, the predominate trading partner for the Port of Seattle. The world region aggregate was developed by combining the tonnage from each country or region identified in Table 3-6. Asia represents 82 percent of containerized imports in 2016. The IHS Global Insight forecast indicates that Asia will dominate Seattle imports, growing to 5.9 million tons by 2035.

Table 3-6. IHS Global Insight's Seattle Containerized Trade Forecast - Imports

World Region	2016	2020	2025	2030	2035	2040	2045
Asia	2,899,686	3,423,145	4,260,431	5,110,001	5,889,802	6,743,784	7,681,030
Middle East/ Indian Sub.	197,035	227,195	264,902	306,597	351,785	401,643	452,976
Europe	256,623	291,408	345,782	414,661	492,869	582,505	689,009
Latin Amer & Car	165,357	180,977	205,145	239,034	279,855	325,785	376,809
Oceania	16,080	16,977	17,784	18,931	20,228	21,339	22,166
Africa	23,493	26,073	30,531	36,515	44,120	53,464	65,106
Total (inc. Canada)	3,558,539	4,166,074	5,124,916	6,126,128	7,079,094	8,128,995	9,287,604

The import forecast rate of change between each year is shown in Table 3-7. The rate of change was calculated from the annual commodity forecast developed by IHS Global Insight. The data illustrate that economic conditions are cyclical and that the fastest growth will take place in the Asia, Europe, Africa, and Middle East/Indian Subcontinent regions.

Table 3-7. Seattle Harbor Import Forecast - Rate of Change (%)

Route Group	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Asia	5%	5%	6%	4%	3%	3%	4%	4%	4%	5%	5%	5%	4%	3%	3%	3%	3%	3%	3%	3%
Middle East/ Indian Sub.	3%	6%	6%	4%	2%	2%	3%	3%	3%	3%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Europe	3%	4%	4%	3%	3%	3%	3%	3%	3%	4%	4%	4%	4%	4%	3%	4%	4%	4%	4%	3%
Latin Amer & Car	-1%	3%	3%	2%	2%	2%	2%	3%	2%	2%	3%	3%	3%	3%	3%	4%	3%	3%	3%	3%
Oceania	1%	6%	4%	2%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	1%	2%	1%	1%
Africa	3%	4%	4%	3%	2%	2%	3%	3%	3%	3%	4%	4%	3%	3%	3%	4%	4%	4%	4%	4%

3.3.2.1.3.2 IHS Global Insight Containerized Exports

The Asia world region represents 79 percent of containerized exports in 2016 as shown in Table 3-8. Exports to Asia are forecast to total 3.8 million tons in 2016 and grow to 8.8 million tons in 2035. Similarly, exports to the Middle East/ Indian subcontinent are forecast to total 0.7 million tons in 2016 and grow to 2.2 million tons in 2035.

Table 3-8. IHS Global Insight's Seattle Containerized Trade Forecast - Exports

World Region	2016	2020	2025	2030	2035	2040	2045
Asia	3,767,009	4,568,876	6,012,985	7,416,889	8,782,951	10,361,189	12,081,019
Middle East/ Indian Sub	712,380	957,545	1,366,719	1,766,289	2,205,899	2,731,373	3,318,920
Europe	113,197	130,774	158,441	183,570	208,589	235,302	260,989
Latin Amer & Car	104,765	117,749	140,340	162,003	183,043	205,892	227,647
Oceania	38,980	42,777	48,582	53,212	57,457	61,470	64,564
Africa	23,648	27,954	34,373	41,088	48,045	55,994	64,182
Total (inc. Canada)	4,760,934	5,846,699	7,762,586	9,624,316	11,487,354	13,652,688	16,018,861

The export forecast rate of change estimates are shown in Table 3-9, with the greatest growth occurring for exports to the Middle East/ Indian subcontinent and Asia.

Table 3-9. Seattle Harbor Export Forecast - Rate of Change (%)

Route Group	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Asia	2%	3%	4%	4%	6%	6%	6%	5%	5%	6%	6%	5%	5%	4%	4%	3%	4%	3%	3%	3%
Middle East/ Indian Sub.	0%	5%	6%	7%	8%	9%	8%	8%	7%	7%	7%	6%	6%	5%	5%	5%	5%	5%	5%	5%
Europe	-9%	2%	2%	3%	5%	5%	5%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Latin Amer & Car	-6%	1%	1%	3%	4%	4%	4%	4%	3%	4%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%
Oceania	-3%	0%	1%	2%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Africa	-12%	1%	3%	4%	5%	5%	5%	4%	4%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%

3.3.3 Port of Seattle Long Term Trade Forecast – Methodology for Container Services

Numerous container services call on Seattle Harbor which are operate by several carriers (e.g. Cosco, Hanjin, Hapag Lloyd, OOCL, CMA CGM, Maersk, MSC) and have trade routes which originate in Asia (Singapore, Hong Kong, Kobe, Port Kelang, Ningbo) or Europe (Gioia Tauro). See Section 2.3.2 for carriers and trade lanes included in this analysis. Given constantly changing alliances on trans-Pacific trade routes, six services originating in Asia which access the U.S. West Coast via the Pacific Ocean (trans-Pacific) were combined into a single route group, “Asia”. Distances of the services included in the route group were evaluated to determine minimum, most likely, and maximum sailing distances in nautical miles to prior port, next port, and the remaining sailing distance.

The route group “Mediterranean” represents a single service which calls Seattle and other U.S. West Coast and Canadian West Coast Ports via the Panama Canal. This service connects to North Europe, South America, Central America, Africa, Middle East and the Indian subcontinent.

Table 3-10 and Table 3-11 present the import and export growth rates that were developed by generating two route groups to represent all world regions: Asia and Mediterranean, respectively. In all, seven services were combined into two route groups for this analysis as just described.

It should be noted that each trade route contains unique characteristics such as cargo volume, cargo weight, ports of call, vessel types, mix of vessels, etc., and are therefore evaluated separately before being combined as part of the National Economic Development (NED) analysis presented in the next chapter. Both route groups will benefit from channel modification at Seattle Harbor. One container terminal, Terminal 46, is located outside of the East and West Waterways, but was included in the evaluation of future vessel calls.

Table 3-10. Seattle Harbor Import Forecast - Rate of Change (%)

Route Group	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Asia	5.4%	5.3%	5.7%	4.3%	3.4%	3.4%	3.8%	4.2%	4.3%	4.5%	5.3%	4.8%	4.3%	3.5%	2.9%	2.9%	3.1%	3.1%	2.8%	2.8%
Med	2.1%	4.2%	4.2%	3.2%	2.3%	2.3%	2.7%	3.1%	3.0%	3.1%	3.8%	3.6%	3.3%	3.2%	3.2%	3.7%	3.3%	3.5%	3.4%	3.2%
Total	4.8%	5.1%	5.5%	4.2%	3.2%	3.2%	3.7%	4.0%	4.1%	4.3%	5.1%	4.6%	4.2%	3.4%	3.0%	3.0%	3.1%	3.2%	2.9%	2.8%

Table 3-11. Seattle Harbor Export Forecast - Rate of Change (%)

Route Group	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Asia	1.5%	3.4%	3.8%	4.6%	6.0%	6.3%	6.0%	5.4%	5.6%	6.0%	6.0%	5.5%	5.0%	4.3%	3.8%	3.2%	3.7%	3.5%	3.4%	3.5%
Med	-3.5%	3.5%	4.2%	5.7%	6.9%	7.3%	6.9%	6.5%	5.8%	5.9%	5.6%	5.3%	4.9%	4.6%	4.1%	4.0%	4.1%	3.9%	3.9%	4.0%
Total	0.8%	3.4%	3.9%	4.7%	6.1%	6.5%	6.1%	5.5%	5.6%	6.0%	5.9%	5.5%	5.0%	4.3%	3.8%	3.3%	3.8%	3.6%	3.5%	3.6%

3.3.3.1 Containerized Import Trade

The respective world region route import rates of change were applied to the 2014 baseline to estimate the Seattle Harbor long-term import forecast, as shown in Table 3-12. Port capacity is not forecast to be reached during the planning period of analysis. The long-term forecast to 2034 was included in the economic analysis presented in the next chapter of this appendix given the expectation that port capacity will not be exceed over the planning period of analysis. As shown in the table, the Asia or trans-Pacific trade will continue to dominate Seattle imports over the forecast period, growing from approximately 2.7 million tons in the 2014 baseline to 5.9 million tons in 2034.

Table 3-12. Seattle Containerized Trade Forecast – Import Tons

Route Group	2014 Baseline	2024	2029	2034	2044
Asia	2,717,803	4,188,657	5,133,773	5,932,367	7,735,505
Mediterranean	511,327	687,702	813,330	962,668	1,317,264
Total Imports	3,229,130	4,876,359	5,947,103	6,895,035	9,052,769

3.3.3.2 Containerized Export Trade

The export tons forecast is shown in Table 3-13. As with imports, exports to Asia are forecast to dominate Seattle export trade over the period of the forecast, growing from 4.0 million tons in 2014 to 9.6 million tons in 2034.

Table 3-13. Seattle Containerized Trade Forecast – Export Tons

Route Group	2014 Baseline	2024	2029	2034	2044
Asia	3,967,765	6,363,367	8,093,702	9,606,623	13,394,589
Mediterranean	598,771	962,723	1,221,085	1,484,168	2,140,758
Total Exports	4,566,536	7,326,090	9,314,787	11,090,791	15,535,347

According to IHS Global Insight, Asian countries will rise in prominence as Seattle's premier trading partners. These countries will be demanding agriculture products and other raw commodities for growing population demands and to process into final goods for sale domestically and abroad. Examples of high-volume, high-growth containerized commodities moving out of Seattle are animal feed, fruits and vegetables, paper and newspaper. Relatively slower growth rates in 2014-2020 compared to 2020-2035 reflects weaker world economic growth and a stronger U.S. dollar.

Using the containerized trade forecast for imports and exports and the average weight per loaded container (in terms of twenty-foot equivalent units, or TEUs), a loaded container forecast was developed. Table 3-14 provides the loaded import and export TEU forecast, along with the weight per loaded container for the two route groups.

Table 3-14. Seattle Loaded TEU Forecast – Import and Export

Route Group	Weight per Loaded Import TEU	2024	2029	2034
Asia	9.0	465,406	570,419	659,152
Mediterranean	10.7	64,271	76,012	89,969
Total Imports		**529,677**	**646,431**	**749,121**
Route Group	**Weight per Loaded Export TEU**	**2024**	**2029**	**2034**
Asia	14.2	448,124	569,979	676,523
Mediterranean	13.7	70,272	89,130	108,333
Total Exports		**518,396**	**659,109**	**784,856**

From the loaded TEU forecast, empty TEUs by route group were developed. The percentage of empty TEUs to loaded TEUs for both import and export by route group was derived from historical data obtained from the Port of Seattle. These percentages were then used to forecast empties to 2034 as shown in Table 3-15.

Table 3-15. Seattle Empty TEU Forecast – Import and Export

Asia	Average of % Empty In	Average of % Empty Out	Average of % Empty In and Out
Sub-Panamax	21.64%	16.40%	22.28%
Panamax	11.42%	31.74%	19.17%
PPX Gen I	15.69%	33.14%	24.86%
PPX Gen II	16.74%	30.90%	21.18%
PPX Gen III	15.78%	27.61%	21.22%
Asia Total	***17.01%***	***29.08%***	***21.10%***
Mediterranean	**Average of % Empty In**	**Average of % Empty Out**	**Average of % Empty In and Out**
Sub-Panamax	36.94%	20.02%	29.57%
Panamax	33.80%	11.33%	22.26%
PPX Gen I	15.35%	2.92%	9.74%
PPX Gen III	18.19%	5.39%	12.44%
Mediterranean Total	***32.53%***	***13.74%***	***23.19%***
Grand Total	**19.38%**	**26.60%**	**21.39%**

The total number of TEUs, included loaded and empty containers, by import and export, and route group are shown in Table 3-16. Import TEUs are forecasted to grow from 793,000 in 2024 to 1.1 million in 2034, and increase of 42.2 percent. Export TEUs are forecasted to grow from 1,095,000 in 2024 to 1,660,000 in 2034, and increase of 51.6 percent. The compound average growth rate (CAGR) for each route represents the geometric average growth of imports and exports, which accounts for the effect of compounding over time. For Asia trade, export are projected to grow from 972,000 to 1.5 million over the 10-year period at a CAGR of 4.2 percent per year.

Table 3-16. Seattle Total TEU Forecast by Route for Imports and Exports

Total TEUs - Imports	**2024**	**2029**	**2034**	**CAGR**
Asia	703,100	863,227	999,993	3.59%
Mediterranean	90,211	107,670	128,464	3.60%
Total	**793,311**	**970,897**	**1,128,457**	3.59%
Total TEUs - Exports	**2024**	**2029**	**2034**	**CAGR**
Asia	975,331	1,240,854	1,473,717	4.21%
Mediterranean	119,456	152,453	186,300	4.54%
Total	**1,094,787**	**1,393,307**	**1,660,017**	4.25%
Total Overall TEUs	**2024**	**2029**	**2034**	**CAGR**
Asia	1,678,431	2,104,081	2,473,710	3.95%
Mediterranean	209,667	260,123	314,764	4.15%
Total	**1,888,098**	**2,364,204**	**2,788,474**	**3.98%**

3.4 Vessel Fleet Forecast

3.4.1 World Fleet

In addition to a commodity forecast, a forecast of the future fleet is required when evaluating navigation projects. To develop projections of the future fleet calling at Seattle, the study team obtained a World Fleet forecast of containerships developed by Maritime Strategies Inc. (MSI), a methodology to forecast total capacity calling at Seattle Harbor, and a breakdown of that capacity calling into containership size and TEU classes.

The methodology developed by MSI was then linked to the IHS commodity forecast data for U.S. West Coast and Seattle. The commodity forecasts were unconstrained forecasts and consequently MSI's model is similarly unconstrained in respect to inter-port competition on the U.S. West Coast or the newly formed Northwest Seaport Alliance. Further, MSI did not consider land-based infrastructure as a limiting factor in its projections of the World Fleet. Table 3-17 shows the fleet subdivision using common vessel labeling terminology and vessel specifications for design draft, beam, and length overall (LOA).

Table 3-17. Fleet Subdivisions on Draft, Beam, and LOA (in feet)

Vessel Fleet Subdivision (Containerships)		From	To
Sub Panamax (MSI size brackets: 0.1-1.3, 1.3-2.9 k TEU)	**Beam**		98
	Draft	8.2	38.1
	LOA	222	813.3
Panamax (MSI size brackets: 1.3-2.9, 2.9-3.9, 3.9-5.2, 5.2-7.6 k TEU)	**Beam**	98	106
	Draft	30.8	44.8
	LOA	572	970
Post-Panamax (Generation I Post-Panamax) (MSI size brackets: 2.9-3.9, 3.9-5.2, 5.2-7.6, 7.6-12 k TEU)	**Beam**	106	138
	Draft	35.4	47.6
	LOA	661	1045
Super Post-Panamax (Generation II Post-Panamax) (MSI size brackets: 5.2-7.6, 7.6-12 k TEU)	**Beam**	138	144
	Draft	39.4	49.2
	LOA	911	1205
Ultra Post-Panamax (New Panamax, or Generation III Post-Panamax) (MSI size brackets: 5.2-7.6, 7.6-12, 12 k + TEU)	**Beam**	144	168
	LOA	Up to	1220
New Post-Panamax (or Generation IV Post-Panamax) (MSI size brackets: 12 k + TEU)	**Beam**	168	200

By combining information from the commodity forecast with MSI's forecasted fleet capacity and Seattle's average share of cargo on a containerized vessel, the study team was able to allocate a number of post-Panamax, Panamax, and sub-Panamax vessels calls to Seattle's fleet. The number of transits, particularly those made by larger vessels, is a key variable in calculating the transportation costs. MSI's forecasting technique begins with performing a detailed review of the current world fleet and how it is deployed on the trade routes of the world. Forecasting of the world fleet was made possible through MSI's proprietary Container Shipping Planning Service (CSPS) model (Figure 3-1), which applies historical and forecasted time series data from 1980 to 2035 for:

- Macroeconomic indicators
- Global container trade and movements by region
- TEU lifts by type (primary/transshipment and full/empty) and by region
- Bilateral trade data for major routes
- Containership supply and fleet developments by vessels size range
- Explicit scrapping, cancellation and slippage assumptions
- Time-charter rates, freight rates and operating costs by segment
- Newbuilding, secondhand (by age) and scrap prices by segment

Data sources for the CSPS model include:

- Macroeconomics: Oxford Economics, leading investment banks;
- World Trade: UNCTAD, Drewry Shipping Consultants, Containerization International;
- Fleet Supply: LR-Fairplay, Worldyards, Howe Robinson;
- Charter Rates, Freight Rates and Vessel Prices: Drewry Shipping Consultants, Howe Robinson, Clarksons and various contacts at shipping lines; and

- World Trade history is provided by UNCTAD, Drewry Shipping Consultants and Containerization International. MSI's forecast for trade in dry goods, including containerized trade, are derived from a series of constantly evolving econometric relationships between trade volumes and macroeconomic drivers. The latter drivers are country/regional specific and form the proprietary core of MSI's business.

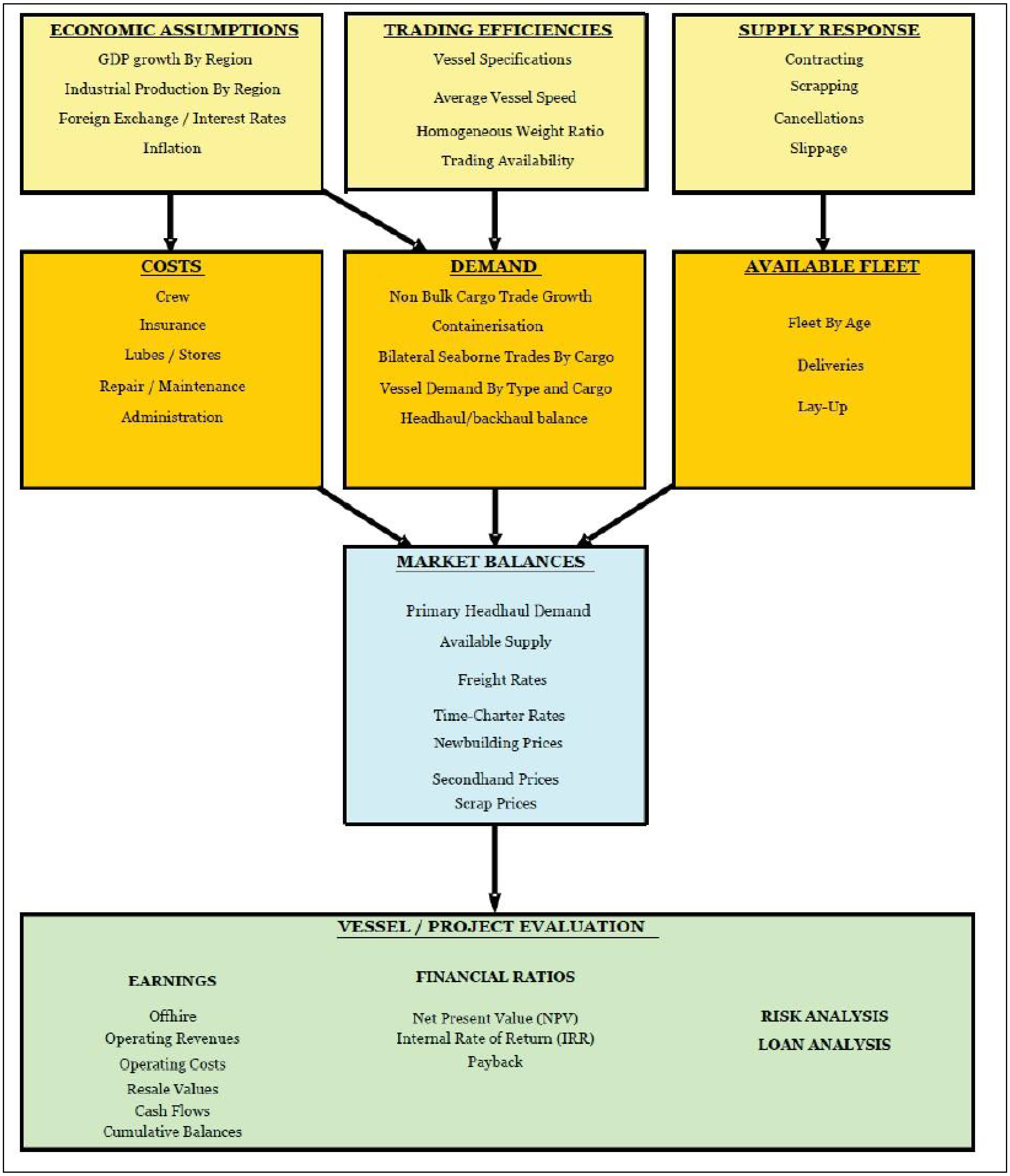

Figure 3-1. Schematic Overview of MSI's CSPS Model

When evaluating data on vessel composition, vessel age, and container markets, MSI considered the "order book" to estimate new deliveries to the fleet into the future. Vessel scrapping is accounted for based on historical scrapping rates by vessel class and age. Containerships, particularly the largest ones, are relatively new, so widespread scrapping is not expected to take place until well in the future. Likewise, when economies are strong, vessel owners are more likely to hold onto their existing vessels (or build new ones) and less likely to scrap them. The forecasted world fleet provides a frame of reference to verify the validity of the Seattle fleet forecast and is provided as background information.

As new larger vessels become a greater percentage of the world fleet and are deployed to Seattle, they replace smaller vessels which are redeployed to shorter routes, which may utilize the smaller vessels more efficiently.

There is a strong relationship between the economic condition of a port and its total nominal vessel capacity. As an economy grows, exports from the port often increase (from the increased output) or demand for imports increase (from increased consumer purchasing power). Vessels respond accordingly to satisfy this increased level of trade. In the Charleston port deepening study, MSI examined the empirical relationship between the nominal capacity of the fleet calling at the port and the historical tonnages moving through the port. MSI found the variables to be highly correlated, having an R-squared value of 0.967. The same statistical relationship observed in that port's study was then applied to Seattle's forecasted tonnages in order to estimate future nominal TEU vessel capacity calling Seattle. As the tonnage in Seattle grows over time, the nominal TEU vessel capacity, i.e., the total number of available container slots, grows. Capacity is adjusted by operators to match demand. Once the forecasted nominal TEU vessel capacity at Seattle was determined, the future containers were allocated to various vessel classes (post-Panamax, Panamax, and sub-Panamax). The allocation to vessel classes was based on MSI's examination of historical utilization of Panamax vessels, current trends in vessel design and orders, and the worldwide redeployment of vessels affected by the expansion of the Panama Canal.

