TACOMA HARBOR, WA
FEASIBILITY STUDY
PIERCE COUNTY, WASHINGTON

APPENDIX A – ECONOMICS

April 2022

US Army Corps of Engineers®
Seattle District

Port of Tacoma

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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
Corps	US Army Corps of Engineers
CSPS	Container Shipping Planning Service
DC	Distribution Center
DWT	Deadweight Tonnes
EGM	Economic Guidance Memorandum
EJ	Environmental Justice
ETTC	Estimated Total Trip Cargo
FWOP	Future Without-Project
FWP	Future With-Project
FCC	Fully Cellular Container
FUSRAP	Formally Utilized Sites Remedial Action Program
FY	Fiscal Year
GDP	Gross Domestic Product
HMST	HarborSym Modeling Suite of Tools
IANA	Intermodal Association of North America
IDC	Interest During Construction
ISIC	International Standard Industrial Classification
IWR	Institute for Water Resources
LFA	Load Factor Analysis
LOA	Length Overall
LPP	Locally Preferred Plan
MLLW	Mean Lower Low Water
MSA	Metropolitan Statistical Area
MSI	Maritime Strategies, Inc.
MXSLLD	Maximum Summer Loadline Draught
NAAQS	National Ambient Air Quality Standards
NAVD	North American Vertical Datum
NED	National Economic Development
NNOMPEAS	National Navigation Operation and Management Performance Evaluation and Assessment System
NOAA	National Oceanic and Atmospheric Administration
NWSA	Northwest Seaport Alliance
OD	Origin-to-Destination
OMRR&R	Operations, Maintenance, Rehabilitation, Repair & Replacement

Acronym	Definition
P&G	Principles & Guidelines
PCT	Pierce County Terminal
PNW	Pacific Northwest
PPX	Post-Panamax
PPX1	Post-Panamax Generation 1
PPX2	Post-Panamax Generation 2
PPX3	Post-Panamax Generation 3
PPX4	Post-Panamax Generation 4
PSP	Puget Sound Pilots
PX	Panamax
RECONS	Regional Economic System
RED	Regional Economic Development
SHINP	Seattle Harbor Navigation Improvement Project
SPX	Sub-Panamax
TEU	Twenty-Foot Equivalent Unit
TPI	Tons Per Inch Immersion
TSP	Tentatively Selected Plan
UKC	Underkeel Clearance
UPRR	Union Pacific Railroad
USGS	US Geological Survey
VOC	Vessel Operating Costs
WCUS	West Coast United States
WRDA	Water Resources Development Act
WTM	World Trade Model
WUT	Washington United Terminal

1 Introduction

This document presents the results of the economic evaluation performed for the Tacoma Harbor, WA Feasibility Study. The US Army Corps of Engineers (Corps) Seattle District, in partnership with the Port of Tacoma, initiated this multi-year feasibility study in 2018 to determine whether navigation improvements to Tacoma Harbor are economically beneficial, technically feasible, and environmentally acceptable to the nation. The Corps Seattle District, under the direction of the Deep Draft Navigation Planning Center of Expertise (DDNPCX), performed the economic analysis. The study area includes the Blair and Sitcum Waterways. The Blair Waterway is a federally authorized navigation channel with high volume container traffic. The Sitcum Waterway is a non-Federal channel (deauthorized in 2002) servicing relatively smaller vessels and domestic traffic. Preliminary screening of both waterways revealed the potential for improvements on the Blair Waterway. However, Sitcum Waterway was removed from further analysis due to the high cost of improvements and the limited potential to accommodate Post-Panamax (PPX) vessels. The following economic analysis focuses on improvements to the Blair Waterway.

The current controlling channel depth of Blair Waterway is -51 feet mean lower low water (MLLW), with authorized channel widths narrowing from 520 feet at the mouth to 330 feet before ending in a 1,300-foot turning basin.

1.1 Study Purpose and Scope

The study identifies the alternative plan, which best addresses the problems and opportunities for navigation at Tacoma Harbor while satisfying all environmental and engineering criteria. The feasibility study's scope involves an analysis of existing conditions, identifying opportunities for improvement, preparing economic analyses of alternatives, identifying environmental impacts, and analyzing the National Economic Development (NED) plan. The purpose of potential improvements is to achieve transportation cost savings by increasing potential efficiencies for PPX containerships on the Blair Waterway.

1.2 Document Layout

Section 2 details the existing conditions at Tacoma Harbor. Section 3 examines future without-project (FWOP) and future with-project (FWP) conditions and includes an evaluation of forecasted trade, terminal upgrades, the forecasted vessel fleet, and future operations at the harbor. Section 4 presents the transportation cost savings benefit analysis. Section 5 presents the results of sensitivity analyses around key study assumptions. Section 6 summarizes multiport considerations. Section 7 describes the socioeconomics of Tacoma and the surrounding region.

2 Existing Conditions

The existing conditions are defined as the current conditions at Tacoma Harbor and any changes expected to occur before the project base year, when proposed improvements are operational. This section summarizes Tacoma Harbor's existing conditions through discussion of the Port's hinterland, historical trade, facilities in the study area, throughput container capacity, current container services operating at Blair Waterway, and the fleet of vessels calling Blair Waterway. The most recent available data at the time of analysis was used to establish existing condition operating assumptions[1]. Where possible, more recent data is presented to asses the validity of the analysis.

2.1 Economic Study Area (Hinterland)

The federally authorized Tacoma Harbor navigation project, consisting of Foss (also known as City) Waterway, Blair Waterway, Hylebos Waterway, and two training structures at the mouth of the Puyallup River, is located in Puget Sound's Commencement Bay at Tacoma, Washington. The study area also includes the non-federal Sitcum Waterway and Foss Waterway. The Corps and Port of Tacoma identified the Blair Waterway as the area of critical importance for navigation improvements and the focus of this feasibility study (Figure 2-1).

Figure 2-1: Tacoma Harbor

2.1.1 Hinterland

The facilities within the study area, especially the Blair Waterway, serve an expansive hinterland reaching as far as the Midwest and Northeast. Multiple ports, including West Coast Canadian ports, compete for market share in this hinterland. The Puget Sound Ports of Seattle and Tacoma formed the Northwest

[1] While this analysis is based on the most recent and complete data available through 2018, economic updates will be completed every three years until the project is fully implemented and constructed per the requirements in ER 1105-2-100. Relevant changed conditions taking place between the completion of this analysis and project implementation will determine the scope and scale of any economic update.

Seaport Alliance (NWSA) in 2015 to better compete for this market share. The NWSA unifies the management of marine cargo facilities to attract more trade. NWSA terminals made up the fourth-largest container gateway. The NWSA is a critical gateway for trade between Asia and the Midwest, Ohio Valley, and the East Coast. The Alliance is also a major center for bulk, breakbulk, project/heavy-lift cargoes, automobiles, and trucks, and it is located adjacent to the second-largest concentration of distribution centers (DCs) on the West Coast of the US (WCUS).

The Puget Sound is a natural gateway for transpacific cargo from Asia bound for large population centers in the Midwest and Northeast, as shown in Figure 2-2. Top international trading partners include China/Hong Kong, Japan, the Republic of Korea, Taiwan, Vietnam, Thailand, Canada, Malaysia, and Indonesia. The value of this two-way international (vessel) trade totaled more than $75 billion in 2017. Burlington Northern Santa Fe (BNSF) Railway and Union Pacific Railroad (UPRR) serve the region. Recent corridor investments such as double tracking, new track, facility expansion, and equipment upgrades increase the gateway and key markets' velocity.