3.4.1.1 World Fleet End of Period 2014

A projection of the World Fleet provides the necessary background for evaluating the future fleet forecast for Seattle. The starting point for this projection was the world fleet by Bessel class as extracted by MSI from the Lloyd's Register (LR)-Fairplay database for the years 2013 and 2014[15]. The fleet is shown by TEU band in Table 3-18.

Table 3-18. World Fleet by TEU Band - 2013 and 2014

TEU Band	2013	2014
0.1 - 1.3 k TEU	1,600	1,557
1.3 - 2.9 k TEU	1,352	1,333
2.9 - 3.9 k TEU	303	295
3.9 - 5.2 k TEU	762	750
5.2 - 7.6 k TEU	519	536
7.6 - 12 k TEU	379	438
12 k TEU +	151	193
TOTAL	**5,066**	**5,102**

[15] LR-Fairplay maintains the largest maritime databases covering ships, movements, owners and managers, maritime companies, ports and terminals.

3.4.1.2 The "Order Book"

The "order book" is short hand for the vessels that have been contracted to be built by ship builders around the world. Vessel deliveries are primarily the function of new building contracting. These contracts can take several forms. There are firm contracts for vessels that are under construction. There are also option contracts that secure the capacity of the shipyard but do not require the buyer to exercise the option to construct the vessel. Some contracts have financing that is committed; others do not. There are several other nuances and the challenge is to translate the number of vessels and types of contracts into future vessels coming online at a specific time. This requires knowledge and expertise of this market and this process. Forecasts must be made for future contracts, vessel scrapping, and vessel deliveries[16]. Over the long term, new building investment tends to equate to the incremental demand for new tonnages to meet cargo growth or replacement of aged or obsolete ships.

A historical breakdown of contracting by TEU band was accomplished using a widely recognized fleet database provided by LR-Fairplay. The breakdown was expressed as a percentage of ships for each TEU band size. These percentages were used as a baseline for forecast future contracting. Figure 3-2 depicts historical and future forecasted contracting by TEU bands for fully cellular container (FCC) vessels[17] for years 2000 to 2035.

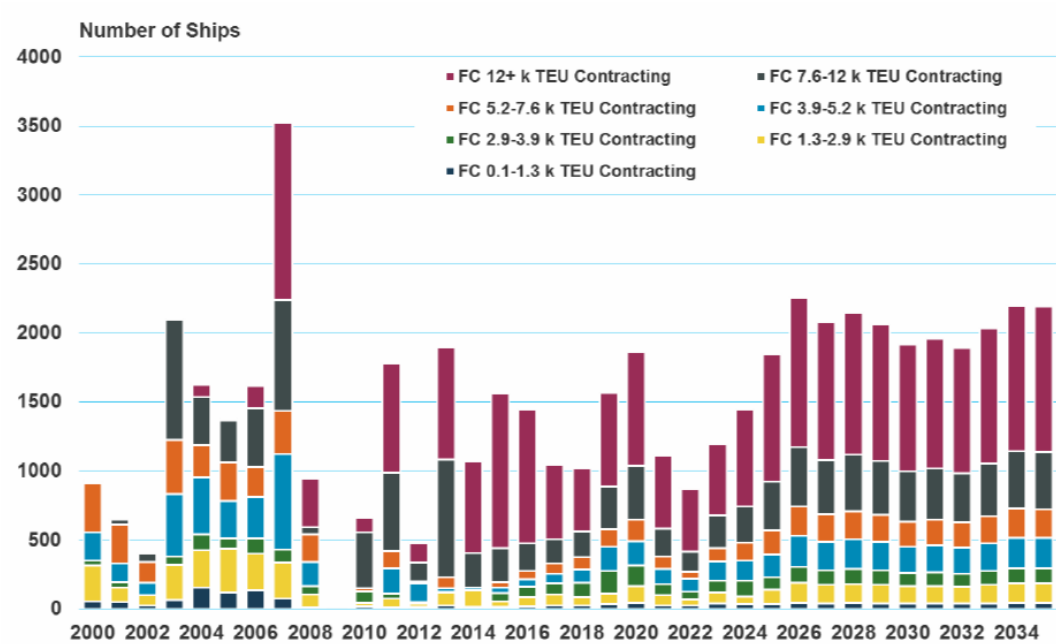

Figure 3-2. Containership Contracting, 2000-2035 (Source: MSI 2015)

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16 Factors such as economic conditions, price of steel, exchange rates, and a host of others can influence the forecasted world fleet.

17 The term "fully cellular" refers to vessels that are purpose built to carry ocean containers. The containers are generally stored in vertical slots on the ship.

3.4.1.3 Deliveries and Scrapping Assumptions

MSI modeled the relationship between annual contracting and annual deliveries by TEU band. The forecast of deliveries by TEU band are depicted in Figure 3-3. The number of new vessel deliveries is expected to increase each year until a 2030 peak, and then taper off to the end of the forecast period, with an upward bounce in 2034.

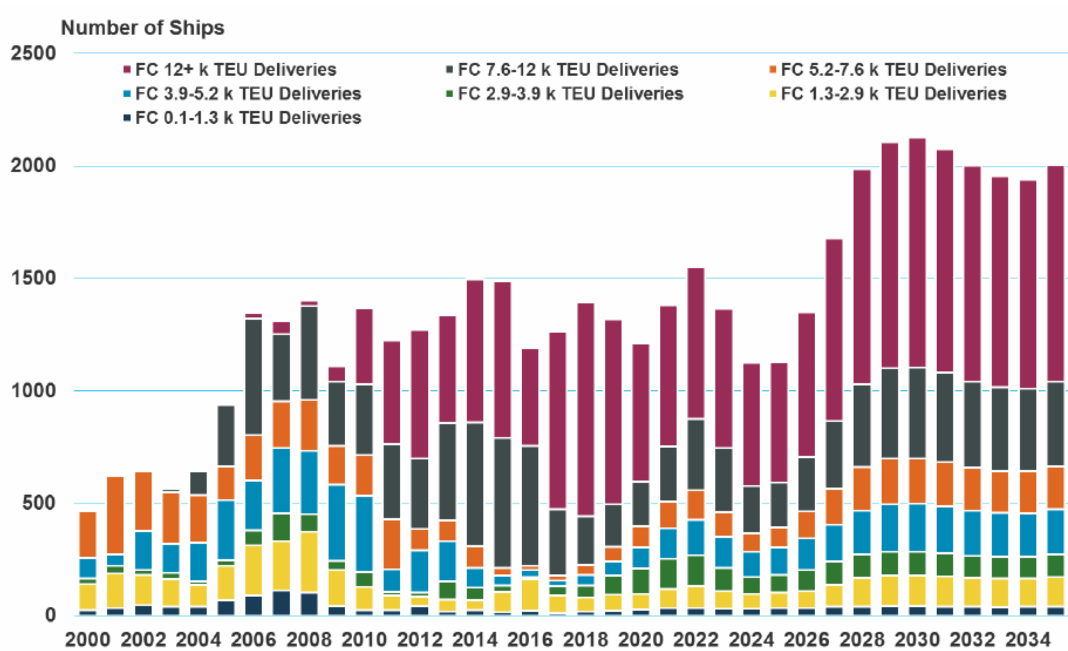


Figure 3-3. Containership Deliverables, 2000-2035 (Source: MSI 2015)

An estimate of annual scrapping was accomplished by examining the LR-Fairplay database for the world fleet each year and noting which vessels drop out each year. This was done by TEU band and transformed into a scrapping profile for each band. Figure 3-4 shows the estimated scrapping by TEU band class.

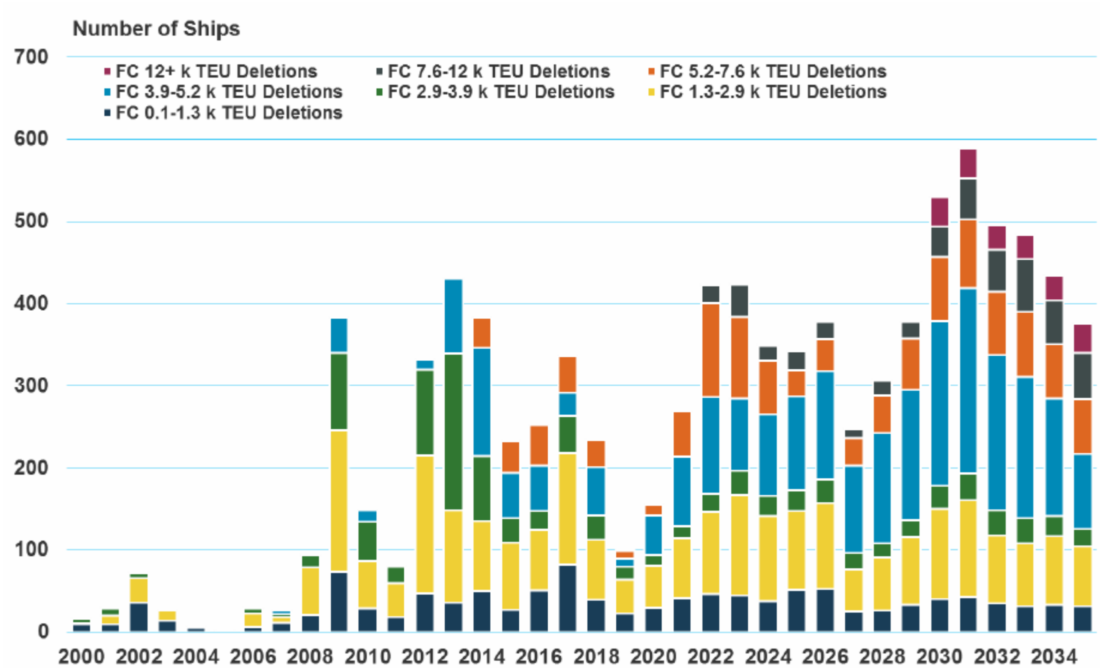


Figure 3-4. Containership Deletions, 2000-2035 (Source: MSI 2015)

3.4.1.4 World Fleet Forecast

With data for deliveries, scrapping, and the 2011 fleet calculated, forecast of the fleet for the end of each forecast year was estimated using the following equation:

$$Fleet\ EoP\ (Year) = Fleet\ EoP\ (Year-1) + Deliveries\ (Year) - Scrapping\ (Year)\ EoP = End\ of\ period$$

Figure 3-5 displays the world FCC forecast by TEU band through 2035.

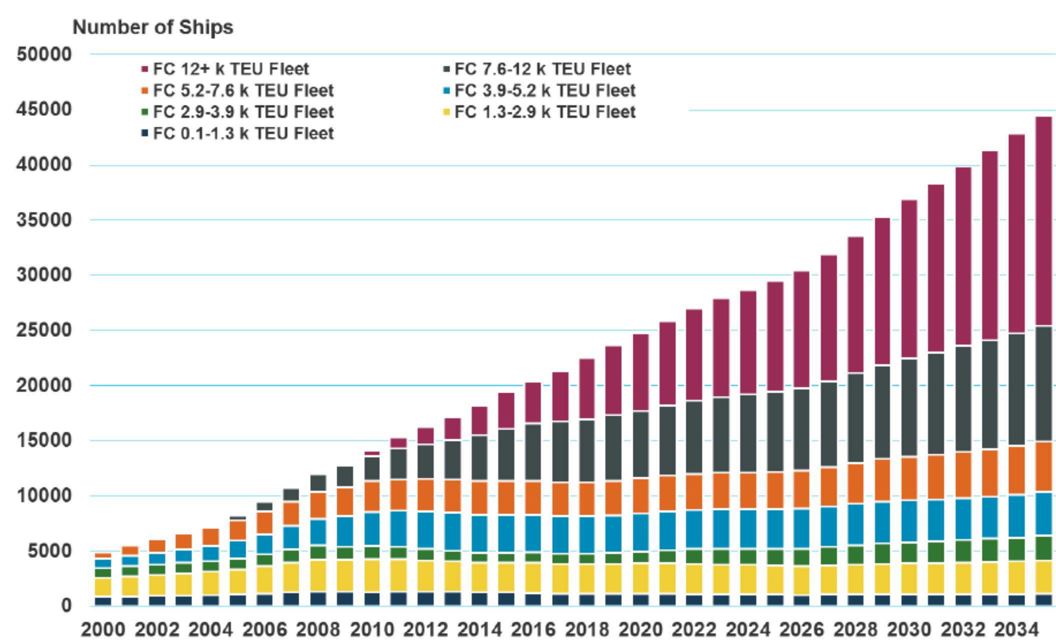


Figure 3-5. World Fleet, Historical and Forecasted FCC by TEU Band, 2000-2035 (Source: MSI 2015)

Figure 3-6 shows the net growth in selected Post-Panamax TEU bands from the 2014 fleet. The figure shows the additional vessels added to the fleet. These types of vessels are a key factor in the evaluation of port deepening studies such as Seattle Harbor.

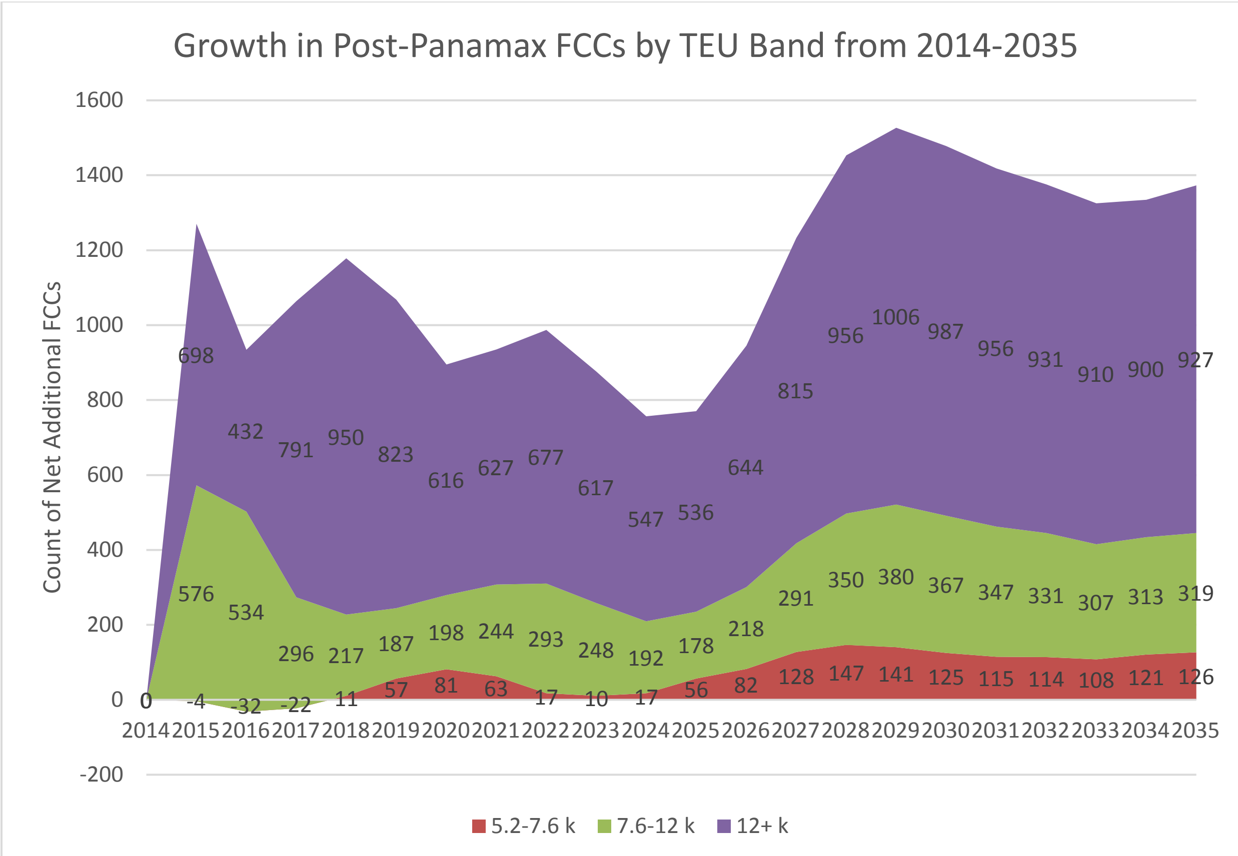


Figure 3-6. World Fleet Net Growth Forecast of Selected TEU Bands

3.4.2 Container Vessels Calling at Port of Seattle

3.4.2.1 Trade Through North America and Port of Seattle Vessel Capacity

MSI developed a forecast of future deployed capacity for the United States based on historical deployment pulled from AXS Alphaliner's vessel deployment database. This data is grouped by trade route to find deployed capacity by route. The forecast then determines the percentage of deployment capacity for the West Coast based on historical distribution by trade route. The forecast is narrowed again to determine Seattle's share of the fleet distribution.

MSI used the historical fleet deployment and capacity as a baseline for forecasting the future fleet. Using a simple linear regression model with headhaul trade as the predictor of port capacity deployment, MSI predicted total number of calls at Seattle. MSI found a correlation between Seattle's headhaul trade and its expected TEU nominal capacity with a correlation coefficient of .6912 and a coefficient of determination of .4778. The correlation equation is as follows:

$$\text{Nominal Capacity} = 1.88(\text{TEU}) + 1{,}615{,}246$$

Table 3-19 and Table 3-20 show the historical calls at Port of Seattle by Size band and the percent share of the calls.

Table 3-19. Historical Vessel Calls at Port of Seattle by TEU Band, 2006-2011

Vessel Class	2006	2007	2008	2009	2010	2011	2012	2013	2014
0.1-1.3 k TEU	112	78	112	113	107	123	38	14	2
1.3-2.9 k TEU	185	141	154	171	178	165	177	126	117
2.9-3.9 k TEU	332	338	278	274	266	172	191	176	108
3.9-5.2 k TEU	54	48	47	59	135	236	177	135	104
5.2-7.6 k TEU	-	-	-	3	9	2	1	17	82
7.6-12+ k TEU	-	-	-	-	-	-	-	-	-
Total	683	605	591	620	695	698	584	468	413

Table 3-20. Historical Share of Nominal Vessel Capacity Calling by TEU Band

Vessel Class	2006	2007	2008	2009	2010	2011	2012	2013	2014
0.1-1.3 k TEU	1%	0%	0%	0%	0%	0%	0%	0%	0%
1.3-2.9 k TEU	6%	5%	7%	8%	9%	12%	10%	5%	2%
2.9-3.9 k TEU	3%	0%	0%	1%	1%	1%	0%	2%	0%
3.9-5.2 k TEU	31%	24%	23%	21%	20%	22%	19%	17%	18%
5.2-7.6 k TEU	59%	59%	59%	59%	59%	59%	59%	59%	59%
7.6-12+ k TEU	0%	0%	0%	7%	24%	38%	24%	22%	46%

3.4.2.2 Forecasted Vessel Capacity Calling Port of Seattle

The Port of Seattle TEU forecast was used to estimate total annual nominal capacity calling at Seattle for the years 2015 to 2034. The forecast was developed using the linear regression equation shown in Equation 2. Once the study team determined the total annual nominal capacity over the period of analysis, the estimated capacity was allocated into TEU bands since this demand is likely to be satisfied by a range of vessels. The allocation was based on TEU band shares developed by MSI.

3.4.2.3 Forecasted Post-Panamax Share of Vessel Capacity

The forecasted capacity calling at Seattle was allocated to Post-Panamax vessel classes according to MSI's forecast of capacity share, as shown in Table 3-21.

Table 3-21. Forecasted Share of Post-Panamax Vessel Capacity

Vessel Class	2014	2024	2029	2034
0.1-1.3 k TEU	0%	0%	0%	0%
1.3-2.9 k TEU	3%	0%	0%	0%
2.9-3.9 k TEU	0%	0%	0%	0%
3.9-5.2 k TEU	21%	0%	0%	0%
5.2-7.6 k TEU	11%	10%	4%	0%
7.6-12 k TEU	63%	58%	37%	15%
12 k TEU+	2%	32%	60%	85%

3.4.2.4 Initial Forecast of Post-Panamax Vessel Calls at Port of Seattle

The PDT developed fleet forecast using MSI projections as well as internal analysis of Port of Seattle historical calls. Namely, the study team used MSI forecasted share of capacity by vessel class to distribute forecasted tonnage. The PDT then used historical average percent empty containers, arrival drafts, and box weights to determine the number of calling vessels.

The initial forecast of containerized vessels through the year 2037 is depicted in Figure 3-7 and

Table 3-22. These values were input into HarborSym's Container Loading Tool (CLT), which then estimated the number of vessel calls required to satisfy the commodity forecast, given the available fleet. The CLT data and loading algorithm is discussed in Section 4.1.2.

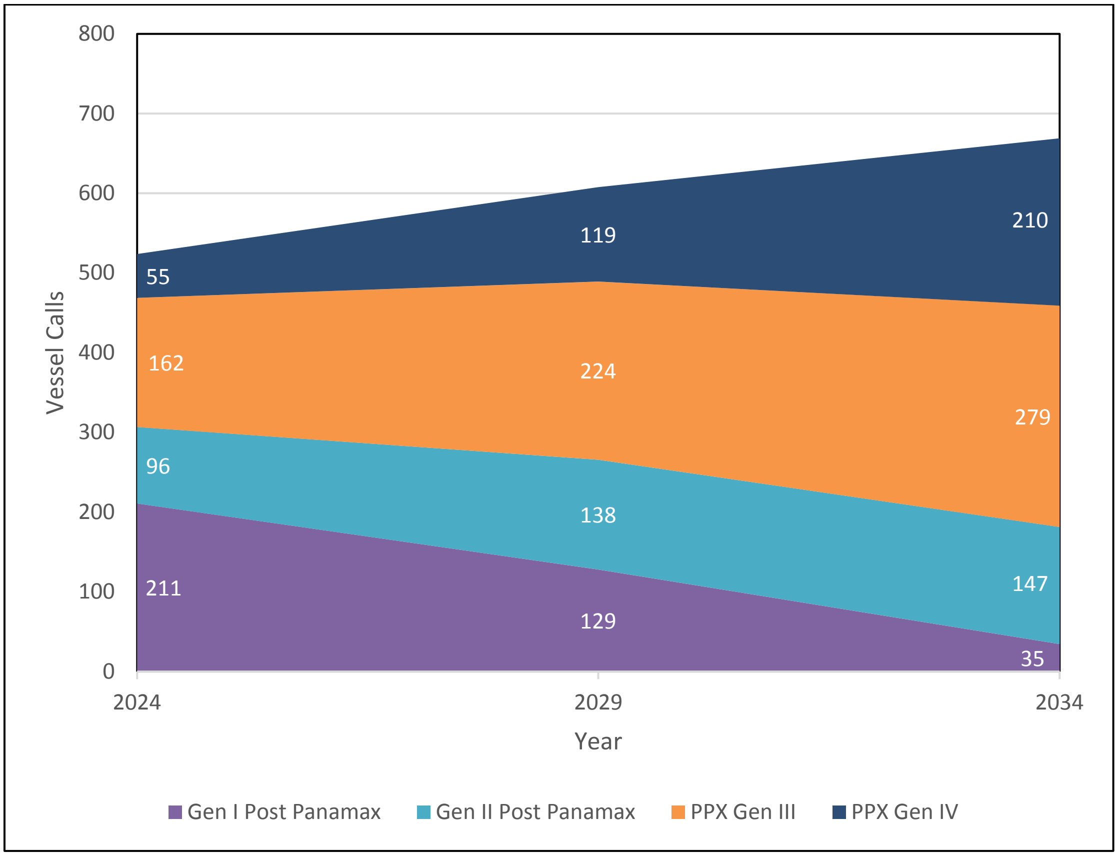


Figure 3-7. Initial Forecast of Vessels Calling at Port of Seattle

Table 3-22. Baseline Vessel Call Forecast for Port of Seattle by Year

Vessel Class	2024	2029	2034
Gen I Post-Panamax	211	129	35
Gen II Post-Panamax	96	138	147
PPX Gen III	162	224	279
PPX Gen IV	55	119	210
Total	**524**	**609**	**669**

3.5 Measures by Channel

An array of six alternatives (four alternatives for the East Waterway and two alternatives for the West Waterway) underwent an initial round of qualitative screening. This screening was based primarily on whether the alternative improves navigation safety at the approach of each waterway, as these areas were identified by the Puget Sound Pilots as critical for navigation improvements to allow vessels to safely access each waterway.

As described in Section 3.2 in the Feasibility Report and Environmental Assessment, PIANC has set design guidelines for entrance reaches that assume a 700-foot channel width is required[18]. In addition, the Puget Sound Pilots also provided input on waterway design widths, indicating that a wider approach channel is required for vessels to safely access each waterway.

The PIANC guidelines and input from the Puget Sound Pilots assisted the team in completing a qualitative screening of the array of alternatives. This screening led the team to carry forward East Waterway Alternative 2, East Waterway Alternative 4, and West Waterway Alternative 2 into the final array of alternatives as summarized in Table 3-23. All of these alternatives include a wider approach channel reach to improve navigation safety in the project area. The three alternatives that do not include a wider entrance channel reach were screened out from further consideration, as they do not directly address navigation safety considerations in the future without-project condition.

Table 3-23. Final Array of Alternatives

Alternative Name / Number	Segment	Station	Length	Width	Depth
East Waterway Alternatives					
East Waterway Alternative 2	Approach	Sta. 0+00 to 12+00	1,200'	700'	Up to --57 MLLW MLLW
	Inner Channel	Sta. 12+00 to 60+00	4,800'	550'	Up to --57 MLLW MLLW
East Waterway Alternative 4	Approach	Sta. 0+00 to 12+00	1,200'	700'	Up to --57 MLLW MLLW
	Inner Channel	Sta. 12+00 to 60+00	4,800'	550'	Up to --57 MLLW MLLW
	South End Channel	Sta. 60+00 to 72+32	1,232'	500'	Up to -40' MLLW
West Waterway Alternatives					
West Waterway Alternative 2	Approach	Sta. 0+00 to 25+00	2,500'	700'	Up to --57 MLLW MLLW
	Inner Channel	Sta. 25+00 to 61+09	3,609'	550'	Up to --57 MLLW MLLW

3.6 Economic Evaluation Assumptions

Economic evaluation will focus on optimizing the alternatives for depth (i.e., up to --57 MLLW MLLW). Based on the outcomes of the deepening optimization and given the expected low costs of these alternatives, the engineering recommendations for width based on the design vessel parameters will be carried forward and an incremental evaluation of channel width is not planned at this time.

[18] The approach channel assumes an additional 0.8*beam width (or 150 feet for a total width of 700 feet) is required per guidelines in PIANC (1995) – Approach Channels: A Guide for Design.

The authorized channel depths were considered in the setup of the economic evaluation which is presented in Section 4. The Federal channel in the West Waterway has been maintained to its -34 MLLW authorized depth; however, actual channel depths range from -50 to -60 MLLW with exception of the shoal at the approach to this waterway. The shoal is a navigational hazard to the pilots accessing the West Waterway. Although this shoaled area can affect transit into the waterways, review of pilot logs did not indicate that drafts were reduced due to this shoal. There is some anecdotal evidence that this area has caused tidal delays. For purposes of setting up the economic evaluation in HarborSym, and given actual depths are greater than the authorized depth for the West Waterway, the limiting depths for the approach (-42 MLLW) and the inner channel (-51 MLLW) were used for alternatives evaluation. For the East Waterway, the north end at Terminal 18 and 30 is maintained to its authorized depth of -51 MLLW. The south end is authorized to -34 MLLW, but actual limiting depths of -40 MLLW were used for alternatives evaluation. Tidal delays based on authorized depths were considered in the economic evaluation, but existing limiting depths are greater than authorized depths.

4 Transportation Cost Savings Benefit Analysis

The purpose of this analysis is to describe the benefits associated with the deepening and widening at the Port of Seattle's waterways. NED benefits were estimated by calculating the reduction in transportation cost at each project depth using the HarborSym Modeling Suite of Tools (HMST) developed by IWR. The HMST reflects USACE guidelines on transportation cost savings analysis[19]. Separate model runs were completed for the origin-to-destination (OD) deepening benefits.

4.1 Methodology

Channel improvement modifications result in reduced transportation cost by allowing a more efficient future fleet mix and less congestion when traversing the port. The HMST was designed to allow users to model these benefits. With a deepened channel, vessel fleet owners allocate their largest vessels to routes that have adequate traffic and reliable project depth. As the Port of Seattle waterways are deepened, the reliability of the channel depth increases. The increased reliability is expected to encourage shippers to replace smaller less efficient vessels with the larger more efficient vessels on Seattle route services.

There are three primary effects from channel deepening that induce changes in the future fleet at Seattle. The first is an increase in a vessel's maximum practicable loading capacity. Channel restrictions limit a vessels capacity by limiting its draft. Deepening the channel reduces this constraint and the vessel's maximum practicable capacity increases towards its design capacity. This increase in vessel capacity results in fewer vessel trips being required to transport the forecasted cargo. The second effect of increased channel depth is the increased reliability of water depth, which encourages the deployment of larger vessels to Seattle. The third effect is a consequence of the second. The increase in Post-Panamax vessels displaces the less economically efficient Panamax class vessels.

While lesser in magnitude when compared to channel deepening, additional transportation cost saving benefits result from the channel modifications aimed at reducing congestion within the harbor. The creation of meeting areas reduces wait times within the harbor. HarborSym allows for detailed modeling of vessel movements and transit rules on the waterway.

To begin, HarborSym was setup with the basic required variables. To estimate OD cost saving benefits, the Container Loading Tool (CLT), a module within the HMST, was used to generate a vessel call list based on the commodity forecast at the Port of Seattle for a given year, Seattle's share of the world's vessel fleet, and available channel depth under the various alternatives. The resulting vessel traffic was simulated using HarborSym, producing average annual vessel OD transportation costs. The transportation costs saving benefits were then calculated from the existing 42-foot limiting depth at the approach to the West Waterway and 51-foot depth in East Waterway for each additional project depth as was described in Section 3.6, Economic Evaluation Assumptions. The Tentatively Selected Plan (TSP)

[19] HarborSym, the Container Loading Tool (CLT), and the Bulk Loading (BLT) are USACE certified planning models.

was identified by considering the highest net benefit based on the OD transportation cost saving benefits.

4.1.1 HarborSym Model

IWR developed HarborSym as a planning level, general-purpose model to analyze the transportation costs of various waterway modifications within a harbor. HarborSym is a Monte Carlo simulation model of vessel movements at a port for use in economic analyses. While many harbor simulation models focus on landside operations, such as detailed terminal management, HarborSym instead concentrates on specific vessel movements and transit rules on the waterway, fleet and loading changes, as well as incorporating calculations for both within harbor costs and costs associated with the ocean voyage.

HarborSym represents a port as a tree-structured network of reaches, docks, anchorages, and turning areas. Vessel movements are simulated along the reaches, moving from the bar to one or more docks, and then exiting the port. Features of the model include intra-harbor vessel movements, tidal influence, the ability to model complex shipments, incorporation of turning areas and anchorages, and within-simulation visualization. The driving parameter for the HarborSym model is a vessel call at the port. A HarborSym analysis revolves around the factors that characterize or affect a vessel movement within the harbor.

4.1.1.1 Model Behavior

HarborSym is an event driven model. Vessel calls are processed individually and the interactions with other vessels are taken into account. For each iteration, the vessel calls for an iteration that fall within the simulation period are accumulated and placed in a queue based on arrival time. When a vessel arrives at the port, the route to all of the docks in the vessel call is determined. This route is comprised of discrete legs (contiguous sets of reaches, from the entry to the dock, from a dock to another dock, and from the final dock to the exit). The vessel attempts to move along the initial leg of the route. Potential conflicts with other vessels that have previously entered the system are evaluated according to the user-defined set of rules for each reach within the current leg, based on information maintained by the simulation as to the current and projected future state of each reach. If a rule activation occurs, such as no passing allowed in a given reach, the arriving vessel must either delay entry or proceed as far as possible to an available anchorage, waiting there until it can attempt to continue the journey. Vessels move from reach to reach, eventually arriving at the dock that is the terminus of the leg.

After the cargo exchange calculations are completed and the time the vessel spends at the dock has been determined, the vessel attempts to exit the dock, starting a new leg of the vessel call; rules for moving to the next destination (another dock or an exit of the harbor) are checked in a similar manner to the rule checking on arrival, before it is determined that the vessel can proceed on the next leg. As with the entry into the system, the vessel may need to delay departure and re-try at a later time to avoid rule violations and, similarly, the waiting time at the dock is recorded.

A vessel encountering rule conflicts that would prevent it from completely traversing a leg may be able to move partially along the leg, to an anchorage or mooring. If so, and if the vessel can use the anchorage (which may be impossible due to size constraints or the fact that the anchorage is filled by other vessels), then HarborSym will direct the vessel to proceed along the leg to the anchorage, where it will stay and attempt to depart periodically, until it can do so without causing rule conflicts in the remainder of the leg. The determination of the total time a vessel spends within the system is the summation of time waiting at entry, time transiting the reaches, time turning, time transferring cargo, and time waiting at docks or anchorages. HarborSym collects and reports statistics on individual vessel movements, including time in system, as well as overall summations for all movements in an iteration.

HarborSym was initially developed as a tool for analyzing channel widening projects, which were oriented toward determining time savings for vessels transiting within a harbor. It did not allow for assessing changes in vessel loading or in shipping patterns. The most recent release of HarborSym was designed to assist analysts in evaluating channel-deepening projects, in addition to the original model capabilities. The deepening features consider fleet and loading changes, as well as incorporating calculations for both within harbor costs and costs associated with ocean voyage.

Each vessel call has a known (calculated) associated cost, based on time spent in the harbor and ocean voyage and cost per hour. Also for each vessel call, the total quantity of commodity transferred to the port (both import and export) is known, in terms of commodity category, quantity, tonnage and value. The basic problem is to allocate the total cost of the call to the various commodity transfers that are made. Each vessel call may have multiple dock visits and multiple commodity transfers at each visit, but each commodity transfer record refers to a single commodity and specifies the import and export tonnage. Also, at the commodity level, the “tons per unit” for the commodity is known, so that each commodity transfer can be associated with an export and import tonnage. As noted above, the process is greatly simplified if all commodity transfers within a call are for categories that are measured in the same unit, but that need not be the case.

When a vessel leaves the system, the total tonnage, export tonnage, and import tonnage transferred by the call are available, as is the total cost of the call. The cost per ton can be calculated at the call level (divide total cost by respective total of tonnage). Once these values are available, it is possible to cycle through all of the commodity transfers for the vessel call. Each commodity transfer for a call is associated with a single vessel class and unit of measure. Multiplying the tons or value in the transfer by the appropriate per ton cost, the cost totals by class and unit for the iteration can be incremented. In this fashion, the total cost of each vessel call is allocated proportionately to the units of measure that are carried by the call, both on a tonnage and a value basis. Note that this approach does not require that each class or call carry only a commensurate unit of measure.

The model calculates import and export tons, import and export value, and import and export allocated cost. This information allows for the calculation of total tons and total cost, allowing for the derivation of the desired metrics at the class and total level. The model can thus deliver a high level of detail on individual vessel, class, and commodity level totals and costs.

Either all or a portion of the at-sea costs are associated with the subject port, depending on whether the vessel call is a partial or full load. The at-sea cost allocation procedure is implemented within the HarborSym Monte-Carlo processing kernel and utilizes the estimate total trip cargo (ETTC) field from the vessel call information along with import tonnage and export tonnage. In all cases the ETTC is the user's best estimate of total trip cargo. Within the CLT, the ETTC field is estimated as cargo on board the vessel at arrival plus cargo on board the vessel at departure, in tons. ETTC can also be expressed as:

$$ETTC = 2 * Cargo\ on\ Board\ at\ Arrival - Import\ tons + Export\ tons$$

There is a basic algorithm implemented to determine the fraction of at-sea costs to be allocated to the subject port. First, if ETTC for a vessel call is equal to zero or null, then none of the at-sea costs are associated with the port. The algorithm then checks if import or export tons are zero for a vessel call. If either are zero, then the following equation is applied to determine the at-sea cost allocation fraction associated with the subject port:

$$At\ Sea\ Cost\ Allocation\ Fraction = (Import\ tons + Export\ tons)/ETTC\ 54$$

Finally, when both import and export tons are greater than zero, the following equation is applied to determine the at-sea cost allocation fraction associated with the subject port:

$$\begin{aligned} At\ Sea\ Cost\ Allocation\ Fraction \\ &= 0.5 * (Import\ tons/Tonnage\ on\ board\ at\ arrival) + 0.5 \\ &* (Export\ tons/Tonnage\ on\ board\ at\ departure) \end{aligned}$$

Where:

$$Tonnage\ on\ board\ at\ arrival = (ETTC + Imports - Exports)/2$$

$$Tonnage\ on\ board\ at\ departure = Tonnage\ on\ board\ at\ arrival - Imports + Exports$$

4.1.1.2 Data Requirements

The data required to run HarborSym are separated into six categories, described below. Key data for the Seattle Harbor study are provided.

Simulation Parameters. Parameters include start date, the duration of the iteration, the number of iterations, the level of detail of the result output, and the wait time before rechecking rule violations when a vessel experiences a delay. These inputs were included in the model runs for the Seattle Harbor study. The base year for the model was 2024. A model run was performed for the following years: 2029 and 2034. After 2034 the forecast number of TEUs was held constant until the end of the period of analysis. Each model run consisted of 40 iterations. The number of iterations was determined to be sufficient when comparing the average time of the fleet in the system. Figure 4-1 illustrates there is very little variation in vessel time in the system for the OD model runs. For the base condition OD model run in 2024, the average total vessel time in the system after 40 iterations was 19,046 hours, with a standard deviation of 42 hours.

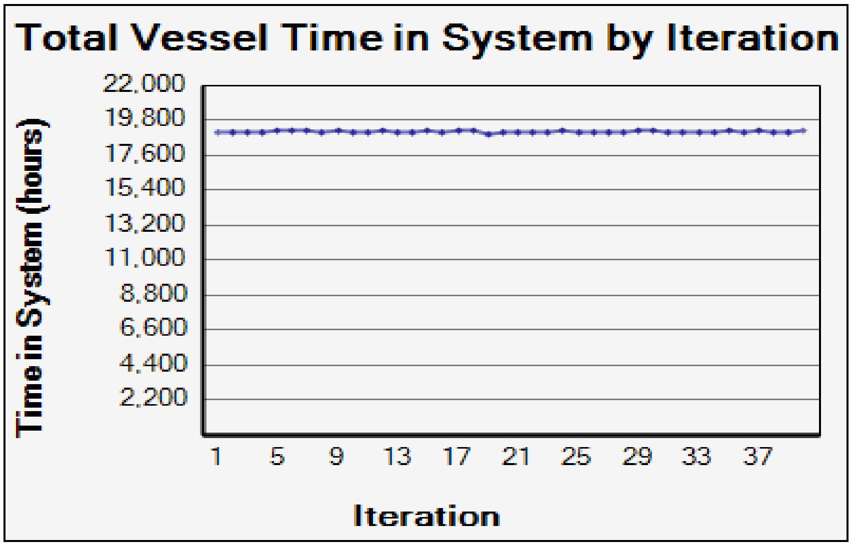


Figure 4-1. HarborSym Iterations - Hours

Physical and Descriptive Harbor Characteristics. These data inputs include the specific network of Seattle Harbor such as the node location and type, reach length, width, and depth, in addition to tide and current stations. This also includes information about the docks in the harbor such as length and the maximum number of vessels the dock can accommodate at any given time. Figure 4-2 displays the Node network used for Seattle Harbor.

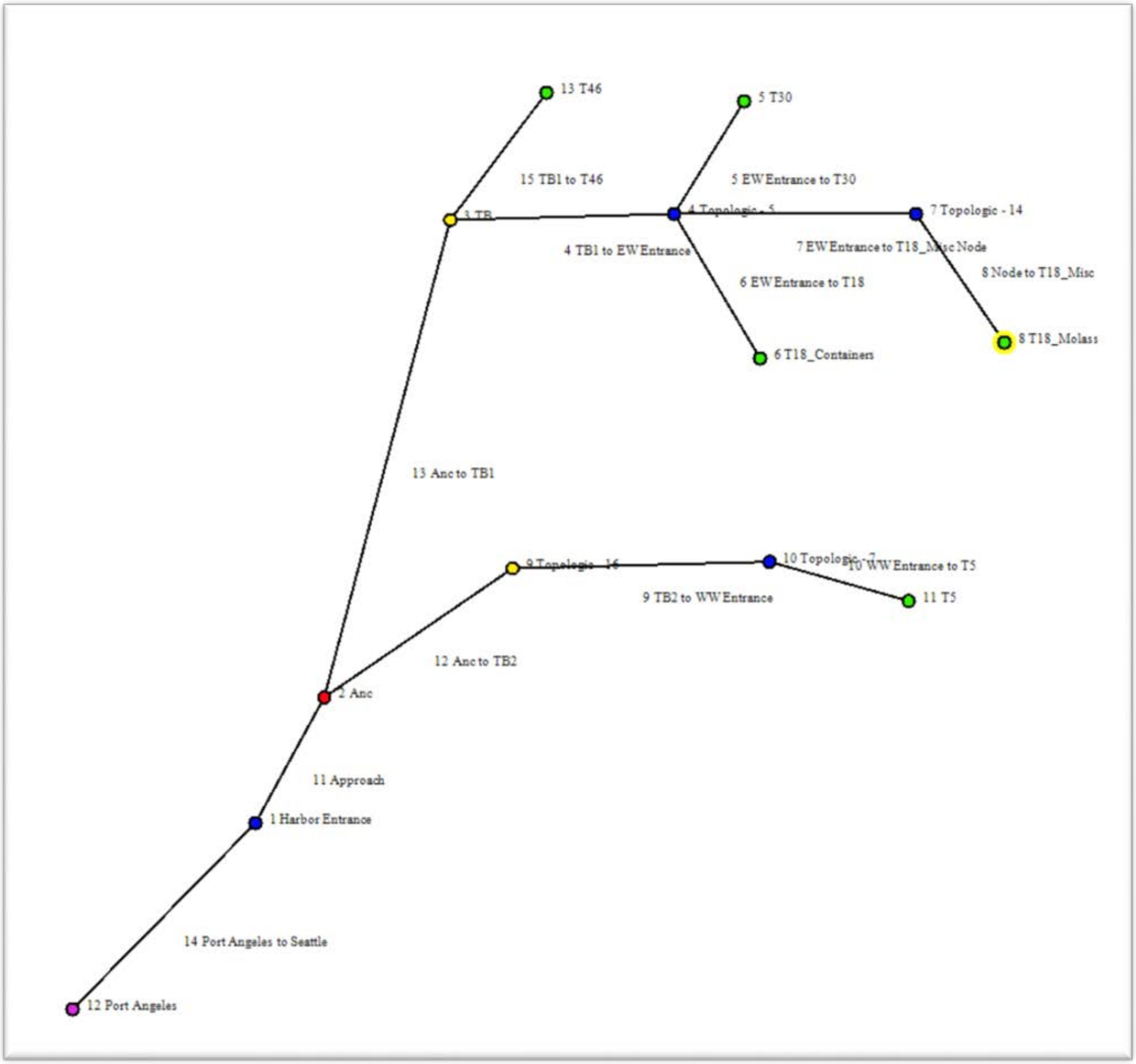


Figure 4-2. Seattle Harbor HarborSym Node Network

General Information. General information used as inputs to the model include: specific vessel and commodity classes, route groups (Table 4-1), commodity transfer rates at each dock (Table 4-2), specifications of turning area usage at each dock, and specifications of anchorage use within the harbor. Distances between the route groups were developed by evaluating the nine trade routes calling on Seattle Harbor in 2013. Those routes were separated into two trade lanes based on their world region and itinerary. The route group distance included in the analysis for each trade lane is calculated from the most likely distance for each trade route that was identified for the specific trade lane, weighted by cargo for each service assigned to a trade lane.