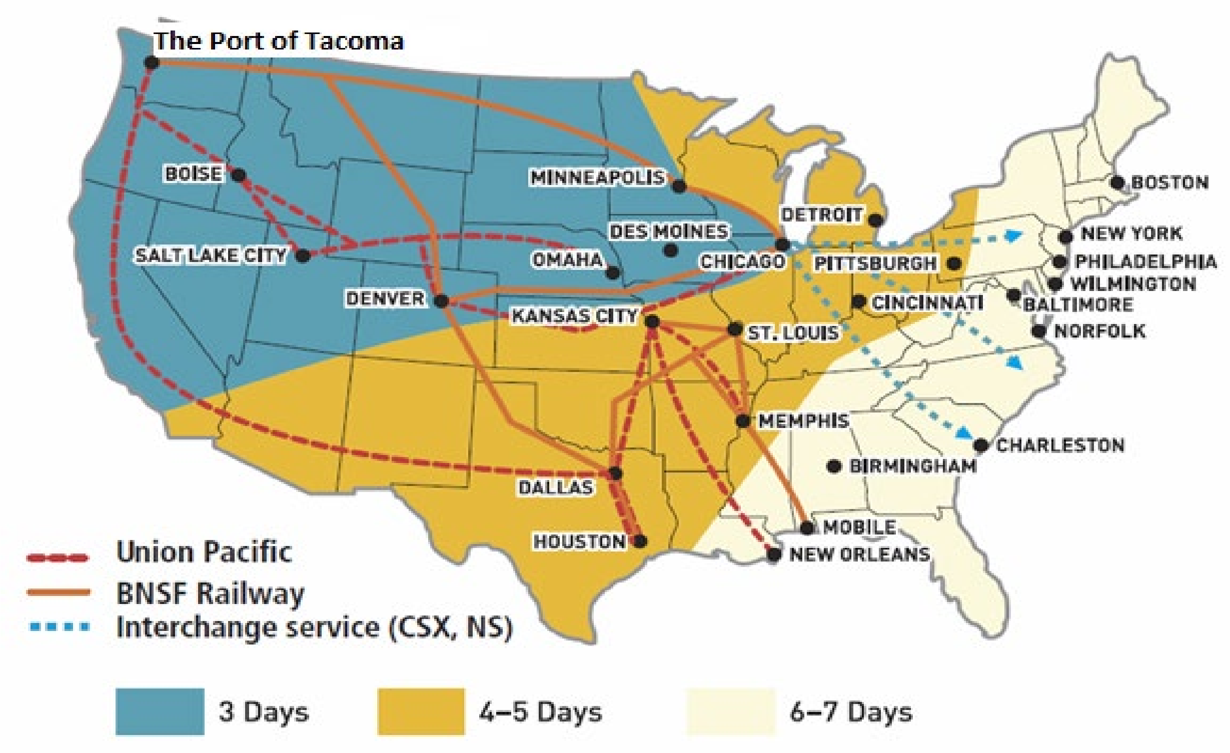


Figure 2-2. Port of Tacoma Hinterland

Nearly 70 percent of international intermodal containers moving through the Puget Sound ship to the Midwest and Northeast. The remaining 30 percent of the cargo remains in the Pacific Northwest (PNW), including Washington and Oregon. Figure 2-3 shows intact intermodal container traffic between major US regions and the PNW.

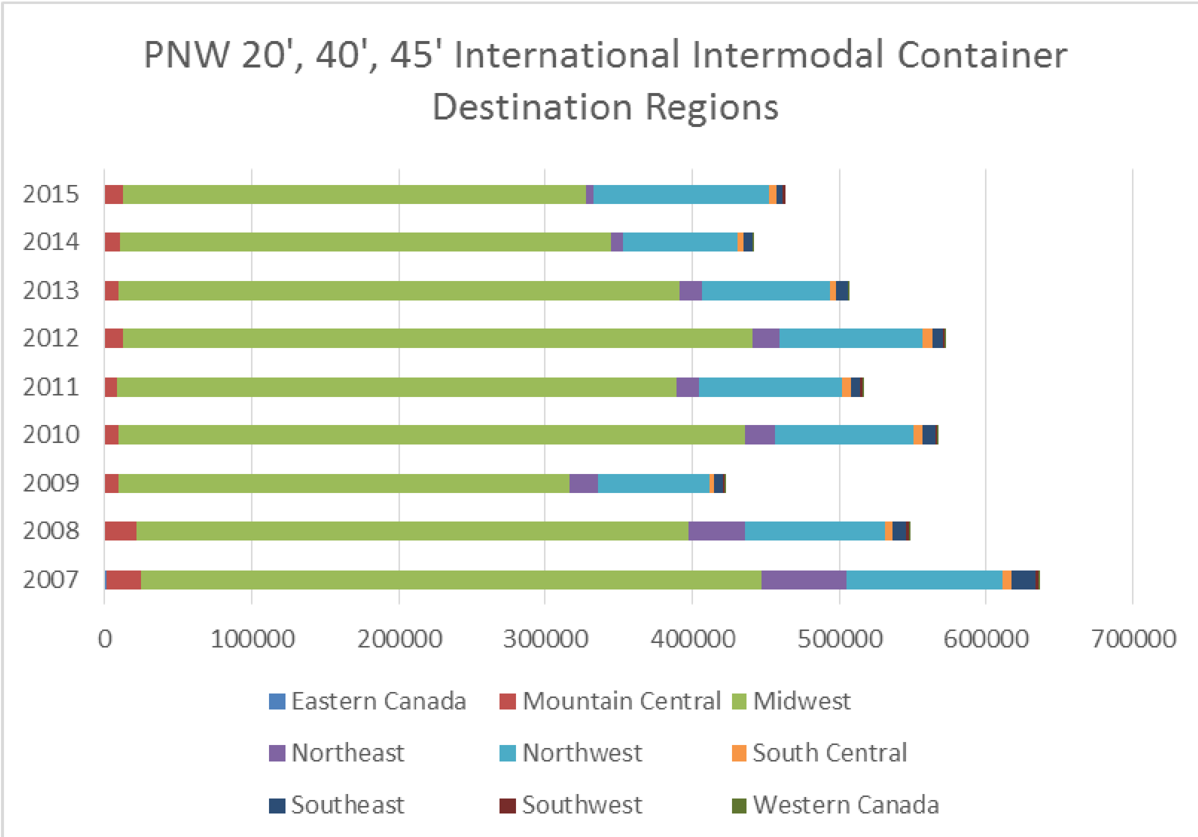


Figure 2-3. PNW International Intermodal Container Destinations[2]

Growing import intermodal activity has created a large eastbound transload business in the Puget Sound Area. Transloading is the transfer of cargo from smaller international shipping containers (twenty-foot equivalent units (TEUs), 40-foot containers, and 45-foot containers) into larger 53-foot containers or trailers near the Port. Uniform container sizes allow more efficient inland movement of cargo by reducing the number of containers, and it offers shipper flexibility to deconsolidate cargo near the port for national distribution. Figure 2-4 illustrates the growth of transloaded cargo, showing a 69 percent increase from 2007 through 2015.

[2] Source: IANA data

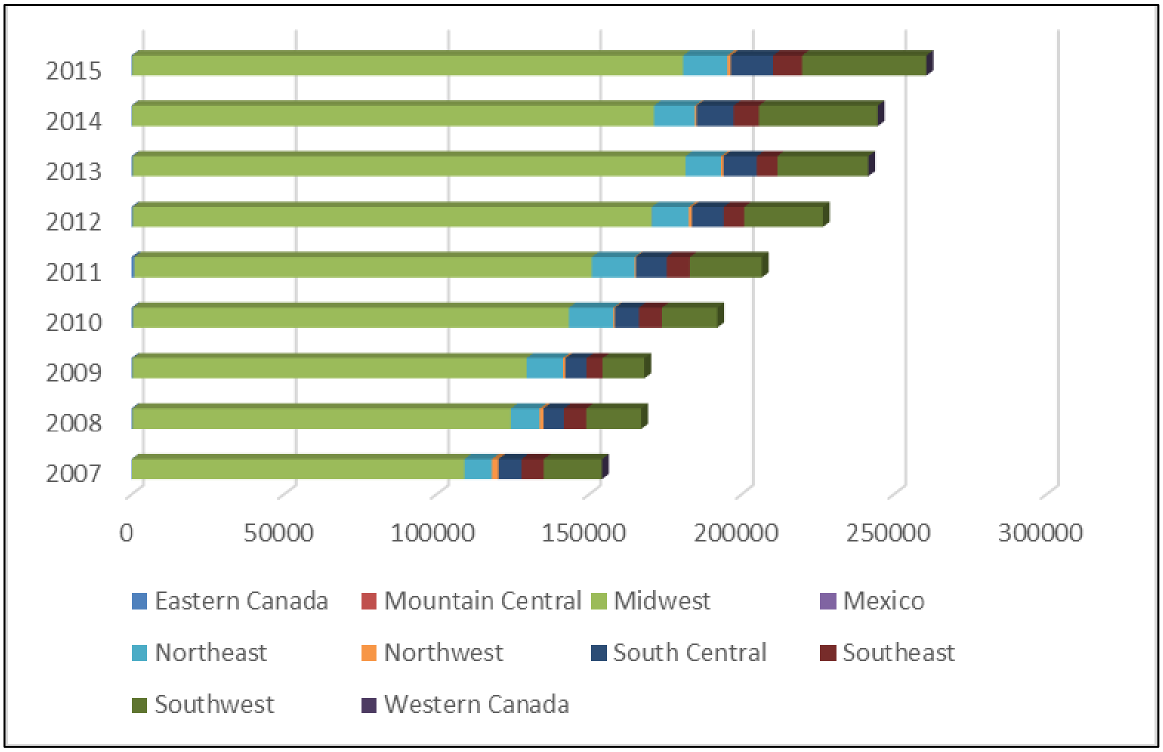


Figure 2-4. Rail Moves of 53-Foot Containers from PNW to Inland Regions[3]

There are 90 commercial facilities within 35 miles of the two ports offering transloading services. All major retailers have transload operations in the PNW to serve DCs across the US. The Kent/Auburn Valley is the fourth-largest warehouse and DC in the US and the second-largest manufacturing center on the WCUS (Des Moines, Washington 2017).