Table 4-1. HarborSym Route Groups

Route Group	Description	Distance to Prior Port (nautical miles)	Distance to Next Port (nautical miles)	Additional Sea Distance (nautical miles)
Asia (Pacific)	Far East including North Asia, China, and Southeast Asia	751	2,114	12,694
Med	Mediterranean	157	956	25,190

Table 4-2. HarborSym Commodity Transfer Rates for Containers

	Sub-Panamax, Panamax, PPX Gen I-II			PPX Gen III-IV		
Dock Name	Min	Most Likely	Max	Min	Most Likely	Max
T-18 (East Waterway)	863	959	1,054	1,150	1,278	1,406
T-30 (East Waterway)	966	1,073	1,180	966	1,073	1,180
T-5 (West Waterway)	863	959	1,054	1,150	1,278	1,406
T-46	966	1,073	1,180	966	1,073	1,180

Although not an input to this analysis, the prior and next port depths were considered in the analysis. They are summarized below in Table 4-4 for the current services that call the Port of Seattle. It is assumed that as larger containerships are deployed on Asian services, rotations will continue to evolve to meet international demand which will consider evolving shipping alliances and port limitations.

Table 4-3. Previous and Next Port Depths (2015)

Previous Ports	Depth (m)	Depth (ft)	Next Ports	Depth (m)	Depth (ft)
Vancouver	15.9-18.4	52.2-60.4	Yokohama	16.0	52.5
Prince Rupert	18.7	61.4	Vancouver	15.9-18.4	52.2-60.4
Tacoma	15.5	50.9	Busan	17.0	55.8
Busan	17.0	55.8	Oakland	15.2	49.9
Oakland	15.2	49.9	Nakhodka	12.5	41.0

Vessel Speeds and Operations. The speed at which vessels operate in the harbor, by vessel class both loaded and light loaded, were determined for each channel segment by evaluating pilot logs and port records and verifying the data with the pilots. Hourly operating costs while in-port and at-sea were determined for both domestic and foreign flagged containerized vessels. Sailing speeds at-sea were also determined and are based on service speeds and operating expenses obtained from Institute for Water Resources (IWR) Vessel Operating Cost spreadsheets and Economic Guidance Memorandum (EGM) 15-04 (dated 28 September 2015), Deep-Draft Vessel Operating Costs FY 2013 Price Level. Economical or slow-steam speeds at sea and associated costs were included in the evaluation. Vessel operating costs and speeds at sea are entered as a triangular distribution (minimum, most likely, maximum). Vessel speed and operations inputs are provided in Table 4-4 and Table 4-5 for each reach of the node network for containerized vessels. Vessel operating costs are redacted from the appendix as some or much of the information integral to the estimates is considered sensitive or proprietary by commercial sources and is protected from open or public disclosure under Section 4 of the Freedom of Information Act.

Table 4-4. HarborSym Vessel Speed in Reach for Containerships (knots)

Reach	Sub-Panamax/Panamax		PPX Gen I-II		PPX Gen III-IV	
	Light	Loaded	Light	Loaded	Light	Loaded
Port Angeles to Seattle	18.5	18.5	18.5	18.5	18.5	18.5
Approach to Elliott Bay	12	10	12	10	12	10
Elliott Bay to East Waterway	6	5	6	5	6	5
Elliott Bay to West Waterway	4	3	4	3	4	3
East Waterway	3	2	2	2	3	1.5
West Waterway	3	2	3	2	2	1.5

Table 4-5. Containerized Vessel Operations

Description	Sub-Panamax	Panamax	PPX Gen I	PPX Gen II	PPX Gen III	PPX Gen IV
Foreign Hourly Operating Cost at Sea, Min	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Foreign Hourly Operating Cost at Sea, Most Likely	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Foreign Hourly Operating Cost at Sea, Max	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Foreign Hourly Operating Cost in Port, Min	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Foreign Hourly Operating Cost in Port, Most Likely	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Foreign Hourly Operating Cost in Port, Max	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Vessel Speed at Sea, Min (knots)	16.9	19.0	20.3	20.0	19.8	19.8
Vessel Speed at Sea, Most Likely (knots)	17.8	20.0	21.4	21.1	20.8	20.8
Vessel Speed at Sea, Max (knots)	18.7	21.0	22.5	22.1	21.9	21.9

Reach Transit Rules. Vessel transit rules for each reach reflect restrictions on passing, overtaking, and meeting in particular segments of Seattle Harbor, and are used to simulate actual conditions in the reaches. For the Tidal Advantage and Meeting Area analysis, underkeel clearance requirements are also used along with tide to determine if a vessel can enter the system.

Under the without project condition, vessel movements are restricted for the Tidal Advantage simulations as described. These rules are not activated in the Origin-Destination simulations to avoid double counting of benefits.

Vessel Calls. The vessel call lists consist of forecasted vessel calls for a given year as generated by the CLT (see Section 4.1.2). Each vessel call list contains the following information: arrival date, arrival time, vessel name, entry point, exit point, arrival draft, import/export, dock name, dock order, commodity, units, origin/destination, vessel type, Lloyds Registry, net registered tons, gross registered tons, dead weight tons, capacity, length overall, beam, draft, flag, tons per inch immersion factor, ETTC, and the route group for which it belongs.

4.1.2 Containerized Vessel Call List

The forecasted commodities for Seattle Harbor were allocated to the future fleet using the CLT. The CLT module produces a containership-only future vessel call list based on user inputs describing commodity forecasts at docks and the available fleet. The module is designed to process in two unique steps to generate a shipment list for use in HarborSym. First, a synthetic fleet of vessels is generated that can service the port. This fleet includes the maximum possible vessel calls based on the user provided availability information. Second, the commodity forecast demand is allocated to individual vessels from the generated fleet, creating a vessel call and fulfilling an available call from the synthetic fleet.

In order to successfully utilize this tool on a planning study, users provide extensive data describing containership loading patterns and services frequenting the study port. The user provides a vessel fleet forecast by vessel class, season, and service, and a commodity forecast by dock, season, and region. The following sections discuss the CLT loading behavior algorithm and the CLT data inputs for the Seattle Harbor study.

4.1.2.1 CLT Loading Algorithm

The CLT generates a vessel call list by first generating a synthetic vessel fleet based on user inputs. Each vessel in the fleet is randomly assigned physical characteristics based on parameters provided by the user.

To begin, tentative arrival draft is determined for each generated vessel based on user-provided cumulative distribution functions (CDFs). A random draw is made from that CDF and the arrival draft is initially set to that value. The maximum allowable arrival draft is then determined as the minimum of:

1. Prior port limiting depth,

2. Design draft, and

3. Limiting depth at the dock + underkeel clearance + sinkage adjustment + tidal availability + sea level change.

The tentative arrival draft is then compared to the maximum allowable arrival draft, and set to the lesser value, that is, either the statistically estimated value or the constrained value.

Next, the CLT conducts a Loading Factor Analysis (LFA) given the physical characteristics of each generated vessel. LFA explores the relationships between a ships physical attributes, considerations for operations and attributes of the trade route cargo to evaluate the operating efficiencies of vessel classes at alternative sailing drafts. Several intermediate calculations are required. The following variables are used by the LFA algorithm but are calculated from the inputs.

$$Vessel\ operating\ cost\ per\ 1000\ miles\ is\ calculated\ as\ 1000\ miles\ divided\ by\ the\ applied\ speed\ times\ the\ hourl$$
$$= \ 1000\ miles\ /\ (Applied\ Speed\ X\ Hourly\ Cost)$$

The allocation of vessel space to vacant slots, empty and loaded containers is calculated by adding the cargo weight per box plus the box weight plus an allowance for the empty

$$\begin{aligned} Total\ weight\ per\ loaded\ container \\ &= \ Average\ Lading\ Weight\ per\ Loaded\ TEU\ by\ Route\ (tonnes) \\ &+ \ Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes) \\ &+ \ (Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes) \\ &* (Percent\ Empty\ TEUs)) \end{aligned}$$

Shares of vessel capacity are then calculated as:

$$Cargo\ Share = Average\ Lading\ Weight\ per\ Loaded\ TEU\ by\ Route\ (tonnes)\ Total\ weight\ per\ loaded\ container\ in\ tonnes$$

$$Laden\ Container\ Share = Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)\ Total\ weight\ per\ loaded\ container\ in\ tonnes$$

$$Empty\ Container\ Share = ((Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)) * (Percent\ Empty\ TEUs\ ))\ Total\ weight\ per\ loaded\ container\ in\ tonnes)$$

Volume capacity limits are calculated as follows:

$$Number\ of\ vacant\ slots = Nominal\ TEU\ Rating * Percent\ vacant\ slots$$

$$Max\ Occupied\ Slots = Nominal\ TEU\ Rating - Number\ of\ vacant\ slots$$

$$Max\ Laden\ TEUs = Occupied\ Slots/(1 + Percent\ Empties)$$

$$Max\ Empty\ TEUs = Occupied\ Slots - Laden\ TEUs$$

Maximum Volume Restricted Tonnage is then calculated as:

$$Max\ weight\ for\ cargo\ (tonnes) = Max\ Laden\ TEUs * Average\ Lading\ Weight\ per\ Loaded\ TEU\ by\ Route\ (tonnes)$$

$$Max\ weight\ for\ laden\ boxes\ (tonnes) = Max\ Laden\ TEUs * Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)$$

$$Max\ weight\ for\ empties (tonnes) = Max\ Empty\ TEUs * Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)$$

$$Total\ volume\ restricted\ tonnage\ (cubed\ out\ tonnage)(tonnes) = Max\ weight\ for\ cargo + Max\ weight\ for\ laden\ boxes + Max\ weight\ for\ empties$$

The LFA proceeds as follows:

The initial draft is varied from the vessels maximum (loaded) to minimum (empty). At each sailing draft the total tonnage that can be carried is calculated using the Tons Per Inch Immersion (TPI) rating for the vessel.

$$DWT\ Available\ for\ Vessel\ Draft = DWT\ Rating\ (tonnes) - [(Aggregate\ Maximum\ Summer\ Load\ Line\ Draft - Sailing\ Draft) * 12\ inches * TPI]$$

This capacity is then allocated, first to ballast and operations to yield capacity available for cargo.

$$Approximate\ Variable\ Ballast\ =\ DWT\ Available\ for\ Vessel\ Draft\ *\ Percent\ Assumption\ for\ Variable\ Ballast$$

$$Allowance\ for\ Operations\ in\ tonnes = DWT\ Rating\ (tonnes)\ *\ Percent\ Allowance\ for\ Operations$$

$$Available\ for\ Cargo = (DWT\ Available\ for\ Vessel\ Draft) - (Approximate\ Variable\ Ballast) - (Allowance\ for\ Operations)$$

The capacity available for cargo is restricted if the vessel has “cubed” or “volumed” out:

$$Available\ for\ Cargo\ adjusted\ for\ volume\ restriction\ if\ any\ (tonnes) = the\ lesser\ of\ Available\ for\ Cargo\ and\ Total\ volume\ restricted\ tonnage\ (cubed\ out\ tonnage)$$

The tonnage available for cargo is then allocated to cargo, laden and empty containers based on the shares of vessel capacity:

$$Distribution\ of\ Space\ Available\ for\ Cargo\ (tonnes) = Available\ for\ Cargo\ adjusted\ for\ volume\ restriction\ if\ any\ in\ tonnes\ *\ Cargo\ Share\ in\ percent$$

$$Distribution\ of\ Space\ Available\ for\ Laden\ TEUs\ (tonnes) = Available\ for\ Cargo\ adjusted\ for\ volume\ restriction\ if\ any\ in\ tonnes\ *\ Laden\ Container\ Share\ in\ percent$$

$$Distribution\ of\ Space\ Available\ for\ Empty\ TEUs\ (tonnes) = Available\ for\ Cargo\ adjusted\ for\ volume\ restriction\ if\ any\ *\ Empty\ Container\ Share$$

The number of TEUs is then estimated for each share use:

$$Number\ of\ Laden\ TEUs = Distribution\ of\ Space\ Available\ for\ Cargo\ /Average\ Lading\ Weight\ per\ Loaded\ TEU\ by\ Route\ (tonnes)$$

$$Number\ Empty\ TEUs = Distribution\ of\ Space\ Available\ for\ Empty\ TEUs\ /Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)$$

$$Occupied\ TEU\ Slots\ on\ Vessel\ =\ Number\ of\ Laden\ TEUs\ +\ Number\ Empty\ TEUs$$

$$Vacant\ Slots\ =\ Nominal\ TEU\ Rating\ -\ Occupied\ TEU\ Slots$$

The CLT then calculates the ETTC (estimate of total trip cargo) for each vessel call as the cargo on board the vessel at arrival plus the cargo on board the vessel at departure, in tons (see description and equation for ETTC in Section 4.1.1.1, Model Behavior).

The CLT works to load each vessel available to carry the commodity on the given route until the forecast is satisfied or the available fleet is exhausted.

4.1.2.2 CLT Data Inputs for Seattle Harbor

There are a number of data required by the CLT. The commodity forecast can be found in Section 3.3 and the vessel fleet can be found in Section 3.4. Vessel sailing draft distributions are critical for determining the benefits of both the meeting area and tide delay analyses due to channel depth and underkeel requirements, as well as determining how much cargo a vessel can carry and thus how many trips are required to satisfy a commodity forecast. Figures x through Figure x below provide the arrival draft CDFs for containerized vessels by channel depth. The CDFs were developed by evaluating the arrival drafts of the container class vessels calling on the harbor from 2010 to 2014. Each call was separated into a container vessel class depending on the vessel characteristics of each call. A probability curve for the arrival draft of the vessels for the existing and future without project condition was developed using this information. The with-project arrival draft curves were developed with the assistance of the Institute for Water Resources (IWR). The assumption was made that for each additional foot of channel depth available to carriers the average container vessel would use approximately 0.6 to 0.8 feet of that depth. Therefore, for the analysis, it was assumed that each container vessel would sail with an additional 0.7 feet for each one foot increment of channel depth evaluated. The restriction placed on this assumption is that once a vessel class reaches its design draft on the curve the class no longer shifts regardless of the channel depth.