The Port of Tacoma is also a critical transportation link for the export of containerized agricultural products from the PNW and the Midwest. Over $18.3 billion of food and agricultural products were exported from the PNW states of Oregon, Idaho, and Washington in 2017, over 80% of which originated in the State of Washington – the third largest exporter of food and agriculture commodities in the nation. The Port of Tacoma's strategic location, close to Washington's agricultural regions via Interstate 90, makes it a natural gateway for agricultural exports to Asian markets. Additionally, export commodities (mostly Washington agricultural products, including forest products) typically weigh substantially more than imports and, therefore, are typically more expensive to transport longer distances due to additional fuel costs, making them less competitive in the international market the further they are shipped. Export commodities are typically heavier and more densely packed at Tacoma Harbor, requiring vessels to depart at deeper sailing drafts. Export and import commodities are discussed in greater detail in Section 2.2.

Port of Tacoma added importance for PNW exports given the shutdown at Terminal 6 in Portland from 2017 to 2020. Terminal 6 was the only deep draft container terminal in Oregon, capturing up to 53 percent of Oregon throughput tonnage. However, the terminal discontinued container services with the

[3] Source: IANA

termination of ICTSI Oregon's lease on March 31, 2017. The discontinuation of major international container service at the Port of Portland with Hanjin Shipping and Hapag-Lloyd withdrawing services at Terminal 6 increased demand for shipping services at the Port of Tacoma, as Oregon exports have sought alternative gateways to get their product to market. The Port of Tacoma is the shortest distance from Oregon export production sites. Oregon exporters can quickly transport cargo via Interstate 5 or by a regularly scheduled port-to-port rail service from Portland to Tacoma. The Port of Portland resumed container operations at Terminal 6 in 2020 and now has two regular services from SM Lines and MSC (Port of Portland, 2021).

The Port of Tacoma and NWSA 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 UPRR), roads ($9.2 billion locally), and dockside and harbor improvements ($800 million).[4] In the past decade, the Port has invested $62 million in various regional transportation infrastructure projects with other jurisdictions, totaling $795 million.

2.1.2 Distribution Centers and Other Maritime Business

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

Warehouse and DCs provide storage for goods received from and delivered to the Port and add flexibility for importers using what is commonly referred to as a "four-corner" national distribution strategy. The four-corner approach diversifies and mitigates supply chain risk from labor disruptions, natural disasters, and other events. Using this model, a major port in each quadrant of the country (PNW, Pacific Southwest, Northeast, and Southeast) serves as the primary import gateway for the region. Upon arrival, goods are transported from the terminal to nearby DCs, 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, repackaging, order pick-and-pack fulfillment, and computerized inventory control to supplement the importer's regular or "just-in-time delivery" needs.

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

A number of transloaders operate adjacent to the Port of Tacoma. 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 WCUS. Currently, 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 DCs are easily accessible via Interstates 5 and 90, the two main interstate arteries

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

serving the Port of Tacoma. All of the country's major retailers have a transload and distribution operation in the PNW.

There are hundreds of transportation and logistics companies facilitating trade at the Port of Tacoma. These businesses include the Port itself; steamship lines; stevedores and longshoreman; truck lines; Class I and short-line railroads; intermodal marketing companies, tug companies; customs house brokers and freight forwarders; docking and harbor pilots; marine survey and fumigation; and other firms.

2.2 Historical Trade

The Port of Tacoma is the 9th largest US container port in terms of TEU volume (Waterborne Commerce Statistics Center, 2020). 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 US Midwest. The Port's top three trading partners for both imports and exports include China, Japan, and South Korea (23 percent, 16 percent, and 7 percent of total trade value, respectively[5]). Additionally, the Port of Tacoma is the last US port of call for multiple Asia-WCUS container services. Vessels tend to load the most cargo at the last port of call before crossing the Pacific to maximize profit on a service's longer legs.

Port of Tacoma's 2020 total containerized throughput tonnage value exceeded $41.7 billion, with imports valued at $36.6 billion and exports valued at $5.1 billion. Industrial machinery and computers, electrical machinery and electronics, vehicles and parts, and furniture were among the greatest value of imported commodities. High-value export commodities included a variety of food products (oil seeds and grains, vegetables, fruits and nuts, cereals, meat products, and fish and seafood), industrial machinery and computers, and paper and paperboard. The Port of Tacoma is also a key gateway for Washington State exports, including apples, pears, potatoes, onions, red raspberries, hay, and hops.

Tacoma Harbor receives regular calls from a 52-foot design draft vessels with 14,000 TEU capacity or greater. These vessels serve Transpacific services. Figure 2-5 provides the average TEU capacity of all calls on the Blair Waterway from 2008 through 2019. Average vessel size data for 2018 and 2019 was made available after the primary analysis was complete and is added for reference. However, the continued growth seen in 2018 and 2019 validates the trends anticipated by this study. The average vessel size used on these services will continue to grow as larger vessels are deployed on Asia-WCUS services.

[5] 2021 USA Trade online (Census Data). https://usatrade.census.gov/data

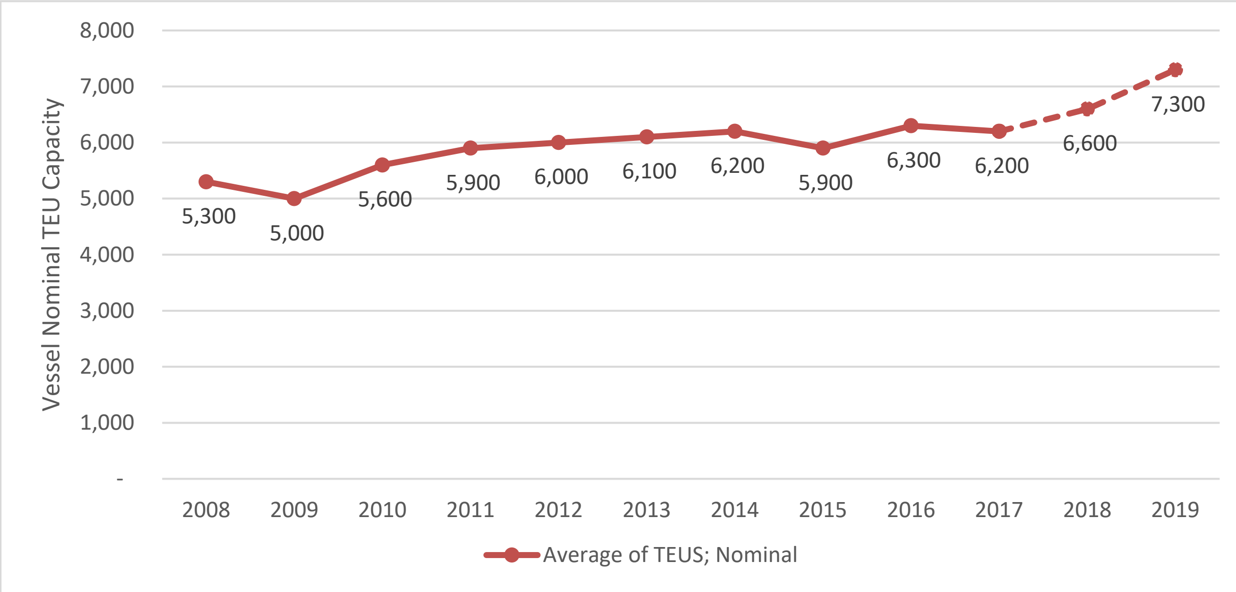
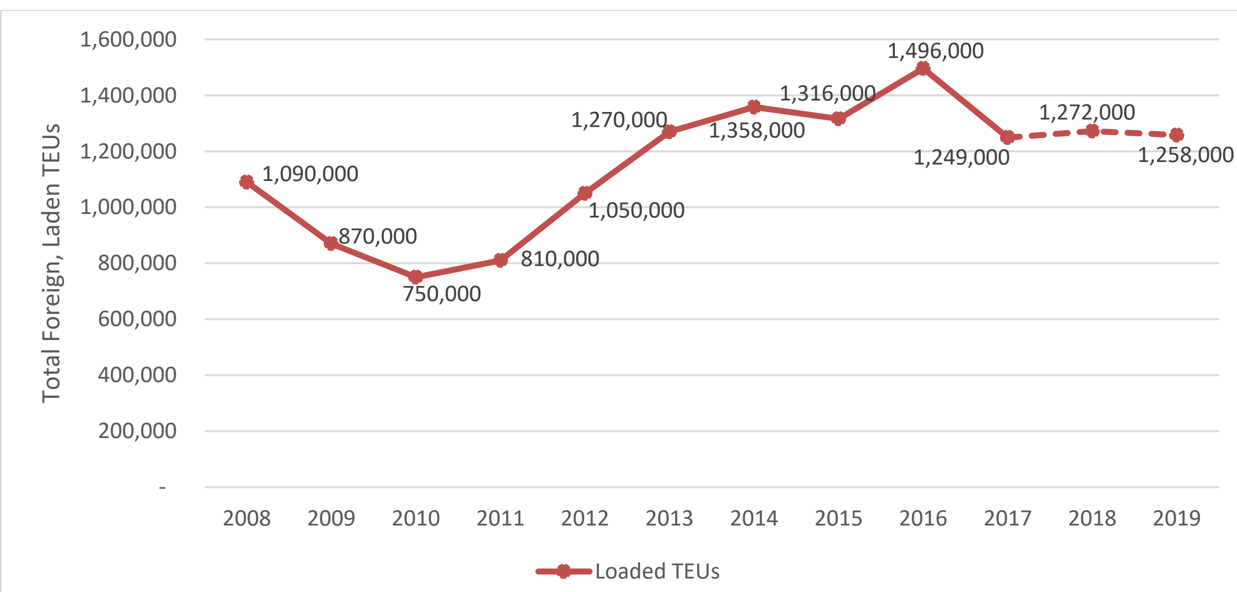


Figure 2-5. Blair Waterway Average Vessel Nominal TEU Capacity (NNOMPEAS[6])

Foreign containerized traffic declined from 2008 to 2010 due to the global economic recession. TEU throughput increased from 2010 to its peak of 1.4 million TEUs in 2016. Figure 2-6 presents trends in TEU throughput from 2008 through 2019. Loaded TEU throughput for 2018 and 2019 was made available after the primary analysis was completed and is added for reference. Preliminary data from 2019 through 2021 reflects the volatility created by the COVID-19 pandemic. TEU volumes for the Northwest Seaport Alliance were down 12 percent from 2019 to 2020 and up 12.5 percent from 2020 to 2021 as consumers adjusted spending.



[6] National Navigation Operation and Management Performance Evaluation and Assessment System

Figure 2-6. Containerized Cargo in Loaded TEUs by Year, 2008-2019 (WCSC)

Tacoma's average share of the WCUS trade volumes from 2009 to 2019 remained relatively stable around 7.1 percent. Figure 2-7 shows the share of trade vlume for West Coast between 2008 and 2019.

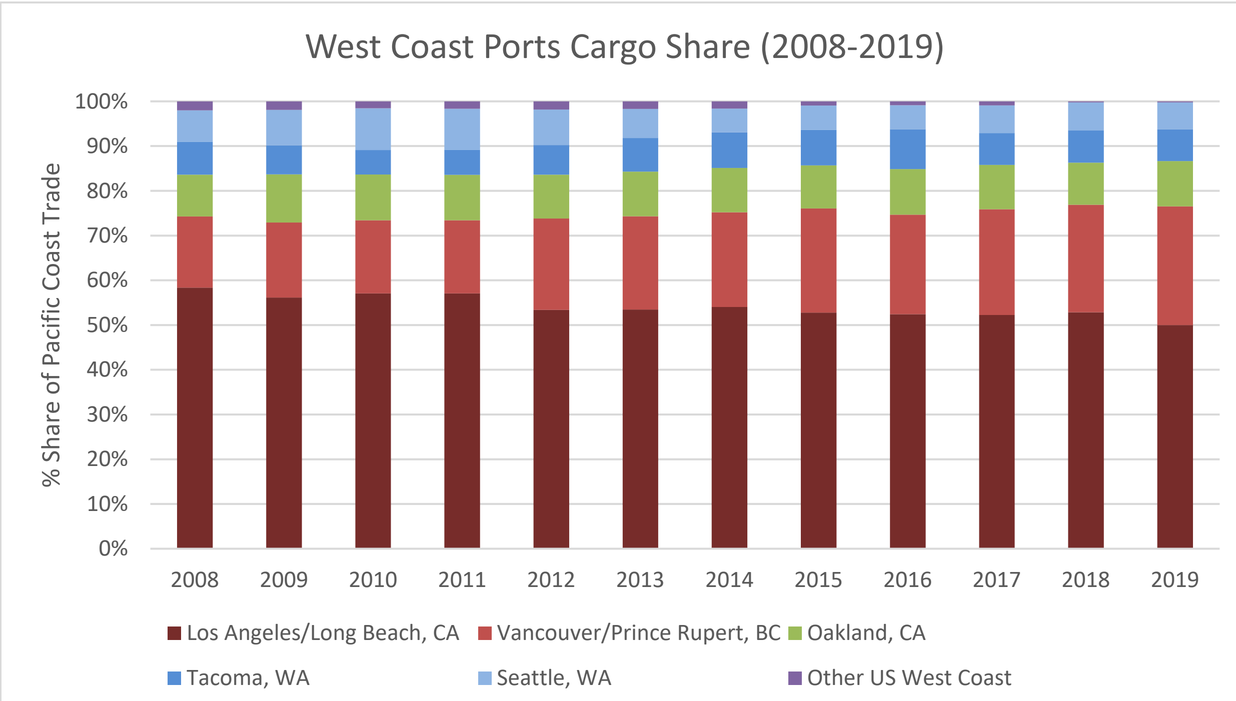


Figure 2-7 West Coast Ports Cargo Share, 2008-2019 (US Customs Data)

Los Angeles, Long Beach, Tacoma, Vancouver (British Columbia, Canada), and Prince Rupert (British Columbia, Canada) all have channels as deep as or deeper than the Port of Tacoma. Prince Rupert has a natural depth of -60 feet MLLW and plans for a major expansion to build a capacity of 2.7 million TEUs by 2020 and 4 to 5 million TEUs in subsequent years[7]. This increased volume represents more than the current combined volumes of Seattle and Tacoma (3 million TEUs in 2019). Other West Coast ports with positive growth trends from 2008 to 2019 include Oakland and Vancouver. Los Angeles-Long Beach had the most significant decline dropping from 58 percent of all West Coast trade to 50 percent.

Shipping line vessel deployments are closely scheduled to meet berthing windows in all ports of call in a rotation. Any vessel delay in Tacoma would increase the shipping line's cost by creating a need to speed up the ship to meet the schedule. Carriers are extremely focused on cost reduction, especially by managing fuel consumption. Delays due to tidal restrictions at Tacoma Harbor create an incentive for shipping lines to look for ways to avoid the port in order to meet tight schedules; ultimately, these shipping lines may call more often at naturally deeper ports. Tacoma market share is based on an average historical share of West Coast trade and is the basis for the commodity forecast. The analysis assumes Port of Tacoma's market share will not change between the without-project and with-project conditions (see Section 6).

[7] Prince Rupert Port Authority. "A Vision for the Future"

2.2.1 Cargo and Vessel Traffic Profile

This section summarizes cargo an vessel traffic for the years 2008 through 2018. At the time of analysis, 2018 was the most recent year with data available at a level of detail sufficient for analysis. Data from subsequent years has since been made available and is presented in previous sections. More recent data validates the assumptions used in this analysis. Tacoma Harbor facilities (including those on the Hylebos, Blair, Sitcum, and Foss Waterways) receive foreign and domestic containership, tanker, and bulker traffic calls. Containerships in the Blair Waterway accounted for approximately 50 percent of all tonnage. Containerized tonnage continued to grow over the past decade. Table 2-1 summarizes annual throughput tonnage at Blair Waterway from 2008 through 2018.