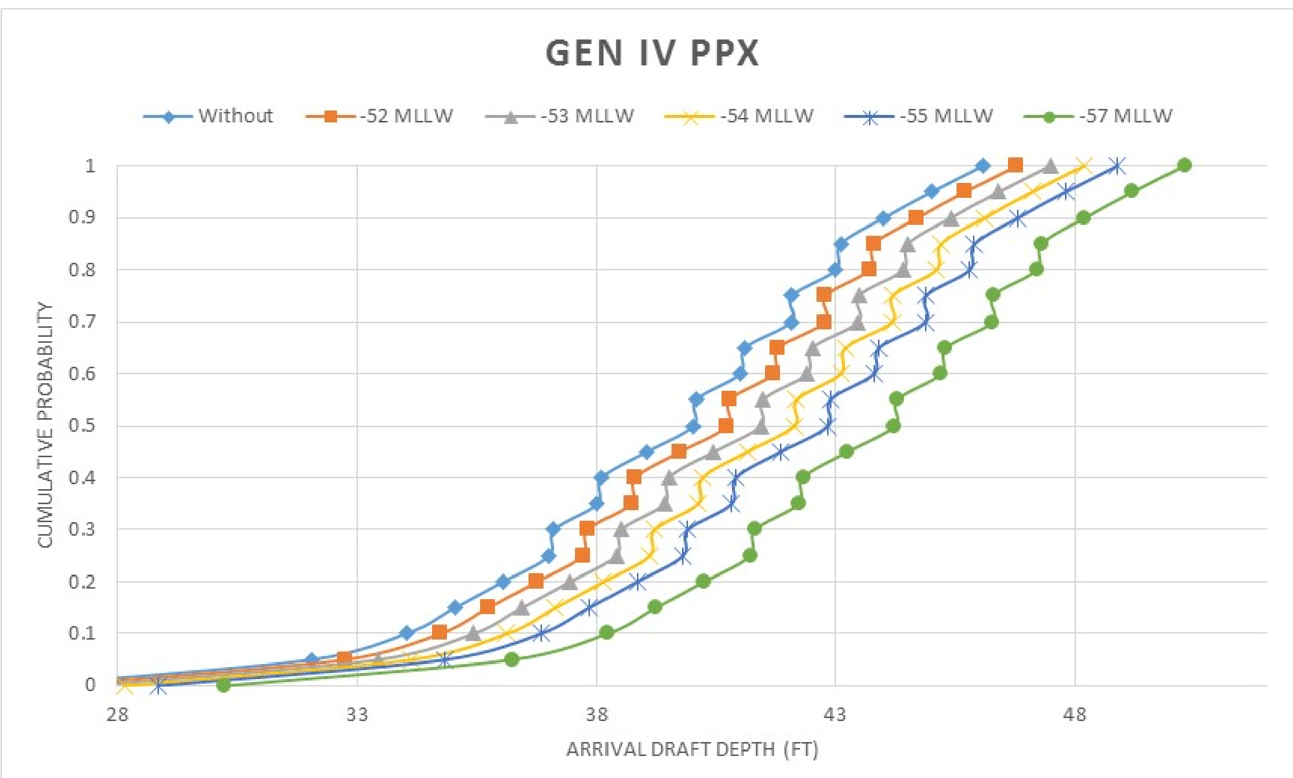


Figure 4-3. Post-Panamax Generation IV Arrival Draft by Channel Depth

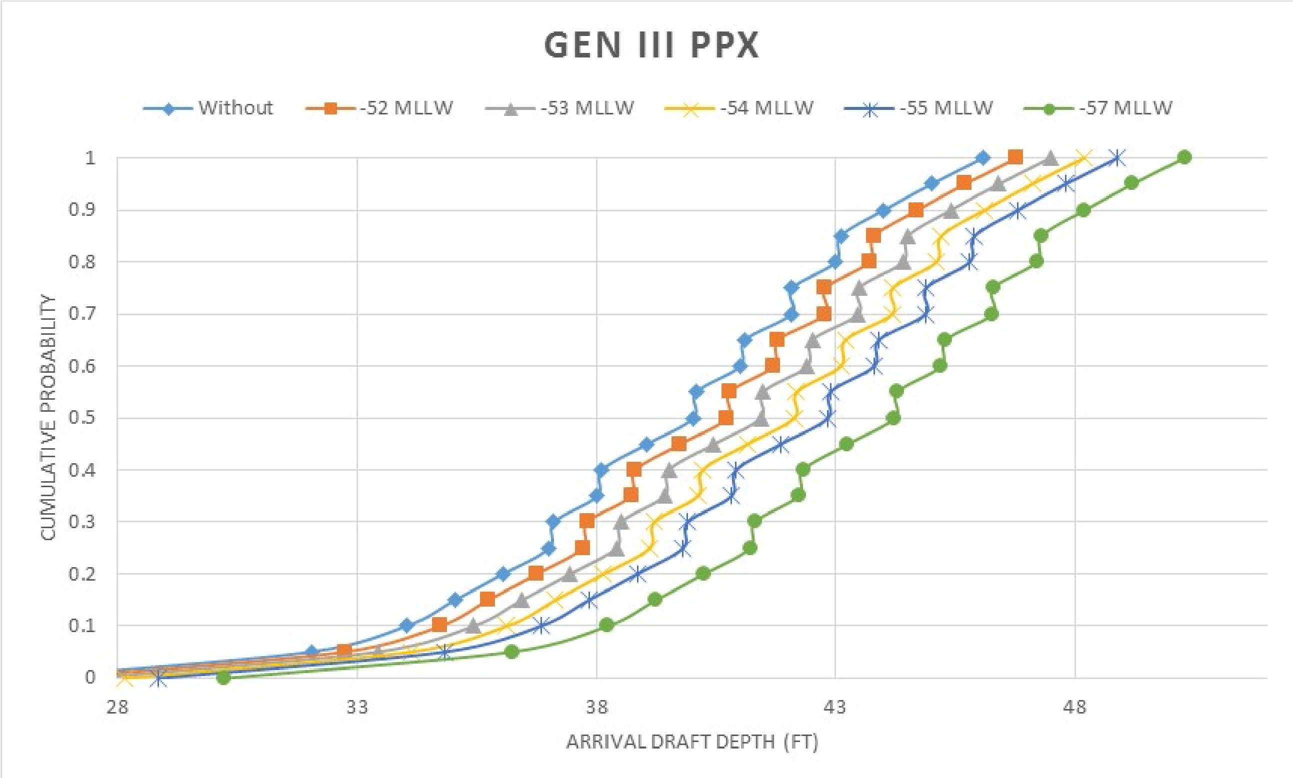


Figure 4-4. Post-Panamax Generation III Arrival Draft by Channel Depth

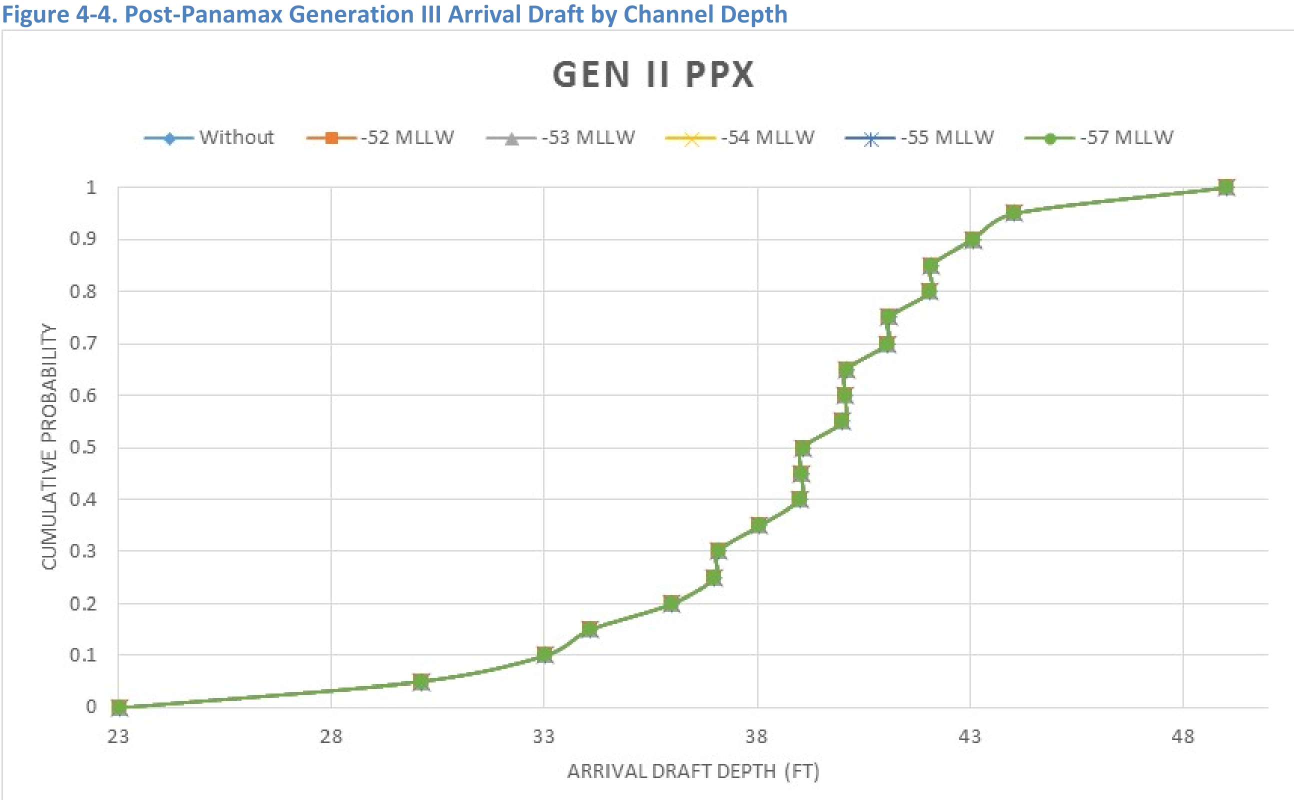


Figure 4-5. Post-Panamax Generation II Arrival Draft by Channel Depth

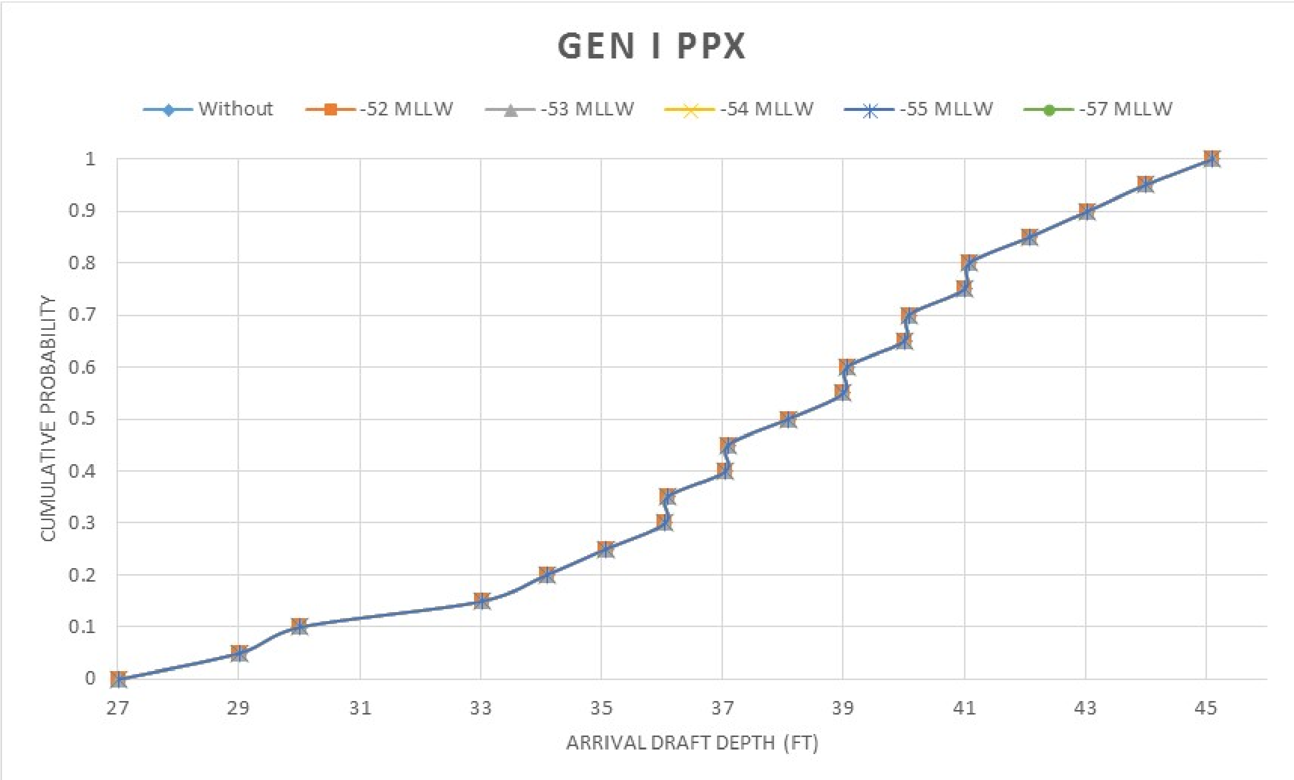


Figure 4-6. Post-Panamax Generation I Arrival Draft by Channel Depth

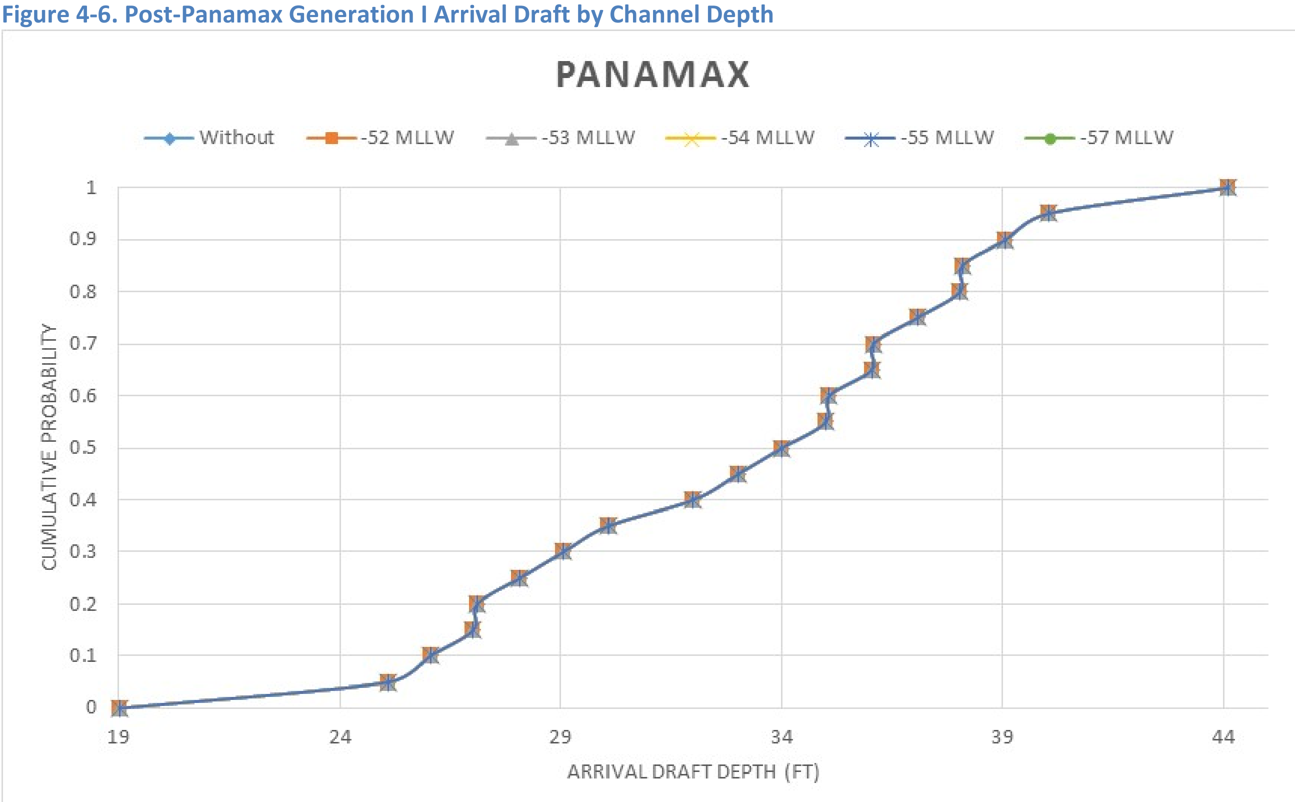


Figure 4-7. Panamax Arrival Draft by Channel Depth

Table 4-6 provides the vessel class assumptions used in the load factor analysis (LFA)[20], such as average lading weight per TEU (see Section 2.3.3), container weight, vacant slot allotment, variable ballast, etc. These inputs were developed using historical data provided by the Port (Import/Export fractions) and with the assistance of IWR (Lading Weight per Loaded TEU, Empty TEU and Vacant Slot allotment, Operations Allowance, and Variable Ballast).

[20] Load factor analysis (LFA) is the analytical effort to evaluate the disposition of vessel carrying capacity according to both weight and volume, and evaluate resulting influences for immersion and associated transit draft as they relate to needs for waterway system depth.

Table 4-6. Vessel Class Inputs

Service	Vessel Class	Ave Lading Wt per Loaded TEU (tonnes)	Ave Container Wt per TEU (tonnes)	Empty TEU Allotment	Vacant Slot Allotment	Operations Allowance (% of DWT)	Variable Ballast (% of DWT)	Import Fraction Most Likely	Export Fraction Most Likely
Asia	Sub-Panamax	9.2	2.0	22.3%	6.2%	7.1%	14.9%	30%	30%
Asia	Panamax	9.2	2.0	19.2%	6.2%	7.1%	14.9%	30%	30%
Asia	PPX 1	9.2	2.0	24.9%	6.2%	7.1%	14.9%	30%	30%
Asia	PPX 2	9.2	2.0	21.2%	6.2%	7.1%	14.9%	30%	30%
Asia	PPX 3	9.2	2.0	21.2%	6.2%	7.1%	14.9%	30%	30%
Asia	PPX 4	9.2	2.0	21.2%	6.2%	7.1%	14.9%	30%	30%
Med	Sub-Panamax	10.3	2.0	29.6%	6.2%	7.1%	14.9%	39%	39%
Med	Panamax	10.3	2.0	22.3%	6.2%	7.1%	14.9%	39%	39%
Med	PPX 1	10.3	2.0	9.7%	6.2%	7.1%	14.9%	39%	39%
Med	PPX 2	10.3	2.0	9.7%	6.2%	7.1%	14.9%	39%	39%
Med	PPX 3	10.3	2.0	12.4%	6.2%	7.1%	14.9%	39%	39%

Table 4-7 provides details on the vessel subclasses, which is used by the CLT to create vessels to satisfy the commodity forecast. The user provides the linkage between the HarborSym vessel class and the IWR-defined vessel subclass. The percentage share of each subclass was defined by historical data provided by the Port.

Table 4-7. Vessel Subclass Inputs

Vessel Class	LOA	LBP	Beam	Maximum SLLD	Capacity (DWT)	Applied Draft	TEU Rating	TPI Factor	Underkeel Clearance	Sinkage Adjustment	% of Class
Sub-Panamax	676	636	99	38	33,887	38.00 to 38.99	2,470	118	3.5	0.2	100
Panamax	887	839	104	44	54,885	44.00 to 44.99	3,993	170	3.6	0.2	100
PPX 1	954	905	132	48	80,651	48.00 to 48.99	6,186	222	3.8	0.3	100
PPX 2	1,106	1,060	143	49	106,737	49.00 to 49.99	8,670	292	4.0	0.3	100
PPX 3	1,203	1,151	168	51.2	152,456	51.00 to 51.99	13,975	394	4.1	0.3	100
PPX 4	1,305	1,232	185	51.7	158,038	51.00 to 51.99	15,550	453	4.1	0.3	100

Table 4-8 shows the maximum sailing draft for each vessel class on each trade route at which vessel cargo capacity is maximized given load factor analysis vessel class inputs and vessel subclass inputs presented in Table 4-6 and Table 4-7 specific to Seattle Harbor.

Table 4-8. Maximum Depth by Vessel Class and Route Group

Vessel Class	Asia Route Group 1: Depth at Which Vessel Cargo Capacity is Maximized (Max Sailing Draft)	Mediterranean Route Group 2: Depth at Which Vessel Cargo Capacity is Maximized (Max Sailing Draft)
Sub-Panamax	37.2	37.7
Panamax	41.0	41.7
PPX Gen I	44.9	45.1
PPX Gen II	46.9	46.9
PPX Gen III	51.2	51.2
PPX Gen IV	51.7	51.7

4.1.2.3 Containerized Vessel Calls

Vessel calls by vessel class are shown in Table 4-9. Vessel calls by route group are shown in Table 4-10. These are a result of the CLT loading algorithm, the containerized trade forecast for Seattle Harbor, the available vessel fleet by service, and the LFA data inputs.

Table 4-9. Vessel Calls by Vessel Class and Channel Depth/Alternative

	No Action	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024													
Sub-Panamax	0	0	0	0	0	0	0	0	0	0	0	0	0
Panamax	0	0	0	0	0	0	0	0	0	0	0	0	0
PPX 1	211	205	198	193	188	184	184	203	194	187	179	175	175
PPX 2	96	96	96	96	96	96	96	96	96	96	96	96	96
PPX 3	162	162	162	162	162	162	162	162	162	162	162	162	162
PPX 4	55	55	55	55	55	55	55	55	55	55	55	55	55
Total	**524**	**518**	**511**	**506**	**500**	**497**	**497**	**515**	**507**	**499**	**491**	**487**	**487**
2029													
Sub-Panamax	0	0	0	0	0	0	0	0	0	0	0	0	0
Panamax	0	0	0	0	0	0	0	0	0	0	0	0	0
PPX 1	129	120	112	105	105	105	105	116	102	89	86	86	86
PPX 2	138	138	138	137	129	123	123	138	138	138	130	124	124
PPX 3	224	224	224	223	223	223	223	224	224	224	224	224	224
PPX 4	119	119	119	119	119	119	119	119	119	119	119	119	119
Total	**609**	**600**	**593**	**585**	**576**	**570**	**570**	**596**	**582**	**569**	**558**	**552**	**552**
2034													
Sub-Panamax	0	0	0	0	0	0	0	0	0	0	0	0	0
Panamax	0	0	0	0	0	0	0	0	0	0	0	0	0
PPX 1	35	35	35	35	35	35	35	21	21	21	21	20	20
PPX 2	147	140	140	140	139	139	138	141	126	124	124	123	123
PPX 3	279	276	269	262	254	251	251	279	278	270	261	253	253
PPX 4	210	210	210	210	210	210	210	210	210	210	210	210	210
Total	**671**	**661**	**653**	**646**	**638**	**634**	**634**	**651**	**635**	**625**	**616**	**607**	**607**

Table 4-10. Vessel Calls by Route Group and Channel Depth/Alternative

	No Action	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024													
Asia	77	77	77	77	77	77	77	77	77	77	77	77	77
Med	447	441	435	429	424	420	420	439	431	422	415	411	411
Total	**524**	**518**	**511**	**506**	**500**	**497**	**497**	**515**	**507**	**499**	**491**	**487**	**487**
2029													
Asia	77	77	77	76	76	76	76	77	77	77	77	77	77
Med	532	523	517	509	500	494	494	519	505	492	481	475	475
Total	**609**	**600**	**593**	**585**	**576**	**570**	**570**	**596**	**582**	**569**	**558**	**552**	**552**
2034													
Asia	79	78	77	76	76	75	75	79	79	78	78	78	78
Med	591	584	577	569	562	559	558	572	556	546	538	529	529
Total	**671**	**661**	**653**	**646**	**638**	**634**	**634**	**651**	**635**	**625**	**616**	**607**	**607**

4.1.2.4 Seattle Share of World Fleet

The previous tables provided the number of vessel calls by route group and vessel class for the Port of Seattle from 2024, 2029, and 2034. The estimated number of vessels required to transport the forecast cargo is shown in the following tables. The number of vessels is approximated and was derived by assuming an average string of vessels is made up of 11 vessels calling weekly. The equivalent vessel numbers are a result of dividing the number of vessel calls in the previous tables by 52 weeks and multiplying by 11 vessels per service. While some services have fewer than 11 vessels and some have more, depending on the frequency of service and the trade route distance, 11 vessels is a general average. The percent of world fleet values is derived by simply dividing the equivalent number of vessels in a given year by the number of vessels in the respective classes by the historical and projected world fleet.

The purpose of this analysis and presentation is to serve as a cross check on the reasonableness of the projected number of vessel calls by comparing them to the historical and future world fleet. As shown in Table 4-11 and Table 4-12, the historical share of the world fleet calling in Seattle for Generation I Post-Panamax vessels has declined from 22 percent to 4 percent, while Generation II Post-Panamax vessel calls have returned to 2006 levels at 8 percent. Generation II Post-Panamax shares have generally grown to 5 percent.

Table 4-11. Historical Percent of World Fleet Calling Seattle Once per Week

	2006		2010		2014	
	Vessels	**% World Fleet**	**Vessels**	**% World Fleet**	**Vessels**	**% World Fleet**
Sub-Panamax	112	1%	107	1%	2	0%
Panamax	185	3%	178	2%	117	2%
Gen I PPX	332	22%	266	13%	108	4%
Gen II PPX	54	8%	135	12%	104	8%
Gen III PPX	0	0%	9	2%	82	5%
Gen IV PPX	0	0%	0	0%	0	0%
Total	**683**	**4%**	**695**	**3%**	**413**	**2%**

Table 4-12. Seattle Share of World Fleet by Vessel Class, 2006-2014

Seattle % World Fleet	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sub-Panamax	1%	1%	1%	1%	1%	1%	0%	0%	0%
Panamax	3%	2%	2%	2%	2%	2%	2%	2%	2%
Gen I Post-Panamax	22%	21%	15%	14%	13%	8%	8%	7%	4%
Gen II Post-Panamax	8%	6%	5%	6%	12%	19%	14%	10%	8%
Gen III Post-Panamax	0%	0%	0%	1%	2%	0%	0%	1%	5%
Gen IV Post-Panamax	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	4%	3%	3%	3%	3%	3%	2%	2%	2%

Table 4-13 and Table 4-14 present the estimated future percent of the world fleet calling Seattle in the West and East Waterways, respectively. As shown, it is estimated Seattle's share of Panamax vessels drops to zero by the base year. Total share of world fleet remains around 2 percent. Larger PPX

Generation 2 and 3 vessels are able to carry more cargo with a deepened channel, and therefore fewer Generation I vessels are required to satisfy commodity forecasts with a deeper channel. Consideration of this projection is discussed further as a consideration for sensitivity analysis in Section 5.3.

The conclusion of the "backcheck" confirms that the projected vessel calls for the Port of Seattle do not result in an excessive amount of the total world fleet in the without or with project conditions, and supports the reasonableness of the results.

Table 4-13. Estimate Future Percent of World Fleet Calling Seattle Once per Week – West Waterway

Alternative	2024		2029		2034	
	Vessels	% World Fleet	Vessels	% World Fleet	Vessels	% World Fleet
Without Project						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	43	5%	26	2%	7	0%
PPX 2	20	6%	28	8%	30	9%
PPX 3	33	5%	45	6%	57	6%
PPX 4	11	2%	24	3%	43	4%
Total	107	2%	124	2%	136	2%
WW -52 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	42	5%	24	2%	7	1%
PPX 2	20	6%	28	8%	29	8%
PPX 3	33	5%	46	6%	56	6%
PPX 4	11	2%	24	3%	43	4%
Total	106	2%	122	2%	135	2%
WW -53 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	40	5%	21	2%	7	1%
PPX 2	20	6%	28	8%	29	8%
PPX 3	33	5%	46	6%	55	5%
PPX 4	11	2%	24	3%	43	4%
Total	104	2%	119	2%	133	2%
WW -54 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	40	5%	21	2%	7	1%
PPX 2	20	6%	28	8%	29	8%
PPX 3	33	5%	45	6%	53	5%
PPX 4	11	2%	24	3%	43	4%
Total	103	2%	119	2%	131	2%
WW -55 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	38	4%	21	2%	7	1%
PPX 2	20	6%	26	8%	28	8%
PPX 3	33	5%	45	6%	52	5%
PPX 4	11	2%	24	3%	43	4%
Total	102	2%	117	2%	130	2%
WW -56 MLLW and WW -57 MLLW Depths						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	37	4%	21	2%	7	0%
PPX 2	20	6%	25	7%	28	8%
PPX 3	33	5%	45	6%	51	5%
PPX 4	11	2%	24	3%	43	4%
Total	101	2%	116	2%	129	2%

Table 4-14. Estimate Future Percent of World Fleet Calling Seattle Once per Week – East Waterway

Alternative	2024		2029		2034	
	Vessels	% World Fleet	Vessels	Vessels	% World Fleet	Vessels
EW -52 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	41	5%	24	2%	7	0%
PPX 2	20	6%	28	8%	28	8%
PPX 3	33	5%	46	6%	51	5%
PPX 4	11	2%	24	3%	43	4%
Total	105	2%	121	2%	129	2%
EW -53 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	40	5%	21	2%	4	0%
PPX 2	20	6%	28	8%	26	7%
PPX 3	33	5%	46	6%	56	6%
PPX 4	11	2%	24	3%	43	4%
Total	103	2%	119	2%	129	2%
EW -54 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	38	4%	18	2%	4	0%
PPX 2	20	6%	28	8%	25	7%
PPX 3	33	5%	46	6%	55	5%
PPX 4	11	2%	24	3%	43	4%
Total	102	2%	116	2%	127	2%
EW -55 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	36	4%	18	2%	4	0%
PPX 2	20	6%	26	8%	25	7%
PPX 3	33	5%	45	6%	53	5%
PPX 4	11	2%	24	3%	43	4%
Total	100	2%	114	2%	125	2%
EW -56 MLLW and EW -57 MLLW Depth						
Sub-Panamax and Panamax	0	0%	0	0%	0	0%
PPX 1	35	4%	18	2%	4	0%
PPX 2	20	6%	25	8%	25	7%
PPX 3	33	5%	46	6%	51	5%
PPX 4	11	2%	24	3%	43	4%
Total	99	2%	112	2%	123	2%

4.2 Origin-Destination Transportation Cost Savings Benefits by Project Depth

Transportation cost benefits were estimated using the HarborSym Economic Reporter, a tool under development by IWR that summarizes and annualizes HarborSym results from multiple simulations. This tool collects the transportation costs from various model run output files and generates the transportation cost reduction for all project years, and then produces an Average Annual Equivalent (AAEQ). Results and calculations were verified using spreadsheet models as well.

Transportation costs were estimated for a 50-year period of analysis for the years 2024 through 2073. Transportation costs were estimated using HarborSym for the years 2024, 2029, and 2034. Since terminal capacity is not expected to be reached during the planning period of analysis, the transportation costs were held constant beyond 2034. The present value was estimated by interpolating between the modeled years. Transportation costs were annualized to determine AAEQ costs and savings by discounting the cost stream from year 2024 to 2034 at the current FY 2016 Federal Discount rate of 3.125 percent using the transportation cost and savings information shown in Tables 4-13 through 4-16. Estimates were determined for each alternative project depth.