Table 2-1: International Containerized Commodity Tonnage (Metric Tons), 2008-2018 (NNOMPEAS)

Year	Import	Export	Total
2008	3,970,000	5,080,000	9,060,000
2009	2,730,000	4,610,000	7,340,000
2010	2,980,000	3,080,000	6,060,000
2011	3,270,000	3,300,000	6,560,000
2012	4,210,000	4,560,000	8,770,000
2013	4,880,000	5,880,000	10,760,000
2014	5,347,000	5,165,000	10,512,000
2015	5,622,000	4,958,000	10,580,000
2016	4,652,000	6,423,000	11,075,000
2017	4,607,000	5,992,000	10,599,000
2018	5,143,000	6,468,000	11,611,000

Table 2-2 summarizes international, loaded TEU throughput at Blair Waterway. Given the relatively consistent weight per TEU of containers at Tacoma Harbor, trends in loaded TEU volumes closely track throughput tonnage growth.

Table 2-2: International TEUs (Loaded), 2008-2018 (NNOMPEAS)

Year	Import	Export	Total
2008	660,000	440,000	1,090,000
2009	470,000	400,000	870,000
2010	480,000	260,000	750,000
2011	540,000	280,000	810,000
2012	660,000	390,000	1,050,000
2013	760,000	510,000	1,270,000
2014	866,000	492,000	1,358,000
2015	845,000	471,000	1,316,000
2016	938,000	558,000	1,496,000
2017	775,000	474,000	1,249,000
2018	767,000	505,000	1,272,000

2.2.2 TEU Weight by Container

Data pulled from the NNOMPEAS database informed the average import and export TEU weights. Table 2-3 presents loaded TEU weights, excluding tare weight for Blair Waterway facilities. The ability to densely pack heavy agricultural exports leads to significantly higher export TEU weights. As a result, exports tend to drive deepening benefits. Overall, average loaded TEU weights between 2014 and 2018 are 6 metric tons for import, 12 metric tons for export, and 8 metric tons average for all TEUs.

Table 2-3. Blair Waterway Average Weight per Loaded TEU, Import and Export (NNOMPEAS)

Metric	Import	Export	Total
AVG Metric Tons (2014-2018)	5,074,000	5,801,000	10,875,000
AVG TEUs (2014-2018)	838,000	500,000	1,286,000
AVG Lading Weight per Loaded TEU (2014-2018)	6	12	8

2.3 Facilities and Infrastructure

Tacoma Harbor has five main container facilities (Figure 2-8). Two of these terminals, East Sitcum and West Sitcum, are outside the Blair Waterway and primarily handle smaller international services and domestic tonnage bound for Alaska. Blair Waterway includes three container terminals, all of which focus on international container trade: Husky Terminal, Washington United Terminal (WUT), and Pierce County Terminal (PCT). Summary information for all Tacoma Harbor container terminals is shown in Table 2-4.

Figure 2-8: Port of Tacoma Facilities

2.3.1 Husky Terminal

Husky Terminal is a 90-acre facility located at the entrance of the Blair Waterway. Port of Tacoma completed berth reconfiguration at Husky Terminal in late 2017 to create two berths with nearly 3,000 feet of dock length capable of simultaneously berthing two Post-Panamax Generation 4 (PPX4) vessels. Eight new super-PPX cranes were installed between early 2018 and 2019. In addition to eight gantry cranes, Husky Terminal operates five transtainers, 19 top handlers, 64 utility tractor rigs (UTR's), two-speed loaders, and one reach stacker. The terminal also offers on-dock rail access with computerized rail planning.

Current ocean carriers with operations at Husky Terminal include Hapag-Lloyd, K Line, MOL, NYK Line, UASC, and Yang Ming (all collectively operating under The Alliance). Husky Terminal handled nine percent of all international container tonnage between 2013 and 2016; however, Husky terminal underwent significant upgrades over this time, leading to disruption in service. Preliminary data from 2017 and 2018 indicate a 13 percent increase in Blair cargo share.

2.3.2 Washington United Terminal

WUT's 100-acre facility is approximately 1.5 miles from the mouth of the Blair Waterway. The terminal is a two-berth facility capable of simultaneously berthing two PPX vessels. The facility operates four PPX and two super-PPX gantry cranes along its 2,600-foot berth. The terminal operates nine reach stackers, 12 top-picks for loaded container handling, 5 side-picks for empty container handling, six rubber tire gantry cranes (RTG's), 12 forklifts, a total of 69 service vehicles, 85-yard tractors, and 61 "Bombcarts" for terminal container handling. WUT also has on-dock rail access.

HMM currently operates two weekly services at WUT (PN2 and PS1). From 2013 through 2016, the terminal handled 20 percent of total tonnage along the Blair Waterway, dropping to 17 percent in 2017 and 14 percent in 2018.

2.3.3 Pierce County Terminal

PCT is a 166-acre facility located at the Blair Waterway's terminus, roughly 2.5 miles from the entrance. PCT has 2 berths capable of loading two PX vessels or one PPX vessel at a time. Together, the terminal has 2,087 feet of berth length and 7 PPX cranes. Like Husky Terminal and WUT, PCT has an on-dock rail.

The Ocean Alliance through Evergreen operates two weekly services at PCT (PNW3 and PSW8). PCT handled 13 percent of international container tonnage from 2013 through 2017, increasing to 19 percent of tonnage in 2018.

2.3.4 Sitcum Container Terminals

Domestic services with rotations between Alaska and Tacoma Harbor call the West Sitcum Container Terminal. The facility has two ship berths with a combined 2,200 feet of berth length. The facility covers 135 acres and operates five cranes capable of servicing two PX vessels simultaneously.

The East Sitcum Terminal, formerly Olympic Container Terminal, is smaller than West Sitcum with only 54 acres. East Sitcum Terminal has 4 cranes for one berth. East Sitcum currently handles all Westwood services at Tacoma Harbor with 3 small, infrequent Asian services using PX-sized vessels.

Table 2-4. Tacoma Harbor Container Terminals[8]

Terminal	Size	Ship Berths	Berth Depths	Cranes	In/Out Truck Lanes	Scales	Reefer Plugs	Rail Ramps
Husky	93 acres	2 2960 ft	51 ft	8 8x24 wide	7/4	6	875	Near-dock
WUT	123 acres	2 2600 ft	51 ft	6 4x18 wide 2x24 wide	9/4	7	884	On-dock
PCT	140 acres	2 2087 ft	51 ft	7 7x23 wide	10/6	6	654	On-dock

[8] Source: NWSA, nwseaportalliance.com, accessed 23 September 2015

Terminal	Size	Ship Berths	Berth Depths	Cranes	In/Out Truck Lanes	Scales	Reefer Plugs	Rail Ramps
West Sitcum	135 acres	2 2200 ft	51 ft	5 4x18 wide 1x14 wide	8/6	6	875	Near-dock
East Sitcum	54 acres	1 1100 ft	51 ft	4 3x15 wide 1x14 wide	5/2	2	300	On-dock
TOTE	48 acres	3 RO/RO ramps	51 ft	N/A	5/4	4	140	Off-dock

2.3.5 Other Port Facilities

Tacoma Harbor includes several other facilities in the Foss, Hylebos, and Foss Waterways, including liquid and bulk operations. The largest of these terminals in throughput tonnage are Tacoma Export Marketing Company (TEMCO), TOTEM Ocean Trailer Express (TOTE), and US oil and Refining Company. TEMCO is the largest facility in Tacoma Harbor by tonnage. It primarily exports agricultural products, including corn and soybeans. TEMCO is located on the south shore of Commencement Bay near the mouth of the Foss Waterway and is outside the study area. TOTE is a 48-acre RO-RO facility located across from Husky Terminal with three RO-RO ramps. TOTE primarily exports manufactured and food products. These facilities do not impact the benefits of proposed alternatives and are not included in the analysis.

2.4 Container Terminal Capacity

A container terminal's annual TEU throughput capacity is the minimum of (1) crane capacity, (2) container yard capacity, and (3) berth capacity. Data specific to Tacoma Harbor supplemented national operational averages developed by IWR to determine throughput capacity by terminal (Tioga Group, 2010).

2.4.1 Crane Capacity

Crane Capacity is the estimated maximum sustainable number of TEUs all cranes can handle per year. Key assumptions for this input include (1) annual working hours and (2) "sustainable hours" set at 80 percent of total working hours based on national average TEU slot turnover speed, crane speed, vessel call frequency, vessel dwell time, and vessel working drafts. Table 2-5 estimates the maximum annual crane capacity by Blair Waterway terminal.