Table 4-15 and Table 4-16 provides the annual transportation costs in total and for the at-sea and in-port portions for the West and East Waterways, respectively. These tables consist of three subtables where the first subtable shows total costs by year for origin-destination (OD) at-sea and in-port transportation costs allocated to the Port of Seattle. The second subtable shows the in-port proportion of total transport cost and the third subtable shows the at-sea proportion of total costs. The total cost is the sum of the in-port and at-sea transportation costs by year. For the Origin-Destination (OD) costs, at-sea costs comprise between 92 percent and 93 percent of the total costs. The transportation cost saving benefit for the West and East Waterways is provided in Table 4-17 and Table 4-18 with the same three subtables which represent, respectively. The AAEQ transportation costs and cost saving benefits are provided in Table 4-19. AAEQ cost statistics including risk and uncertainty are provided in Table 4-20 and Table 4-21 for the West and East Waterways, respectively.

Table 4-15. Origin-Destination Annual Transportation Cost (in Thousands $) – West Waterway

Annual O-D At-Sea and In-Port Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW
2024	$725,873	$718,350	$714,097	$709,536	$704,588	$700,804	$700,623
2025	$753,702	$745,853	$741,394	$736,186	$730,495	$726,447	$726,282
2026	$781,532	$773,355	$768,691	$762,836	$756,401	$752,091	$751,940
2027	$809,361	$800,857	$795,988	$789,486	$782,308	$777,734	$777,598
2028	$837,190	$828,359	$823,285	$816,136	$808,214	$803,378	$803,257
2029	$865,020	$855,861	$850,582	$842,787	$834,121	$829,021	$828,915
2030	$892,527	$882,304	$876,173	$867,910	$859,122	$853,507	$853,346
2031	$920,035	$908,746	$901,764	$893,034	$884,124	$877,993	$877,776
2032	$947,543	$935,188	$927,354	$918,158	$909,126	$902,479	$902,207
2033	$975,050	$961,630	$952,945	$943,282	$934,127	$926,965	$926,638
2034-2073	$1,002,558	$988,072	$978,535	$968,405	$959,129	$951,451	$951,069
Annual O-D In-Port Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW
2024	$51,733	$51,413	$51,116	$50,832	$50,587	$50,425	$50,425
2025	$54,295	$53,950	$53,655	$53,345	$53,047	$52,851	$52,850
2026	$56,858	$56,488	$56,194	$55,858	$55,507	$55,277	$55,275
2027	$59,420	$59,025	$58,733	$58,371	$57,968	$57,703	$57,699
2028	$61,982	$61,563	$61,272	$60,884	$60,428	$60,130	$60,124
2029	$64,544	$64,100	$63,811	$63,397	$62,889	$62,556	$62,549
2030	$66,743	$66,253	$65,926	$65,480	$64,967	$64,646	$64,638
2031	$68,941	$68,405	$68,041	$67,563	$67,046	$66,736	$66,728
2032	$71,140	$70,558	$70,155	$69,647	$69,125	$68,826	$68,817
2033	$73,339	$72,711	$72,270	$71,730	$71,203	$70,917	$70,906
2034-2073	$75,537	$74,864	$74,385	$73,813	$73,282	$73,007	$72,996
Annual O-D At-Sea Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW
2024	$674,140	$666,938	$662,981	$658,703	$654,002	$650,379	$650,198
2025	$699,407	$691,902	$687,739	$682,841	$677,448	$673,596	$673,431
2026	$724,674	$716,867	$712,497	$706,978	$700,894	$696,813	$696,665
2027	$749,941	$741,832	$737,255	$731,115	$724,340	$720,031	$719,899
2028	$775,208	$766,797	$762,013	$755,253	$747,786	$743,248	$743,132
2029	$800,475	$791,761	$786,771	$779,390	$771,232	$766,465	$766,366
2030	$825,784	$816,051	$810,247	$802,430	$794,155	$788,861	$788,707
2031	$851,094	$840,340	$833,723	$825,471	$817,078	$811,257	$811,049
2032	$876,403	$864,630	$857,199	$848,511	$840,001	$833,653	$833,390
2033	$901,712	$888,919	$880,675	$871,552	$862,924	$856,048	$855,731
2034-2073	$927,021	$913,209	$904,151	$894,592	$885,847	$878,444	$878,073

Table 4-16. Origin-Destination Annual Transportation Cost (in Thousands $) – East Waterway

Annual O-D At-Sea and In-Port Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024	$725,873	$715,732	$708,305	$700,048	$690,710	$685,543	$685,377
2025	$753,702	$743,229	$735,113	$726,197	$716,592	$711,275	$711,049
2026	$781,532	$770,727	$761,922	$752,347	$742,474	$737,007	$736,721
2027	$809,361	$798,224	$788,730	$778,496	$768,357	$762,739	$762,393
2028	$837,190	$825,721	$815,538	$804,646	$794,239	$788,471	$788,064
2029	$865,020	$853,219	$842,347	$830,795	$820,121	$814,203	$813,736
2030	$892,527	$879,135	$867,561	$855,644	$844,795	$837,991	$837,514
2031	$920,035	$905,051	$892,776	$880,493	$869,469	$861,779	$861,291
2032	$947,543	$930,967	$917,991	$905,342	$894,144	$885,567	$885,069
2033	$975,050	$956,883	$943,206	$930,191	$918,818	$909,355	$908,847
2034-2073	$1,002,558	$982,799	$968,421	$955,040	$943,492	$933,142	$932,624
Annual O-D In-Port Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024	$51,733	$51,331	$50,938	$50,498	$50,075	$49,886	$49,889
2025	$54,295	$53,836	$53,391	$52,912	$52,437	$52,212	$52,214
2026	$56,858	$56,342	$55,843	$55,326	$54,798	$54,538	$54,539
2027	$59,420	$58,847	$58,296	$57,739	$57,159	$56,864	$56,864
2028	$61,982	$61,352	$60,748	$60,153	$59,521	$59,190	$59,190
2029	$64,544	$63,858	$63,200	$62,567	$61,882	$61,516	$61,515
2030	$66,743	$65,977	$65,266	$64,615	$63,955	$63,529	$63,525
2031	$68,941	$68,095	$67,332	$66,662	$66,029	$65,541	$65,535
2032	$71,140	$70,214	$69,399	$68,710	$68,102	$67,554	$67,546
2033	$73,339	$72,333	$71,465	$70,757	$70,175	$69,566	$69,556
2034-2073	$75,537	$74,452	$73,531	$72,805	$72,248	$71,579	$71,566
Annual O-D At-Sea Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024	$674,140	$664,401	$657,366	$649,550	$640,634	$635,657	$635,488
2025	$699,407	$689,393	$681,722	$673,286	$664,155	$659,063	$658,835
2026	$724,674	$714,385	$706,078	$697,021	$687,676	$682,469	$682,181
2027	$749,941	$739,377	$730,434	$720,757	$711,197	$705,875	$705,528
2028	$775,208	$764,369	$754,790	$744,492	$734,718	$729,281	$728,875
2029	$800,475	$789,361	$779,146	$768,228	$758,239	$752,686	$752,221
2030	$825,784	$813,158	$802,295	$791,029	$780,840	$774,462	$773,989
2031	$851,094	$836,955	$825,444	$813,831	$803,441	$796,237	$795,756
2032	$876,403	$860,753	$848,593	$836,632	$826,042	$818,013	$817,523
2033	$901,712	$884,550	$871,741	$859,434	$848,643	$839,788	$839,291
2034-2073	$927,021	$908,347	$894,890	$882,235	$871,244	$861,564	$861,058

Table 4-17. Origin-Destination Annual Transportation Cost Savings Benefits by Channel Depth (in Thousands $) – West Waterway

Annual O-D At-Sea and In-Port Transportation Cost Saving Benefits ($1,000s)						
Year	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW
2024	$7,522	$11,776	$16,337	$21,284	$25,069	$25,250
2025	$7,850	$12,308	$17,516	$23,207	$27,255	$27,421
2026	$8,177	$12,841	$18,696	$25,130	$29,441	$29,592
2027	$8,504	$13,373	$19,875	$27,053	$31,627	$31,763
2028	$8,831	$13,905	$21,054	$28,976	$33,813	$33,934
2029	$9,158	$14,437	$22,233	$30,899	$35,999	$36,105
2030	$10,224	$16,354	$24,617	$33,405	$39,020	$39,182
2031	$11,289	$18,271	$27,001	$35,911	$42,042	$42,259
2032	$12,355	$20,188	$29,385	$38,417	$45,064	$45,336
2033	$13,420	$22,106	$31,769	$40,923	$48,085	$48,413
2034-2073	$14,486	$24,023	$34,153	$43,429	$51,107	$51,490
Annual O-D In-Port Transportation Cost Saving Benefits ($1,000s)						
Year	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW
2024	$320	$617	$901	$1,147	$1,308	$1,308
2025	$345	$641	$950	$1,248	$1,444	$1,445
2026	$370	$664	$1,000	$1,350	$1,580	$1,583
2027	$395	$687	$1,049	$1,452	$1,716	$1,720
2028	$419	$710	$1,098	$1,554	$1,852	$1,858
2029	$444	$733	$1,148	$1,656	$1,988	$1,995
2030	$490	$817	$1,263	$1,776	$2,097	$2,105
2031	$536	$901	$1,378	$1,895	$2,205	$2,214
2032	$582	$985	$1,494	$2,015	$2,314	$2,323
2033	$628	$1,069	$1,609	$2,135	$2,422	$2,432
2034-2073	$674	$1,152	$1,724	$2,255	$2,531	$2,542
Annual O-D At-Sea Transportation Cost Saving Benefits ($1,000s)						
Year	WW Alt 2 -52 MLLW	WW Alt 2 -53 MLLW	WW Alt 2 -54 MLLW	WW Alt 2 -55 MLLW	WW Alt 2 -56 MLLW	WW Alt 2 -57 MLLW
2024	$7,202	$11,159	$15,436	$20,138	$23,761	$23,942
2025	$7,504	$11,668	$16,566	$21,959	$25,811	$25,975
2026	$7,807	$12,177	$17,696	$23,780	$27,860	$28,009
2027	$8,109	$12,686	$18,826	$25,601	$29,910	$30,042
2028	$8,412	$13,195	$19,956	$27,422	$31,960	$32,076
2029	$8,714	$13,704	$21,085	$29,243	$34,010	$34,109
2030	$9,733	$15,537	$23,354	$31,630	$36,923	$37,077
2031	$10,753	$17,371	$25,623	$34,016	$39,837	$40,045
2032	$11,773	$19,204	$27,891	$36,402	$42,750	$43,012
2033	$12,792	$21,037	$30,160	$38,788	$45,663	$45,980
2034-2073	$13,812	$22,870	$32,428	$41,174	$48,577	$48,948

Table 4-18. Origin-Destination Annual Transportation Cost Savings Benefits by Channel Depth (in Thousands $) – East Waterway

Annual O-D At-Sea and In-Port Transportation Cost Saving Benefits ($1,000s)						
Year	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024	$10,141	$17,568	$25,825	$35,163	$40,330	$40,496
2025	$10,473	$18,589	$27,505	$37,110	$42,427	$42,653
2026	$10,805	$19,610	$29,185	$39,057	$44,525	$44,811
2027	$11,137	$20,631	$30,865	$41,004	$46,622	$46,968
2028	$11,469	$21,652	$32,545	$42,952	$48,719	$49,126
2029	$11,801	$22,673	$34,224	$44,899	$50,817	$51,284
2030	$13,393	$24,966	$36,883	$47,732	$54,537	$55,014
2031	$14,984	$27,259	$39,542	$50,566	$58,256	$58,744
2032	$16,576	$29,552	$42,201	$53,399	$61,976	$62,474
2033	$18,167	$31,844	$44,859	$56,233	$65,696	$66,204
2034-2073	$19,759	$34,137	$47,518	$59,066	$69,416	$69,934
Annual O-D In-Port Transportation Cost Saving Benefits ($1,000s)						
Year	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024	$403	$795	$1,235	$1,658	$1,847	$1,844
2025	$459	$905	$1,384	$1,859	$2,083	$2,081
2026	$516	$1,014	$1,532	$2,060	$2,319	$2,318
2027	$573	$1,124	$1,680	$2,260	$2,556	$2,555
2028	$630	$1,234	$1,829	$2,461	$2,792	$2,792
2029	$686	$1,344	$1,977	$2,662	$3,028	$3,029
2030	$766	$1,476	$2,128	$2,787	$3,214	$3,218
2031	$846	$1,609	$2,279	$2,913	$3,400	$3,406
2032	$926	$1,742	$2,430	$3,038	$3,586	$3,594
2033	$1,006	$1,874	$2,581	$3,164	$3,773	$3,783
2034-2073	$1,085	$2,007	$2,733	$3,289	$3,959	$3,971
Annual O-D At-Sea Transportation Cost Saving Benefits ($1,000s)						
Year	EW Alt 2 -52 MLLW	EW Alt 2 -53 MLLW	EW Alt 2 -54 MLLW	EW Alt 2 -55 MLLW	EW Alt 2 -56 MLLW	EW Alt 2 -57 MLLW
2024	$9,739	$16,773	$24,590	$33,505	$38,483	$38,651
2025	$10,014	$17,684	$26,121	$35,252	$40,344	$40,572
2026	$10,289	$18,596	$27,653	$36,998	$42,205	$42,492
2027	$10,564	$19,507	$29,184	$38,744	$44,066	$44,413
2028	$10,839	$20,418	$30,716	$40,490	$45,928	$46,334
2029	$11,115	$21,329	$32,247	$42,237	$47,789	$48,254
2030	$12,626	$23,490	$34,755	$44,945	$51,322	$51,796
2031	$14,138	$25,650	$37,263	$47,653	$54,856	$55,338
2032	$15,650	$27,810	$39,770	$50,361	$58,390	$58,879
2033	$17,162	$29,970	$42,278	$53,069	$61,923	$62,421
2034-2073	$18,674	$32,131	$44,786	$55,777	$65,457	$65,963

Table 4-19. Origin-Destination AAEQ Transportation Cost and Cost Savings Benefits by Alternative Depth (in Thousands $)

Alternative/Depth	O-D AAEQ Transportation Cost ($1,000s)	O-D AAEQ Transportation Cost Savings ($1,000s)
No Action	$948,999	---
WW Alt 2-52 MLLW	$936,170	$12,829
WW Alt 2 -53 MLLW	$927,926	$21,072
WW Alt 2 -54 MLLW	$918,802	$30,196
WW Alt 2 -55 MLLW	$910,108	$38,890
WW Alt 2 -56 MLLW	$903,291	$45,708
WW Alt 2 -57 MLLW	$902,977	$46,022
EW Alt 2 -52 MLLW	$931,628	$17,371
EW Alt 2 -53 MLLW	$918,604	$30,395
EW Alt 2 -54 MLLW	$906,096	$42,903
EW Alt 2 -55 MLLW	$894,938	$54,060
EW Alt 2 -56 MLLW	$885,900	$63,099
EW Alt 2 -57 MLLW	$885,429	$63,570

Table 4-20. Origin-Destination AAEQ Cost Statistics by Alternative and Depth (in Thousands $) – West Waterway

Statistic	No Action	WW Alt 2 - 52 MLLW	WW Alt 2 - 53 MLLW	WW Alt 2 - 54 MLLW	WW Alt 2 - 55 MLLW	WW Alt 2 - 56 MLLW	WW Alt 2 - 57 MLLW
Mean	$948,999	$936,170	$927,926	$918,802	$910,108	$903,291	$902,977
Std Dev	$5,812	$5,880	$5,779	$4,608	$5,513	$5,697	$5,813
Median	$948,972	$936,736	$927,858	$918,284	$909,392	$902,586	$903,792
Min	$936,705	$923,699	$917,132	$910,963	$900,579	$894,641	$892,513
Max	$958,481	$951,930	$943,512	$937,454	$923,476	$916,244	$915,778
Range	$21,776	$28,231	$26,380	$26,491	$22,897	$21,604	$23,266
Confidence for Mean +/-	$1,801	$1,822	$1,791	$1,428	$1,709	$1,765	$1,802

Table 4-21. Origin-Destination AAEQ Cost Statistics by Alternative and Depth (in Thousands $) – East Waterway

Statistic	No Action	EW Alt 2 - 52 MLLW	EW Alt 2 - 53 MLLW	EW Alt 2 - 54 MLLW	EW Alt 2 - 55 MLLW	EW Alt 2 - 56 MLLW	EW Alt 2 - 57 MLLW
Mean	$948,999	$931,628	$918,604	$906,096	$894,938	$885,900	$885,429
Std Dev	$5,812	$5,552	$6,476	$5,650	$5,056	$5,333	$5,308
Median	$948,972	$931,694	$918,717	$905,502	$895,160	$885,638	$885,278
Min	$936,705	$920,779	$904,673	$896,135	$882,393	$874,669	$874,283
Max	$958,481	$945,252	$933,303	$920,106	$904,788	$895,836	$895,105
Range	$21,776	$24,473	$28,630	$23,971	$22,395	$21,167	$20,822
Confidence for Mean +/-	$1,801	$1,720	$2,007	$1,751	$1,567	$1,653	$1,645

Table 4-22 and Table 4-23 provides the OD cost saving benefits for the benefiting trade routes for each alternative depth for the West and East Waterways, respectively. It should be noted that benefits are for containerized cargo only and therefore benefit information for different commodity types is not presented.

Table 4-22. Origin-Destination AAEQ Transportation Cost Saving Benefits by Route Group and Depth (in Millions $) – West Waterway

Route Group	WW Alt 2 -52 MLLW		WW Alt 2 -53 MLLW		WW Alt 2 -54 MLLW		WW Alt 2 -55 MLLW		WW Alt 2 -56 MLLW		WW Alt 2 -57 MLLW	
	$	%	$	%	$	%	$	%	$	%	$	%
Asia	$3.7	29%	$4.4	21%	$6.4	21%	$7.5	19%	$9.4	20%	$9.2	20%
Med	$9.1	71%	$16.6	79%	$23.8	79%	$31.4	81%	$36.4	80%	$36.8	80%
Total	$12.8		$21.1		$30.2		$38.9		$45.7		$46.0	

Table 4-23. Origin-Destination AAEQ Transportation Cost Saving Benefits by Route Group and Depth (in Millions $) – East Waterway

Route Group	EW Alt 2 -52 MLLW		EW Alt 2 -53 MLLW		EW Alt 2 -54 MLLW		EW Alt 2 -55 MLLW		EW Alt 2 -56 MLLW		EW Alt 2 -57 MLLW	
	$	%	$	%	$	%	$	%	$	%	$	%
Asia	$0.3	2%	($0.6)	-2%	$1.9	4%	$2.1	4%	$2.7	4%	$2.7	4%
Med	$17.1	98%	$31.0	102%	$41.0	96%	$52.0	96%	$60.4	96%	$60.9	96%
Total	$17.4		$30.4		$42.9		$54.1		$63.1		$63.6	

4.3 Transportation Cost Saving Benefit Analysis

The benefit-cost analysis presented in this section is for each incremental foot evaluated to -57 MLLW in each waterway and considered origin-destination benefits. Parametric costs have been annualized using the current discount rate of 3.125 percent and are presented at the October 2015 price level. The costs include all economic costs such as project first costs (construction cost) for the Federal project, associated local service facility improvements at Terminal 18 on the East Waterway and Terminal 5 on the West Waterway, interest during construction, and 10-year operations and maintenance (O&M) dredging expenses associated with maintenance of those channel depths. Local service facility improvements are required at Terminal 18 to include berth deepening beyond -51 MLLW, as well as structural slope stability improvements for channel deepening beyond -54 MLLW, hence the large jump in total average annual equivalent (AAEQ) cost from East Waterway Alternative 2 at -54 MLLW to -55 MLLW. Berth deepening would also be required at Terminal 5 for channel deepening beyond -55 MLLW. The results of the origin-destination (OD) transportation cost saving benefit analysis are displayed in Table 4-24 for each waterway on their own. Table 4-25 presents the results for combinations of depths for each waterway. As shown, the -56 MLLW depth provides the greatest total net benefits in the OD analysis for each individual waterway, and in combination. At this time, local service facility costs of the combined -56 MLLW alternative are estimated to be $263 million and construction costs of the proposed channel are $68 million, with a total economic cost of approximately $330 million before interest during construction, and associated O&M of $4.1 million every 10 years. It should be noted that benefits are for containerized cargo only.

Table 4-24. Origin-Destination Benefit Cost Analysis

Alt	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Incremental Net Benefits	BCR
East Waterway Alternative 2					
EW Alt 2 -52 MLLW	$1,030,000	$17,371,000	$16,340,000		16.9
EW Alt 2 -53 MLLW	$1,415,000	$30,395,000	$28,980,000	$12,640,000	21.5
EW Alt 2 -54 MLLW	$1,843,000	$42,903,000	$41,059,000	$12,079,000	23.3
EW Alt 2 -55 MLLW	$11,105,000	$54,060,000	$42,955,000	$1,896,000	4.9
EW Alt 2 -56 MLLW	$11,564,000	$63,099,000	***$51,535,000***	$8,580,000	5.5
EW Alt 2 -57 MLLW	$12,100,000	$63,570,000	$51,470,000	($65,000)	5.3
West Waterway Alternative 2					
WW Alt 2 -52 MLLW	$1,457,000	$12,829,000	$11,371,000	-40099000	8.8
WW Alt 2 -53 MLLW	$1,604,000	$21,072,000	$19,468,000	$8,097,000	13.1
WW Alt 2 -54 MLLW	$1,786,000	$30,196,000	$28,410,000	$8,942,000	16.9
WW Alt 2 -55 MLLW	$2,033,000	$38,890,000	$36,857,000	$8,447,000	19.1
WW Alt 2 -56 MLLW	$2,386,000	$45,708,000	***$43,322,000***	$6,465,000	19.2
WW Alt 2 -57 MLLW	$2,802,000	$46,022,000	$43,221,000	($101,000)	16.4

Table 4-25. Origin-Destination Benefit Cost Analysis for East and West Waterway Plan Combinations

Combined	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Incremental Net Benefits	BCR
-52 MLLW	$2,487,000	$30,200,000	$27,711,000		12.1
-53 MLLW	$3,019,000	$51,467,000	$48,448,000	$20,737,000	17.0
-54 MLLW	$3,629,000	$73,099,000	$69,469,000	$21,021,000	20.1
-54 MLLW East & -56 MLLW West	$4,229,000	$88,611,000	$84,382,000	$14,913,000	21.0
-55 MLLW	$13,138,000	$92,950,000	$79,812,000	($4,570,000)	7.1
-56 MLLW	$13,950,000	$108,807,000	***$94,857,000***	$15,045,000	7.8
-57 MLLW	$14,902,000	$109,592,000	$94,691,000	($166,000)	7.4

5 Sensitivity Analysis

The Principles and Guidelines (P&G) and subsequent Engineering Regulation (ER) 1105-2-100, also known as the Planning Guidance Notebook, recognize the inherent variability to water resources planning. Navigation projects and container studies in particular are fraught with uncertainty about future conditions. Therefore a sensitivity analysis in which key quantitative assumptions and computations are changed is required to assess their effect on the final outcome. The sensitivity analysis for this study was a repeat of the primary analysis, substituting commodity and fleet forecasts with a range of values that were projected to be below and above the base scenario. The HarborSym model used in the basic evaluation included variations or ranges for many of the variables involved in the vessel costs, loading, distances, speeds, etc. However, it used only one basis for the commodity forecast, a key area of potential uncertainty. The sensitivity analysis presents the results of a large range of potentially different future commodity and vessel fleet forecasts at Seattle.