Table 2-5. Crane Capacity by Terminal

Terminal	Crane Size	Cranes	Working Hours	Sustainable Hours (80%)	Crane Capacity (TEUs)
Husky	24 wide	8	32,000	25,600	1,101,000
WUT	18 wide	4	16,000	12,800	550,000
	24 wide	2	8,000	6,400	275,000
PCT	23 wide	7	28,000	22,400	963,000
Blair Waterway Total		**21**	**84,000**	**67,200**	**2,890,000**

2.4.2 Container Yard Capacity

Container Yard Capacity is the estimated maximum number of TEUs turned per year. The estimate assumes containers can be stacked five high with 21 average annual slot turns per slot. Table 2-6 estimates the maximum annual container yard capacity by Blair Waterway terminal. PCT uses straddle carriers rather than Rubber Tired Gantry Cranes (RTGs), so the container yard capacity metric developed by the Corps study does not apply. Straddle carriers are typically more efficient than RTGs, so PCT's limiting metric is unlikely to be container yard capacity.

Table 2-6. Container Yard Capacity by Terminal

Terminal	TEU Slots	Containers/Stack	Capacity	Avg. Annual Slot Turns	Annual Capacity
Husky	9,600	5	48,000	21	1,008,000
WUT	7,500	5	38,00	21	788,000
PCT	N/A	5	N/A	21	unknown
Total	**17,100**	**10**	**+86,000**	**42**	**+1,796,000**

2.4.3 Berth Capacity

Berth Capacity is the estimated maximum TEU throughput based on vessel size constraints and berth capacity. This input incorporates dwell time from Tacoma pilot data, assumes a maximum of five calls per week at each berth, and uses cargo share from the Maritime Strategies, Inc. (MSI) fleet forecast first developed for the Seattle Harbor Navigation Improvement Project (SHNIP). The maximum berth capacity is based on full utilization of Super PPX vessels. Table 2-7 estimates total berth capacity for each terminal on Blair Waterway.

Table 2-7. Berth Capacity by Terminal

Terminal	Berth Count	Total Length (ft.)	Vessel Size	Berths	Dwell Time (hrs)*	Calls per Year**	Avg. TEU Parcel	Max TEU
Husky	2	2,960	SPX-PX	2	18	520	1,600	855,000
			PPX	2	30	520	1,700	863,000
			Super-PPX	2	69	243	7,100	1,722,000
WUT	2	2,600	SPX-PX	2	18	520	1,600	855,000
			PPX	2	30	520	1,700	863,000
			Super-PPX	2	69	122	7,100	861,000
PCT	2	2,087	SPX-PX	2	18	520	1,600	855,000
			PPX	1	30	260	1,700	432,000
			Super-PPX	1	69	122	7,100	861,000
Total	6	7,647	SPX-PX	6	54	1,560	4,900	2,566,000
			PPX	5	90	1,300	5,000	2,159,000
			Super-PPX	4	207	487	21,200	3,445,000

*Estimated from pilot data and future parcel sizes
**Limited to 5 calls per week per terminal

2.4.4 Total Capacity Estimate

Capacity equals the minimum of the three capacity measures. Table 2-8 summarizes the results and provides an initial estimate of annual TEU capacity for Blair Waterway: 2.7 million TEUs.

Table 2-8. Total Capacity Estimate

Terminal	Crane Capacity	Container Yard Capacity	Berth Capacity	Maximum Capacity
Husky	1,101,000	1,008,000	1,722,000	1,008,000
WUT	826,000	788,000	863,000	788,000
PCT	963,000	unknown	861,000	861,000
Total	**2,900,000**	**+1,796,000**	**3,400,000**	**2,700,000**

2.5 Carriers and Trade Lanes

Ten weekly container services called the Port of Tacoma in 2019. Historically, more services have called, but the formation of shipping alliances has reduced the number of services worldwide. Three smaller, intermittent services call the Sitcum Waterway, and seven more frequent weekly services call Blair Waterway. Table 2-9 summarizes services considered for the economic evaluation, including the terminal, carrier(s), service name, vessel rotation, number of ships, and ship sizes. All services call from Asia via trans-Pacific routes. Major lines include COSCO, CMA CGM, OOCL, Hyundai, and Maersk. Importantly, every service currently calling the Blair Waterway is a “first” or “last” port of call for the WCUS. This implies greater volumes unloaded (“first”) and loaded (“last”) than intermediate port calls.

Table 2-9. Tacoma Carriers Services by Terminal (2019)

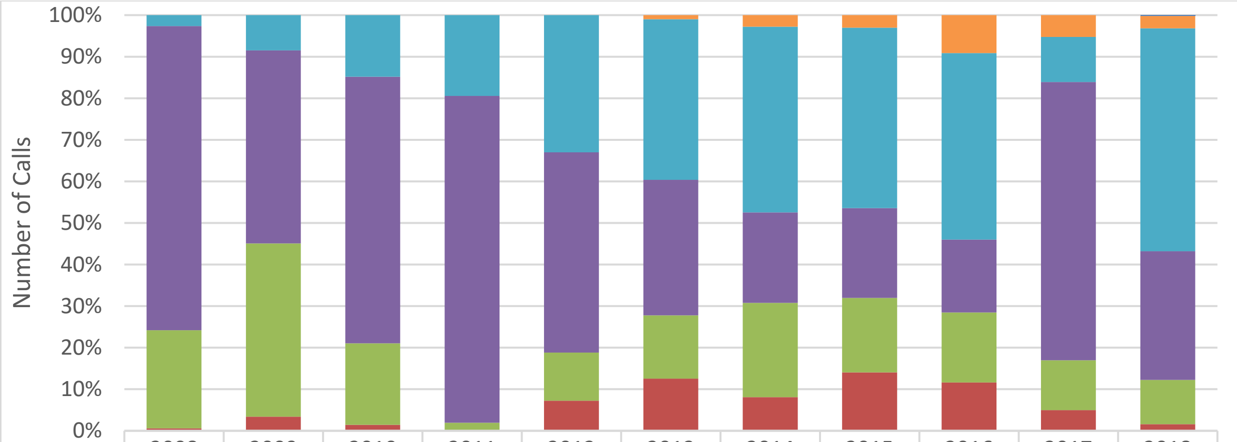
Terminal	Frequency	Carrier(s)	Service Name	Vessel Rotation	First	Last	No. of Ships	Ship Size in TEUs
PCT	Wkly	Ocean*	PNW 3	China – Taiwan – China –**Tacoma** – Vancouver BC – Japan – China	Y	Y	6	5,600-7,000
	Wkly	Ocean*	PSW8	China – Taiwan – Los Angeles – Oakland – **Tacoma** – Taiwan – China	N	Y	6	8,500
Husky	Wkly	THE Alliance**	PN1	China – Japan – **Tacoma** – Vancouver BC – Japan – China	Y	Y	6	8,500
	Wkly	THE Alliance**	PN2	Singapore – Thailand – Vietnam – Taiwan – China – **Tacoma** – Vancouver BC – Japan – Taiwan – Singapore	Y	Y	7	6,300-6,500
WUT	Wkly	THE Alliance**	PN4	China – Taiwan – Japan – **Tacoma** – Vancouver BC – Alaska – Japan – China	N	Y	6	6,500
	Wkly	HMM	PN2	China – Taiwan – China – S Korea– **Tacoma** – Vancouver BC – S Korea – China	Y	Y	6	4,500-5,700
	Wkly	HMM	PS1	China – S Korea – Long Beach –**Tacoma** – S Korea	N	Y	5	6,250-6,800

*Ocean Alliance: APL, CMA, COSCO Shipping, Evergreen, OOCL
**THE Alliance: Hapag-Lloyd, Ocean Network Express (ONE), Yang Ming

2.6 Existing Fleet

Data for the container fleet was obtained from the Puget Sound Pilot's (PSP) log, NNOMPEAS tool, and the Waterborne Commerce Statistics Center Data Analysis and Pre-Processor (W-DAPP) tool. These ships are classified as sub-Panamax (SPX), Panamax (PX), Post-Panamax Generation 1 (PPX1), Post-Panamax Generation 2 (PPX2), and Post-Panamax Generation 3 (PPX3), depending on their capacity.

From 2008 to 2017, the average vessel capacity for calls at the Port of Tacoma increased by over 1,000 TEUs. Maximum vessel size increased to 11,000 TEUs in 2017, and the Port began receiving regular calls from a 14,000 TEU capacity vessel in 2018. Figure 2-9 shows vessel calls by class at the Port of Tacoma from 2008 through 2017. Port of Tacoma has continued to receive more vessels with a capacity of 7,000 TEUs and above (PPX2 and PPX3 class vessels) at the same time as larger vessels make up a larger percentage of the world fleet. Figure 2-10 shows vessels in the world fleet from 1998 to 2017 based on information obtained from the Maritime Strategies Inc. (MSI) vessel fleet forecast described in Section 3.3. Through the study period, PPX3 and PPX4 vessels are expected to transition to Pacific routes and make frequent calls at the Port of Tacoma. Figure 2-11 shows the progression of containerships calling the Port of Tacoma from 2000 to the present day.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
PPX4	-	-	-	-	-	-	-	-	-	-	1
PPX3	-	-	-	-	-	4	12	14	40	18	15
PPX2	9	25	31	40	100	160	193	201	197	37	272
PPX1	251	137	134	162	146	135	94	100	77	229	157
PX	81	123	41	4	35	63	98	83	74	41	54
SPX	2	10	3	-	22	52	35	65	51	17	8

Figure 2-9. Blair Waterway Vessel Calls by Class, 2008-2017 (NNOMPEAS)

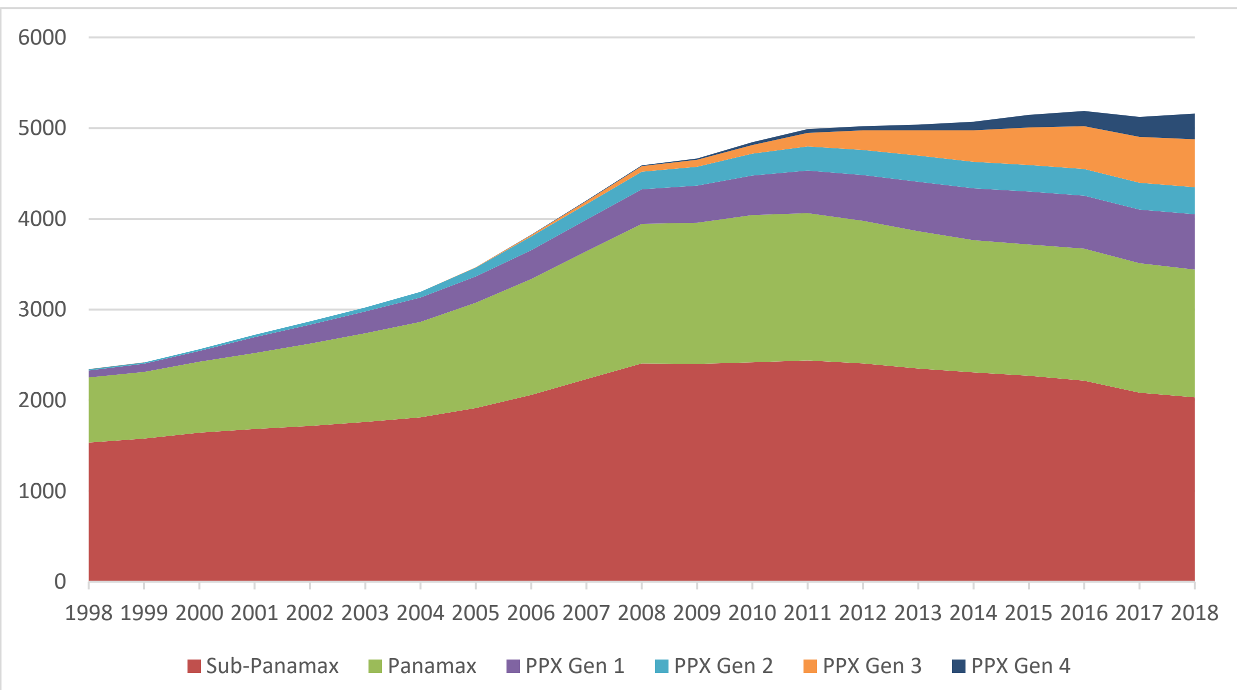


Figure 2-10. Vessels in World Fleet, 1998-2017 (MSI 2015)

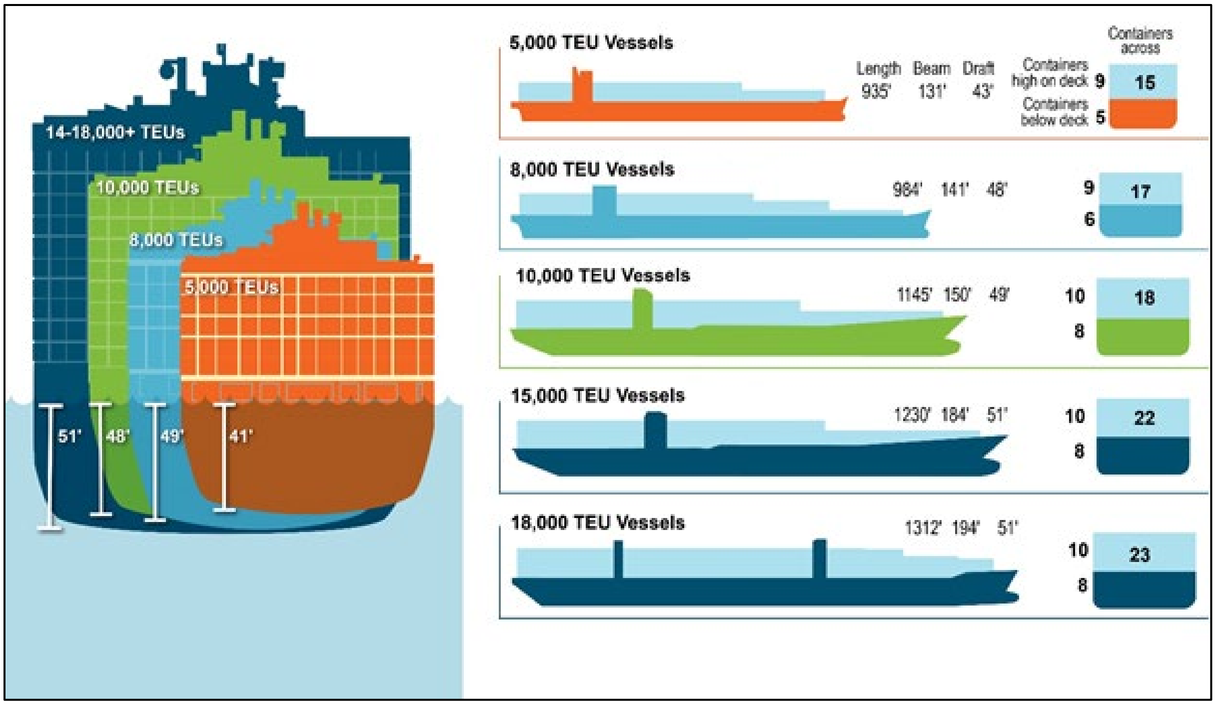


Figure 2-11. Containership Growth at Port of Tacoma

Average containership TEU capacity calling at US ports was 4,900 TEUs in 2016, up 18 percent from 2012. Growth in TEU capacity is the result of growing use of PPX (5,000+ TEU) containerships on US services. PPX vessels generally have a maximum sailing draft of at least 43 feet and up to 53 feet. From 2012 through 2016, PPX vessel calls increased by 50 percent.

The average containership size in the Port of Tacoma at Blair Waterway grew 6 percent from 5,980 TEU capacity in 2012 to 7,300 TEU capacity in 2018 (Figure 2-5). As shown in Table 2-10 below, the average ship size calling Tacoma Harbor in 2012 was about 68,000 gross tons compared to 72,000 gross tons in 2017, a 1.1 percent compound annual growth rate (CAGR). If sustained, the average ship gross tonnage for the base year 2030 would be over 82,000 tons—typically classified as a PPX2 vessel.

Table 2-10. Average Ship Gross Tonnage by Year, 2012-2017

Year	Average Gross Tonnage
2012	67,791
2013	67,035
2014	69,730
2015	66,628
2016	71,451
2017	71,706
2018	74,525

Vessel design draft, length, beam, and air draft typically increase with increases in gross tonnage. Each of these vessel characteristics impacts navigation safety and port capacity. Figure 2-12 summarizes the growth in the average maximum summer load line draft (MXSLLD) of vessel calls at Blair Waterway from 2008 to 2018. This growth is an indicator of future capacity constraints at Tacoma Harbor at the existing channel depth.