5.1 Data

Commodity forecasts were obtained from IHS Global Insight for a low growth, baseline growth, and high growth estimate. The analysis presented in Chapter 4 utilized the low growth estimates and the vessel fleet forecast developed by MSI and adjusted based on the low growth commodity forecast estimates. The baseline analysis was established from historical trade information as discussed in Section 3.3.1. Next, a long-term trade forecast for the U.S. West Coast, Pacific Northwest, and Seattle Harbor was obtained from IHS Global Insight. That forecast was obtained in 2015 and the Corps decided that using the baseline established by empirical data and applying the low growth year-to-year growth rates calculated by evaluating and combining world regions calculated from the IHS Global Insight forecast would result in a forecast with less uncertainty than that which is typically present in long-term forecasts. The same low growth commodity forecast was used to develop growth rates from 2014 to 2034.

Three scenarios were evaluated to compare against the outputs of the analysis presented in Chapter 4. The included the following:

- No growth in commodity or fleet forecast from base year 2024
- No growth in commodity or fleet forecast from 2029
- No growth in commodity or fleet forecast from 2014

Table 5-1 displays the vessel fleet forecast under the three scenarios as compared to the baseline forecast presented in Section 3.4.2.4.

Table 5-1. Vessel Fleet Forecast for Sensitivity Scenarios

	Baseline (Low Growth)				No Growth from Base Year 2024			No Growth from 2029			No Growth from 2014		
Vessel Calls	**2014**	**2024**	**2029**	**2034**	**2024**	**2029**	**2034**	**2024**	**2029**	**2034**	**2024**	**2029**	**2034**
Panamax	143	--	--	--	--	--	--	--	--	--	143	143	143
Post-Panamax Gen I	68	211	129	35	211	211	211	211	129	129	68	68	68
Post-Panamax Gen II	127	96	138	147	96	96	96	96	138	138	127	127	127
Post-Panamax Gen III	67	162	224	279	162	162	162	162	224	224	67	67	67
Post-Panamax Gen IV	0	55	119	210	55	55	55	55	119	119	0	0	0
Total	**405**	**524**	**609**	**669**	**524**	**524**	**524**	**524**	**609**	**609**	**405**	**405**	**405**

Figure 5-1 and Figure 5-2 show the import and export containerized commodity tonnage forecast for each of the three scenarios as compared to the baseline forecast presented in Section 3.4.2.4.

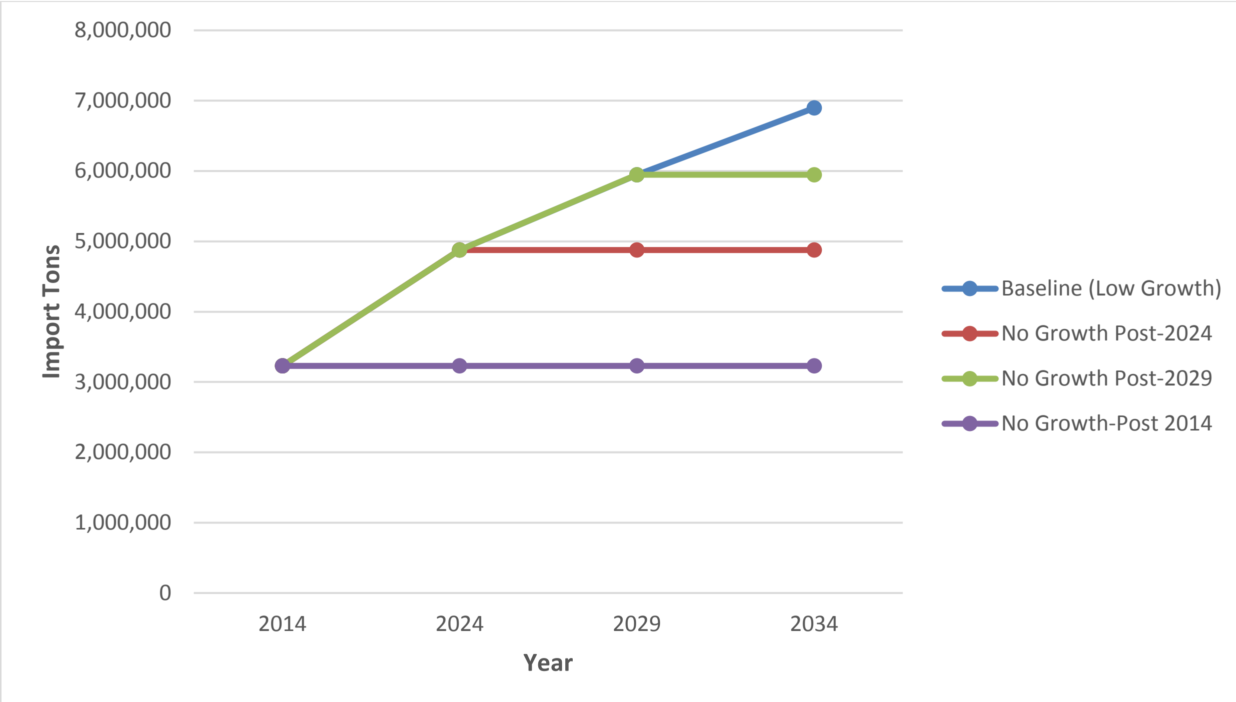


Figure 5-1. Containerized Trade Commodity Forecast Scenarios - Imports

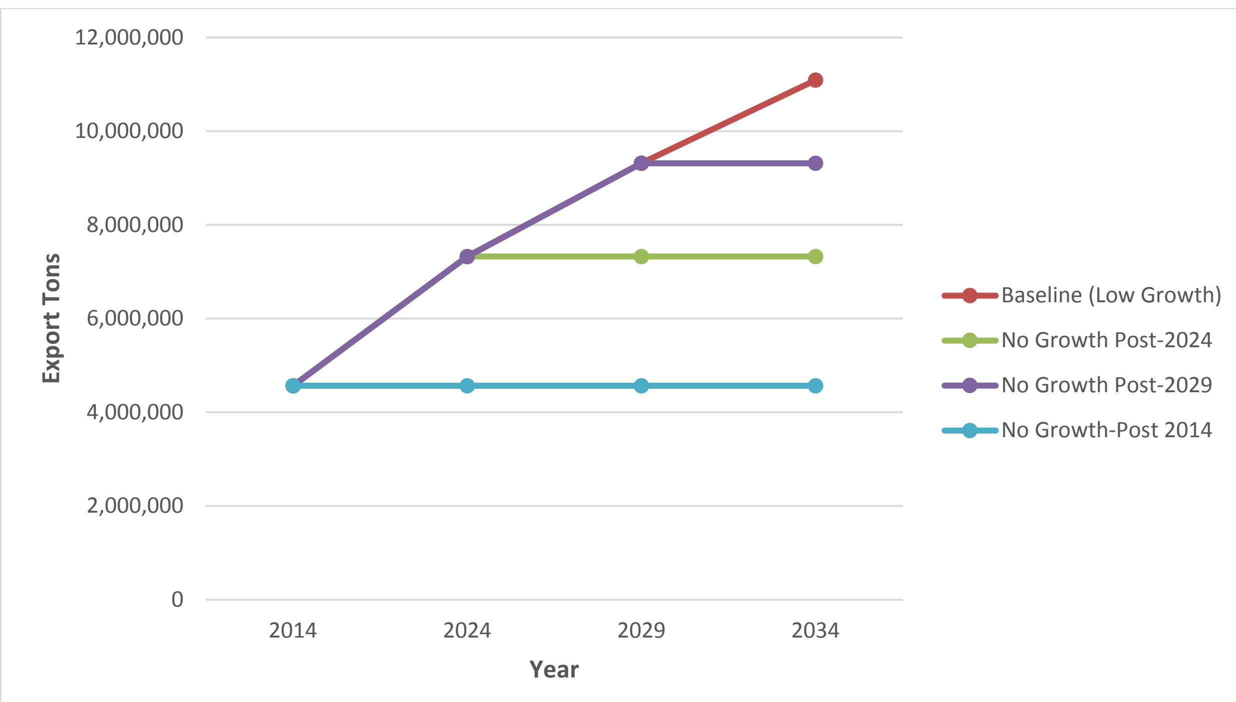


Figure 5-2. Containerized Trade Commodity Forecast Scenarios - Exports

5.2 Results

Table 5-2 provides sensitivity analysis results for the "No Growth Post-2029" scenario under the low growth commodity forecast. HarborSym was run with the same low growth forecast as the baseline except tonnage was held constant after 2029. Total import and export tonnages forecast for year 2029 are 5,947,103 and 9,314,787 metric tons, respectively. The net benefits for all alternative plan combinations are positive, with the combined -56 MLLW alternative producing the greatest net benefits. This finding is consistent with the base scenario results presented in Section 4.3.

Table 5-2. No Growth Post-2029 Commodity Forecast - AAEQ Transportation Cost Savings

Alternative Combination	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Incremental Net Benefits	BCR
-52 MLLW	$2,487,000	$20,592,000	$18,105,000		8.3
-53 MLLW	$3,019,000	$36,246,000	$33,227,000	$15,122,000	12.0
-54 MLLW	$3,629,000	$54,867,000	$51,238,000	$18,011,000	15.1
EW -54 MLLW, WW -56 MLLW	$4,229,000	$68,073,000	$63,844,000	$12,606,000	16.1
-55 MLLW	$13,138,000	$73,646,000	$60,508,000	-$3,336,000	5.6
-56 MLLW	$13,950,000	$84,434,000	***$70,484,000***	$9,976,000	6.1
-57 MLLW	$14,902,000	$84,982,000	$70,080,000	-$404,000	5.7

Table 5-2 provides sensitivity analysis results for the "No Growth Post-2024" scenario under the low growth commodity forecast. HarborSym was run with the same low growth forecast as the baseline except tonnage was held constant after the base year 2024. Total import and export tonnages forecast for year 2024 are 4,876,359 and 7,326,090 metric tons, respectively. The net benefits for all alternative plan combinations are positive, with the combined -56 MLLW alternative producing the greatest net benefits. This finding is consistent with the base scenario results presented in Section 4.3.

Table 5-3. No Growth Post-2024 Commodity Forecast - AAEQ Transportation Cost Savings

Alternative Combination	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Incremental Net Benefits	BCR
-52 MLLW	$2,487,000	$17,663,000	$15,176,000		7.1
-53 MLLW	$3,019,000	$29,344,000	$26,325,000	$11,149,000	9.7
-54 MLLW	$3,629,000	$42,162,000	$38,533,000	$12,208,000	11.6
EW -54 MLLW, WW -56 MLLW	$4,229,000	$50,894,000	$46,665,000	$8,132,000	12.0
-55 MLLW	$13,138,000	$56,447,000	$43,309,000	-$3,356,000	4.3
-56 MLLW	$13,950,000	$65,399,000	***$51,449,000***	$8,140,000	4.7
-57 MLLW	$14,902,000	$65,746,000	$50,844,000	-$605,000	4.4

Finally, as an extreme-case sensitivity analysis, HarborSym was run with existing traffic and commodities imported and exported from year 2014, referred to as "No Growth Post-2014". The Total AAEQ Benefits are positive, but lowest under this scenario for all combinations of alternatives as presented in Table 5-4. However, given the changes in costs from the combination of East Waterway Alternative 2 at -54 MLLW and West Waterway Alternative 2 at -56 MLLW to the next highest cost plan combination of -55 MLLW in both waterways, the combination of East Waterway Alternative 2 at -54 MLLW and West

Waterway Alternative 2 at -56 MLLW is the plan that results in the greatest net benefits under this scenario.

Table 5-4. No Growth Post-2014 Commodity Forecast - AAEQ Transportation Cost Savings

Alternative Combination	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Incremental Net Benefits	BCR
-52 MLLW	$2,487,000	$5,202,000	$2,715,000		2.1
-53 MLLW	$3,019,000	$9,677,000	$6,658,000	$3,943,000	3.2
-54 MLLW	$3,629,000	$13,979,000	$10,350,000	$3,692,000	3.9
EW -54 MLLW, WW -56 MLLW	$4,229,000	$16,532,000	***$12,303,000***	$1,953,000	3.9
-55 MLLW	$13,138,000	$17,280,000	$4,142,000	-$8,161,000	1.3
-56 MLLW	$13,950,000	$19,373,000	$5,423,000	$1,281,000	1.4
-57 MLLW	$14,902,000	$19,373,000	$4,471,000	-$952,000	1.3

5.3 Discussion

As shown in Table 5-2, Table 5-3, and Table 5-4, all alternative plan combinations result in positive net benefits with consideration of various no growth scenarios from year 2029, year 2024, and year 2014, respectively. The No Growth Post-2029 and Post-2024 sensitivities support the conclusion that the combined -56 MLLW alternative results in the greatest net benefits supporting a National Economic Development (NED) plan selection. Under the extreme case that commodities do not grow from present conditions (year 2014), this plan still results in positive net benefits.

Other sensitivities were considered but not evaluated at this time. While these sensitivity runs would provide additional information, they are not anticipated to change the overall outcome of the analysis and NED plan selection. They include the following:

- Panamax vessels were considered in the evaluation of alternatives; however, as larger containerships become more efficient and available in the World fleet, it is anticipated that the fleet of Panamax vessels will transition away from Seattle. Recent trends in the upsizing of ships due to few services attributable to mega shipping alliances for Far East traffic to the North American West Coast, which accounts for approximately 90 percent of trade in Seattle, suggest these vessels will not call too much longer, as observed in historic trends for the Port of Seattle and as reflected in MSI projections which show that these vessels will likely go away by prior to the base year 2024. Therefore, there is a reasonable likelihood that these Panamax vessels would not deploy on international routes to Seattle by year 2024.
- Incremental evaluation of channel widths was considered, but not conducted at this time due to relatively low cost of deepening alternatives with these proposed widths. Widths were based on design vessel channel recommendation in PIANC for safe navigation of the harbor. Narrower channels would not satisfy the study objective to improve navigational safety for harbor pilots operating ultralarge containerships. Further, widening measures are not intended and will not change one-way traffic or other navigational practices in either the East or West Waterways.

- Vessel speeds at sea may affect vessel operating costs and project benefits. The analysis currently presented includes economical slow-steam speeds and associated costs. An evaluation of service speeds was also conducted, but is not presented. The use of economic versus service speeds did not change the outcomes of the analysis.
- A qualitative multiport analysis will be conducted as part of the final report, as described in Section 6. However, it should be noted that the analysis presented assumes Seattle will maintain its historic share of U.S. West Coast and North American West Coast market share even though much of the cargo originating or destined for the Midwest is discretionary and can shift to other ports based on a number of factors including rail and trucking costs. No assumptions were made with regards to cargo diverting from one port to another. This historic market share takes into account recent port developments with new container operations at Port of Prince Rupert which reduced average market share for the Port of Seattle. The analysis of future without project conditions does assume or claim benefits for traffic shifting back to the U.S. and thus support the claim that a deepening project would result in "build it and they will come" benefits. Traffic that currently calls and the anticipated growth of that share is based on historic market share and growth projections for the U.S. West Coast. This is the basis of the projected commodity forecasts. While a multiport analysis will be conducted, a sensitivity analysis is not expected at this time with regards to Seattle share of West Coast trade but may be considered in the future as additional historic data is obtained.
- Use of low growth forecasts from IHS Global Insight may underestimate the amount of cargo and traffic at the Port of Seattle over the planning period of analysis. At this time, the likelihood of this occurring is low and the impact to the economic evaluation is low based on preliminary analysis which considered the IHS baseline forecast data. Increased output at the Port of Seattle would likely result in greater net benefits than those presented in this analysis, as well as some additional vessel and associated truck and rail traffic.

6 Multiport Analysis

A multiport analysis will be conducted for Seattle Harbor that presents the results of a systematic assessment of potential effects the deepening of Seattle Harbor could have on other ports. The analysis will consider factors related to port competition such as proximity, hinterland overlap, commodity throughput and sea, port and land-based transportation options and costs. Since the purpose of a multiport analysis is to estimate potential changes in the with-project condition traffic forecasts, only the commodities affecting benefits and handled by alternative ports were analyzed. A detailed semi-quantitative assessment will be conducted as part of the finalization of this report in the next phase of the feasibility analysis.

Ports that will be considered in this analysis include U.S. West Coast ports including Tacoma, Oakland Los Angeles and Long Beach; as well as Canadian West Coast ports in Vancouver and Prince Rupert. These ports all serve overlapping hinterlands in the Midwest. Study and investment in port infrastructure improvements is ongoing at each of these ports, including a feasibility evaluation to deepen sections of Long Beach, as well as expansion and upgrades at both Port Metro Vancouver and Prince Rupert. Seattle Harbor represents a small proportion of overall trade in terms of loaded TEUs and metric tonnage for U.S. West Coast ports as shown in Figure 6-1 and Figure 6-2.

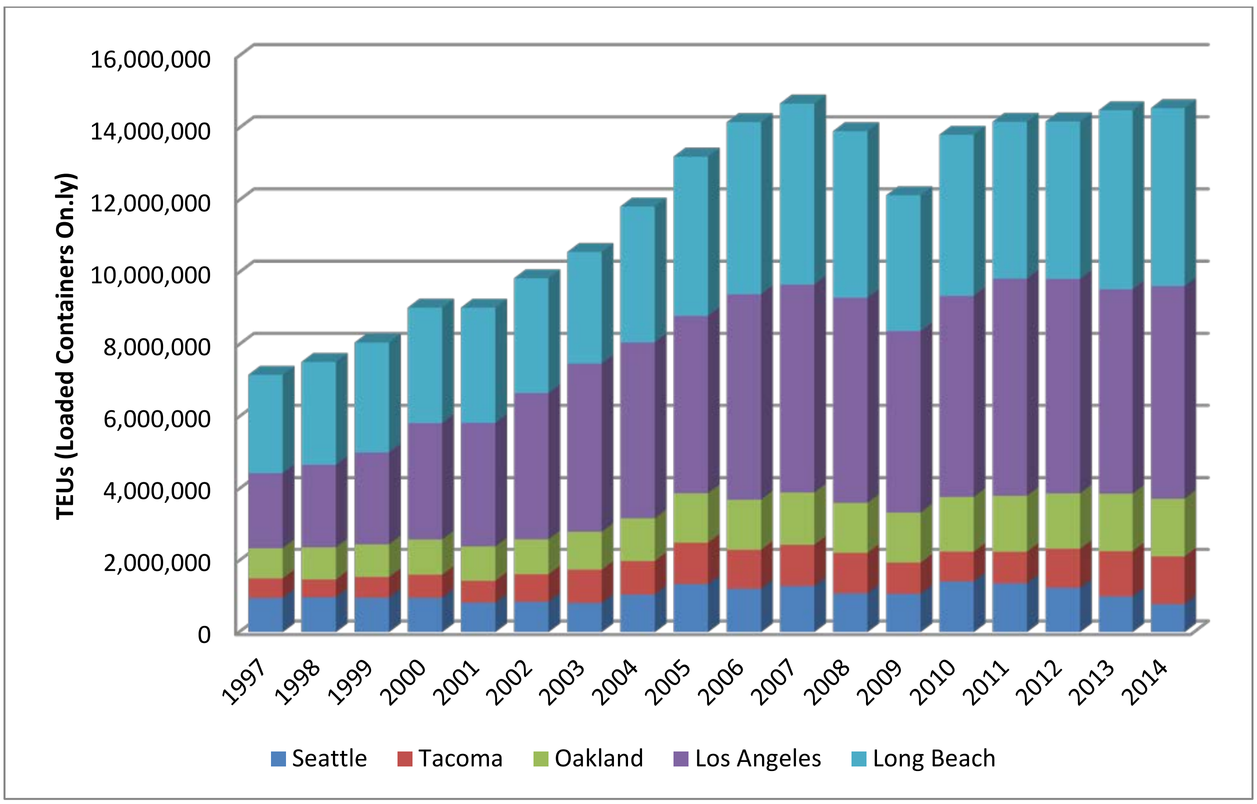


Figure 6-1. Historical Container Volumes (Loaded TEUs) at U.S. West Coast Ports

Source: U.S. Department of Transportation, Maritime Administration, 1997-2014 U.S. Waterborne Container Trade by U.S. Customs Port (Series), released 9 Apr 2015, accessed online 17 Sep 2015

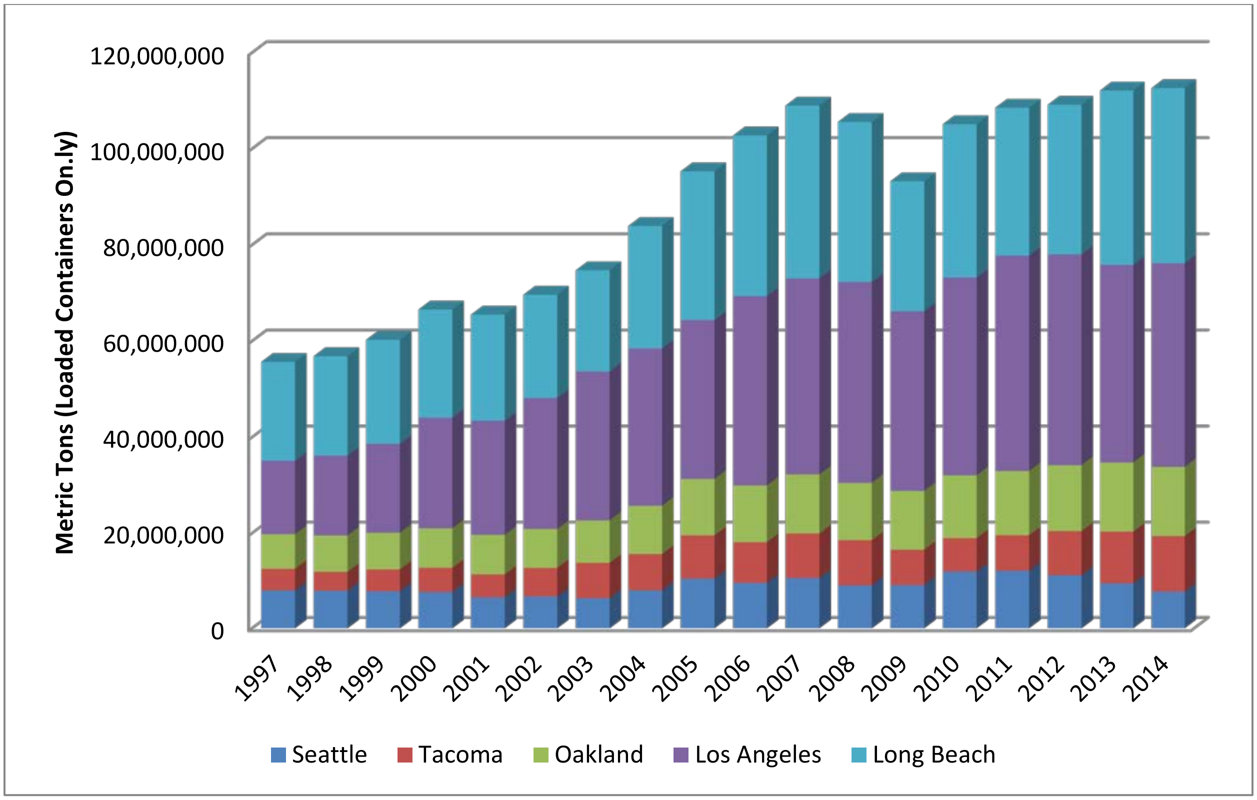


Figure 6-2. Historical Total Trade (in Metric Tons) at U.S. West Coast Ports

Source: U.S. Department of Transportation, Maritime Administration, 1997-2014 U.S. Waterborne Container Trade by U.S. Customs Port (Series), released 9 Apr 2015, accessed online 17 Sep 2015

7 Socioeconomic and Regional Analysis

The socioeconomics of the community area are summarized in this section. The parameters used to describe the demographic and socioeconomic environment include recent trends in population for thirteen counties that make up the immediate economic study area of the Port of Seattle, private sector employment, wage earnings by sectors for Washington Stage and three counties that make up the Seattle-Tacoma-Bellevue Metropolitan Statistical Area, including King County, Pierce County, and Snohomish County. Other social characteristics such as race composition, age distribution, poverty, and environmental justice (EJ) issues will be examined within the Seattle metro area (composed of King, Snohomish, and Pierce Counties), whose communities may be directly impacted by the deepening and expansion of the Port.

7.1 Overview

7.1.1 Population

Washington is ranked as the 13th most populous state in the United States with 6.7 million residents in 2010. Between 1990 and 2010, Washington's population increased by 38 percent from 4.9 million to 6.7 million, as shown in Table 7-1. Washington's growth was greater than the national growth over the same historic period. All counties in the Seattle metro area experience population growth rates over this time frame that were greater than the national growth rate. Population growth was slowest in King County with 28 percent growth from 1990 to 2010, whereas Snohomish County grew 53 percent during this same period of time. The Seattle metro area which includes the city of Seattle and King, Snohomish, and Pierce Counties, is ranked 15th among Metropolitan Statistical Areas (MSA's) in the United States. The Seattle metro area is home to more than half of people living in the state of Washington.

Table 7-1. Population Trends, 1990 to 2010

	Population			Percentage Change		
Geographical Area	**1990**	**2000**	**2010**	**1990 to 2000**	**2000 to 2010**	**1990 to 2010**
King County	1,507,319	1,737,034	1,931,249	15.2%	11.2%	28.1%
Pierce County	586,203	700,820	795,225	19.6%	13.5%	35.7%
Seattle-Tacoma-Bellevue MSA	2,559,164	3,043,878	3,439,809	18.9%	13.0%	34.4%
Washington State	4,866,692	5,894,121	6,724,540	21.1%	14.1%	38.2%
United States	248,709,873	281,421,906	308,745,538	13.2%	9.7%	24.1%
Source: U.S. Census Bureau						

7.1.2 Employment

Washington employment in 2014 totaled 2.5 million (excluding public employees), with average annual wage of $55,000 as shown in Table 7-2. In 2014, over 157 thousand people were employed in federal, state, and local government. Within the private sector, Health Care and Social Assistance, Retail Trade, and Manufacturing make up 40 percent of total industry employment, with over 1 million total employees. Combined service industries, i.e., NAICS industries 54 through 81, are also noteworthy sectors within the State, with the health care and social assistance services, and accommodation and food services industries employing the largest share of those aggregated sectors.

Table 7-2. Private Sector Employment, 2014

	NAICS Industry Sector*	Annual Average Employment	Total Annual Wages	Average Wage per Employee
11	**Agriculture, Forestry, Fishing and Hunting**	99,666	$2,768,253,098	$27,775
21	**Mining, Quarrying, and Oil and Gas Extraction**	2,192	$138,981,871	$63,404
22	**Utilities**	4,770	$416,001,925	$87,212
23	**Construction**	150,086	$8,270,681,977	$55,106
31-33	**Manufacturing**	285,354	$21,209,680,136	$74,328
42	**Wholesale Trade**	127,878	$8,970,635,354	$70,150
44-45	**Retail Trade**	337,102	$12,180,141,000	$36,132
48-49	**Transportation and Warehousing**	87,250	$4,578,135,383	$52,471
51	**Information**	108,873	$16,161,995,907	$148,448
52	**Finance and Insurance**	90,856	$7,458,273,421	$82,089
53	**Real Estate, Rental and Leasing**	46,092	$2,085,695,833	$45,251
54	**Professional and Technical Services**	177,218	$15,047,717,003	$84,911
55	**Management of Companies and Enterprises**	39,919	$4,252,384,297	$106,525
56	**Administrative and Waste Services**	148,358	$6,586,833,436	$44,398
61	**Educational Services**	38,472	$1,420,561,630	$36,925
62	**Health Care and Social Assistance**	392,557	$17,368,804,193	$44,245
71	**Arts, Entertainment, and Recreation**	46,661	$1,387,405,577	$29,734
72	**Accommodation and Food Services**	246,704	$4,825,474,838	$19,560
81	**Other Services, Except Public Administration**	89,438	$3,181,428,654	$35,571
92	**Public Administration (Federal, State, and Local)**	157,139	$10,245,278,520	$65,199
99	**Unclassified**	21	$1,360,919	$64,806
	All Private Sectors	2,519,467	$138,310,446,452	$54,897

*Source: Bureau of Labor Statistics Quarterly Census of Employment and Wages, 2014

7.1.3 Wage Earnings by Sector

Of the private sector industries, information sector employees are paid the highest in average annual earnings, slightly over $148,000 followed by employees within the management of companies and enterprises sector. The average annual earnings of information sector employees is 2.7 times the average annual wage earnings across all industry sectors. Comparatively, the manufacturing sector, the major port user, generates average wages statewide of $74,328. The unemployment rate for the state of Washington in 2014 was 6.1 percent, 0.1 percent below the national average.

7.1.4 Median Household Income

Median household incomes for selected counties in 2012 are shown in Table 7-3. The Seattle-Tacoma-Bellevue MSA's median household income is over 110 percent of the state median income.

Table 7-3. Median Household Income for Selected Areas, 2012

Geography	Median Household Income, 2012	% of State Median Household Income
King County	$71,175	119.9%
Pierce County	$59,105	99.5%
Seattle-Tacoma-Bellevue MSA	$65,855	110.9%
Washington State	$59,374	100.0%
United States	$53,046	N/A
Source: U.S. Census, 2008-2012 American Community Survey		

As shown in Table 7-4 below, the unemployment rate in the Seattle-Tacoma-Bellevue MSA was 5.2 percent, nearly 1 percent below the state and national average.

Table 7-4. Unemployment for Selected Areas, 2010

Geographical Area	Unemployment Rate
King County	7.30%
Pierce County	10.30%
Seattle-Tacoma-Bellevue MSA	8.40%
Washington State	8.90%
United States	9.30%
Source: U.S. Census Bureau, 2008-2012 American Community Survey	

7.1.5 Social Characteristics

This section describes the social characteristics of the Seattle-Tacoma-Bellevue Metropolitan Statistical Area, or Seattle metro area, which includes King County, Snohomish County, Pierce County, and the City of Seattle. Most Port related infrastructure in located in the City of Seattle. The social characteristics that are assessed in this section include population, race, age, education, income, poverty, and unemployment.

7.1.5.1 Population Trends

The population trends from 1980 through 2010 for the Seattle metro area are shown in Table 7-5. The Seattle metro area as a whole has experienced a rapid rate of growth between 1980 and 2010, with a net population increase of 1.3 million residents.

Table 7-5. Population Growth for Selected Areas, 1980 to 2010

Geographical Area	1980	1990	2000	2010	% Increase, 1980-2010
King County	1,269,749	1,507,319	1,737,034	1,931,249	52.1%
Pierce County	485,643	586,203	700,820	795,225	63.7%
Seattle-Tacoma-Bellevue MSA	2,093,112	2,559,164	3,043,878	3,439,809	64.3%
Washington State	4,132,156	4,866,692	5,894,121	6,724,540	62.7%
United States	226,545,805	248,709,873	281,421,906	308,745,538	36.3%
Source: U.S. Census Bureau					

The 2010 population density for the Seattle metro area was estimated by the U.S. Census Bureau to be 585.8 persons per square mile. Population density varied from a low of 341.8 persons for square mile for Snohomish County, 476.3 persons per square mile for Pierce County, and a high of 912.9 persons per square mile in King County. Population density in the City of Seattle was 7250.9 persons per square mile.

7.1.5.2 Racial Composition

As shown in Table 7-6, all three counties, the Seattle metro area, and the state of Washington have lower percentages of minority populations than the United States for all races with exception of American Indian, Asian and Pacific populations according to the 2010 U.S. Census. In the Seattle metro area, King County has the higher percentage of minority populations than Snohomish and Pierce Counties, mostly attributable to the higher Asian population in King County. The Seattle metro has a higher percentage of minority populations compared to the state of Washington.

Table 7-6. Racial Composition by Geographical Area, 2010

	King County		Pierce County		Seattle MSA		WA	U.S.
Race	**No.**	**%**	**No.**	**%**	**No.**	**%**	**%**	**%**
White	1,325,845	68.7%	590,040	74.2%	2,474,896	71.9%	77.30%	72.40%
Black	119,801	6.2%	53,998	6.8%	191,967	5.6%	3.60%	12.90%
American Indian	16,147	0.8%	10,879	1.4%	36,819	1.1%	1.50%	0.90%
Asian	282,075	14.6%	47,501	6.0%	392,961	11.4%	7.20%	4.80%
Pacific	14,486	0.8%	10,588	1.3%	28,209	0.8%	0.60%	0.20%
Other race	75,319	3.9%	27,872	3.5%	130,312	3.8%	5.20%	6.20%
Two or more races	96,562	5.0%	54,347	6.8%	183,631	5.3%	4.70%	2.90%
Hispanic or Latino	172,378	8.9%	72,849	9.2%	309,476	9.0%	11.20%	16.30%
Source: U.S. Census Bureau, 2010 Census								

7.1.5.3 Age Distribution

The age characteristics of the Seattle metro area are shown in Table 7-7. All three counties have lower median ages than the state of Washington and the United States according to the 2010 U.S. Census. In 2010, the median age was 37.1 for King and Snohomish Counties, and 35.9 for Pierce County, and 37.3 for the Seattle metro area and the state of Washington, compared to 37.2 for the United States. The higher median age for the Seattle metro area is partly due to the lower proportion of people under age 18 in King County.

Table 7-7. Age Characteristics, 2010

	King County		Pierce County		Seattle MSA	WA	U.S.
Age Group	**No.**	**%**	**No.**	**%**	**%**	**%**	**%**
Under 18	413,502	21.4%	198,127	24.9%	22.8%	23.5%	24.0%
18-64	1,307,068	67.7%	509,313	64.1%	66.3%	64.2%	63.0%
65 or above	210,679	10.9%	87,785	11.0%	10.8%	12.3%	13.0%
Median Age	37.1		35.9		37.3	37.3	37.2
Source: U.S. Census Bureau, 2010 Census							

7.1.5.4 Income and Poverty

The U.S. Census Bureau 2008-2012 American Community Survey income and poverty data for the Seattle metro area and the state of Washington are summarized in Table 7-8. King and Snohomish

Counties had higher median household incomes than for the state, and Pierce County was slightly lower than the state median. Poverty levels are lower in the Seattle metro than the State.

Table 7-8. Regional Income and Poverty Data, 2010

Regional Income and Poverty Data, 2012	King County	Pierce County	Washington State
Median Household Income	$71,175	$59,105	$59,374
Per Capita Income	$39,664	$28,187	$30,661
Total for whom poverty status is determined	1,912,058	778,518	6,606,382
Persons Below Poverty Level	207,956	92,759	853,960
Percent of Persons Below Poverty Level	10.9%	11.90%	12.90%
Persons Below 50% of Poverty Level	97,804	43,182	380,066
Percent of Persons Below 50% Poverty Level	5.1%	5.5%	5.8%
Source: U.S. Census Bureau, 2008-2012 American Community Survey			

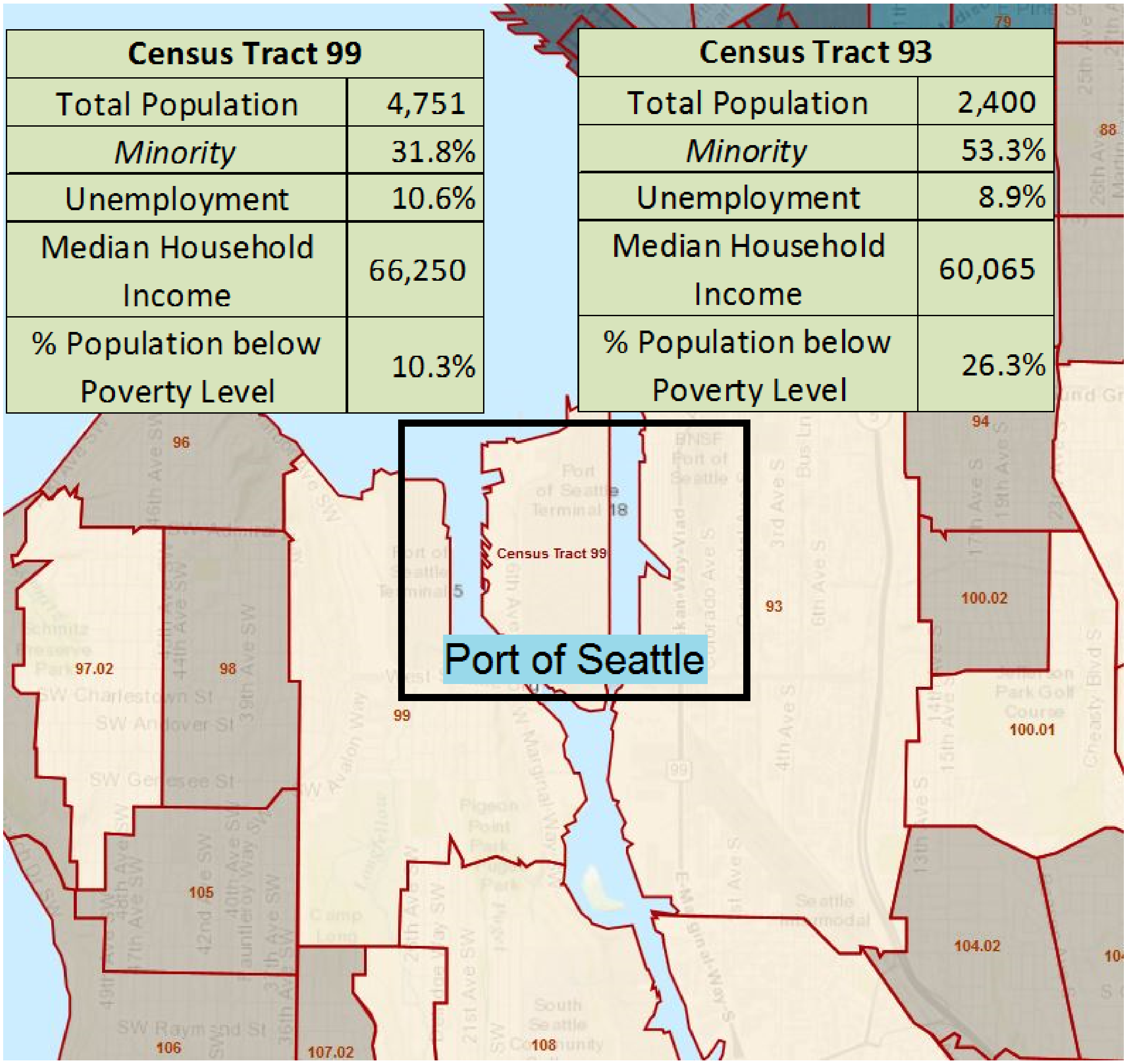
7.1.6 Environmental Justice

An environmental justice analysis was conducted to assess whether the populations currently residing in the vicinity of the proposed Port of Seattle alternatives can be defined as minority and/or low-income populations. Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, provides that "*each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies and activities on minority populations and low-income populations*."

The proposed Port of Seattle project is located in King County, Washington. According to the U.S. Bureau of Census 2014, King County has a population of 2,079,000. Minorities comprise approximately 31.3 percent of the population, most of whom are Asian (16.4 percent). The Port of Seattle facilities are mostly located in industrial areas around Harbor Island. Combining Census Tract 93 and 99, which surround the Port of Seattle, the population residing in the immediate area around Port of Seattle totals only 7,151 inhabitants, of which 39 percent are minority.

Any individual with total income less than an amount deemed to be sufficient to purchase basic needs of food and shelter, clothing, and other essential goods and services is classified as poor. The amount of income necessary to purchase these basic needs is the poverty line or. The 2014 poverty line according to the U.S. Department of Health and Human Services for an individual under 65 years of age is $11,670. For the population surrounding Port of Seattle, a total of 1,120 residents, or 15.6 percent of the population, live below the poverty line. This is significantly higher than the county average of 10.9 percent.

The proposed project included dredging in both the East and West Waterways around Harbor Island. The existing activities, including deposition of dredged sediment, will not have significant impacts on any populations, including minority populations and low-income populations. The dredging activities would be focused in the West and East Waterway, and sediment deposition is expected to occur requiring sediment removal on average every 10 years in the proposed Federal navigation channel and placed at pre-determined open water and upland disposal sites.



Census Tract 99	
Total Population	4,751
Minority	31.8%
Unemployment	10.6%
Median Household Income	66,250
% Population below Poverty Level	10.3%

Census Tract 93	
Total Population	2,400
Minority	53.3%
Unemployment	8.9%
Median Household Income	60,065
% Population below Poverty Level	26.3%

Figure 7-1. Port of Seattle Demographics

The proposed harbor deepening would not increase the number of containers moving through the port on a given year. Although vessel fleet forecast predicts an increase in the number of containers moving through the port over time as a result of increasing demand, that increase is expected to occur in the Without Project Condition – independent of a harbor deepening project.

It is anticipated that without deepening (i.e., the -56 foot depth) more vessels would be required to carry this cargo. With deepening of the harbor to a 56-foot depth, the total number of vessels would decrease (when compared to without project conditions) as newer, larger vessels would be able to load more deeply and efficiently under the improved conditions.

Since the number of containers per year is not predicted to increase as a result of the deepening, no landside changes in emissions would occur as a result of the deepening. The Corps predicts a reduction in the number of vessels used to transport the number of containers for each year (when compared to without project conditions) if the harbor is deepened. As a result, total emissions would decrease in a given year if the harbor is deepened (when compared to without project conditions). Since overall air emissions in the port would decrease slightly as a result of the project (when compared to without conditions), there is no technical need for the project to conduct a detailed analysis of the how those emissions disperse. Additionally, since there would be an overall decrease to emissions (including air toxins when compared to without project conditions), the Corps does not expect any National Ambient Air Quality Standards (NAAQS) violations as a result of harbor deepening. Therefore, a risk-based assessment of the health effects associated with the proposed action is not warranted. Any potential adverse effects of the presently permitted air emissions would be reduced if the harbor is deepened because of the reduction in vessels (when compared to without project conditions).

The Corps evaluated potential project impacts of the proposed harbor deepening and found that the information shows that the proposed action would not cause disproportionately high and adverse impacts to minority populations, low-income populations, or children.

7.2 Regional Economic Development (RED) Analysis

The regional economic development (RED) account measures changes in the distribution of regional economic activity that would result from each alternative plan. Evaluations of regional effects are measured using nationally consistent projection of income, employment, output and population.

The USACE Online Regional Economic System (RECONS) is a system designed to provide estimates of regional, state, and national contributions of federal spending associated with Civil Works and American Recovery and Reinvestment Act (ARRA) Projects. It also provides a means for estimating the forward linked benefits (stemming from effects) associated with non-federal expenditures sustained, enabled, or generated by USACE Recreation, Navigation, and Formally Utilized Sites Remedial Action Program (FUSRAP). Contributions are measured in terms of economic output, jobs, earnings, and/or value added. The system will be used to perform the regional analysis for the Seattle Harbor study for the final submittal of the Feasibility Report and Environmental Assessment in 2017.

This report will provide estimates of the economic impacts of Civil Works Budget Analysis for New Analysis Project. The Corps' IWR, the Louis Berger Group, and Michigan State University developed RECONS to provide estimates of regional and national job creation, and retention and other economic measures such as income, value added, and sales. This modeling tool automates calculations and generates estimates of jobs and other economic measures, such as income and sales associated with USACE's ARRA spending, annual Civil Works program spending, and stem-from effects for Ports, Inland Water Way, FUSRAP, and Recreation. This is done by extracting multipliers and other economic measures from more than 1,500 regional economic models that were built specifically for USACE project locations. These multipliers are then imported to a database and the tool matches various spending profiles to the matching industry sectors by location to produce economic impact estimates.

8 References

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