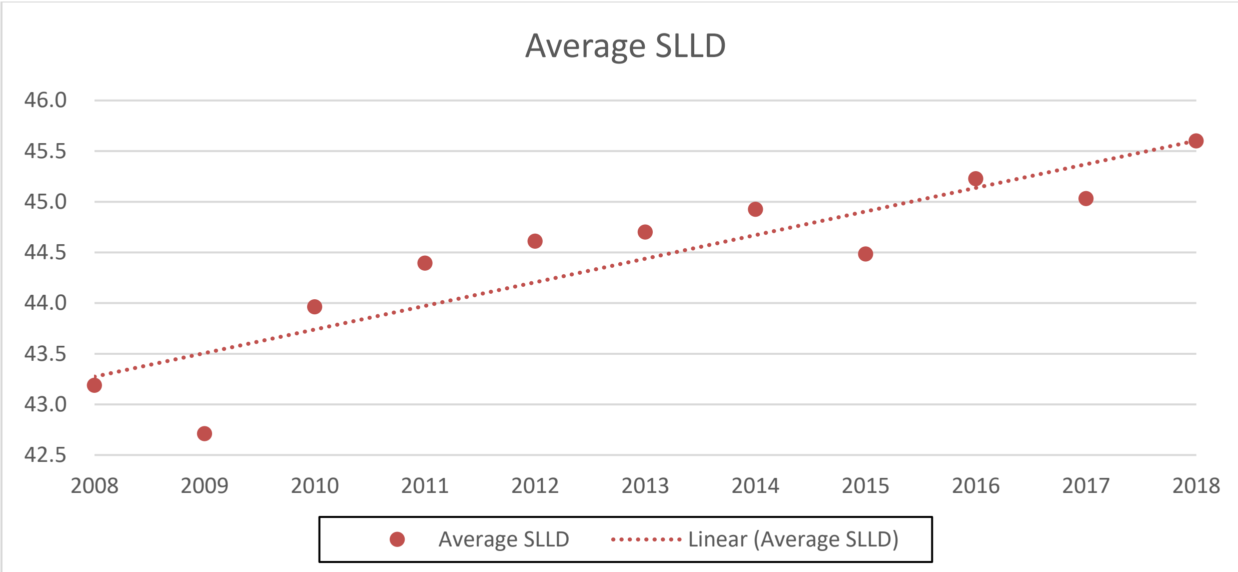


Figure 2-12. Blair Waterway Average Summer Load Line Draft (Port of Tacoma Call Data)

Tacoma Harbor is already handling a significant number of PPX ships. From 2012 through 2017, 72 percent of all calls to the Blair Waterway were PPX vessels. Table 2-11 and Figure 2-13 summarizes the percentage of cargo carried by each vessel class for the years 2013 through 2017. Cargo movements on PPX vessels in Blair Waterway averaged 90 percent for this time period.

Table 2-11. Percent Cargo by Vessel Class, 2013-2017

Direction	Vessel Class	2013	2014	2015	2016	2017	2018
Import	SPX	3%	2%	2%	1%	0%	0%
	PX	9%	10%	9%	8%	10%	10%
	PPX1	55%	31%	33%	30%	72%	46%
	PPX2	32%	55%	52%	50%	18%	41%
	PPX3	1%	2%	3%	11%	0%	3%
	PPX4	0%	0%	0%	0%	0%	0%
Export	SPX	3%	3%	5%	4%	1%	1%
	PX	4%	7%	8%	6%	9%	8%
	PPX1	41%	31%	28%	31%	59%	32%
	PPX2	51%	57%	59%	60%	30%	58%
	PPX3	1%	2%	0%	0%	1%	1%
	PPX4	0%	0%	0%	0%	0%	0.4%
Total	SPX	3%	2%	3%	2%	1%	0%
	PX	7%	9%	9%	7%	10%	9%
	PPX1	47%	31%	31%	31%	65%	38%
	PPX2	42%	56%	56%	55%	24%	50%
	PPX3	1%	2%	1%	6%	0%	2%
	PPX4	0%	0%	0%	0%	0%	0.3%

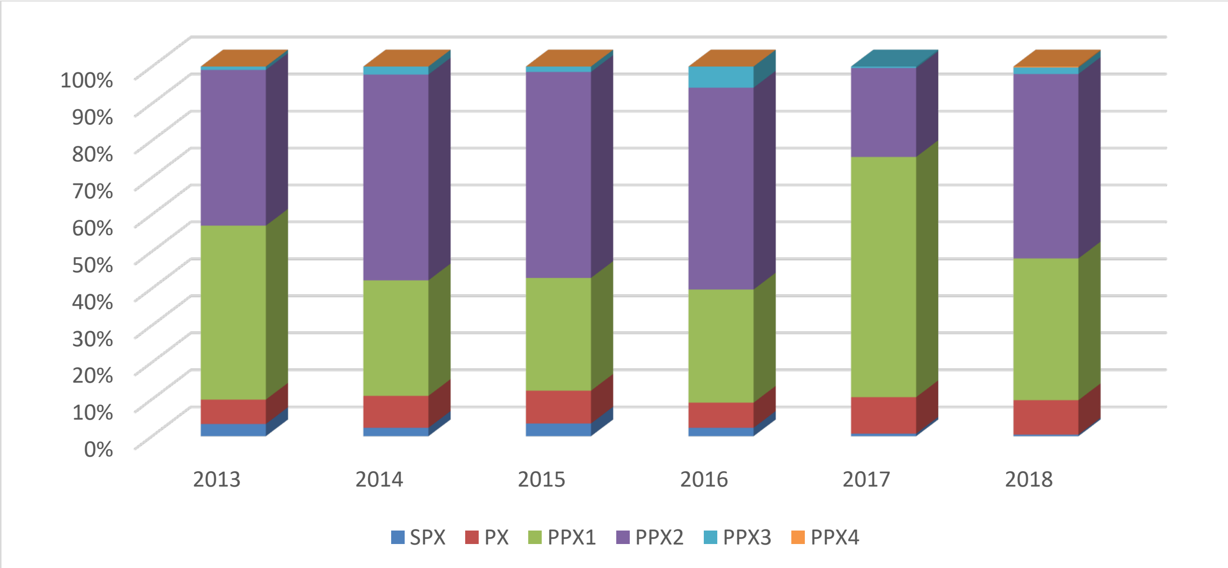


Figure 2-13. Blair Waterway Tonnage by Vessel Class, 2013-2017

2.7 Shipping Operations

2.7.1 Underkeel Clearance

Vessel transit guidelines are documented for the PSP in "General Guidelines for Vessels Transiting Restricted Waterways or Ports." Underkeel clearance (UKC) requirements for the economic analysis utilized evaluation was obtained from recent Corps evaluations and expertise, as shown in Table 4-7. Below are the general guidelines for UKC which apply to all vessel types, including containerships. These guidelines are not expected to change as a result of a deepening project:

1. *Vessels exceeding 400 feet in length transiting restricted waterways and channel will be dispatched to maintain a minimum under-keel clearance of three (3) feet or 10 percent of draft, 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.*

2.7.2 Marine Conditions

2.7.2.1 Tidal Range

Tides in Puget Sound are mixed semidiurnal in type. The mean tidal range published by the National Oceanic and Atmospheric Administration (NOAA) for Tacoma, Washington, is 8.1 feet. The great diurnal tidal range is 11.8 feet. Tidal data for Tacoma, Washington, at Commencement Bay are listed in Table 2-12.

Table 2-12. Tidal Data at Tacoma NOS/CO-OPS station 9447130 (1983-2001 tidal epoch)

Datum	Value (feet)	Description
MHHW	11.8	Mean Higher-High Water
MHW	10.9	Mean High Water
MTL	6.9	Mean Tide Level
MSL	6.8	Mean Sea Level
MLW	2.8	Mean Low Water
MLLW	0.0	Mean Lower-Low Water
NAVD	2.4	North American Vertical Datum
Maximum	14.9	Highest Observed Water Level
Minimum	-4.7	Lowest Observed Water Level

2.7.2.2 Tidal Delays

Table 2-13 summarizes the tidal limitations on vessel drafts for the Blair Waterway at Tacoma Harbor. As an example, current channel dimensions provide 61 percent reliability for a fully loaded PPX4 vessel with a 52.5-foot transit draft. Given the 39 hour average dwell time for containerships docking at terminals on the Blair Waterway, vessels with a transit draft greater than 45 feet likely face tide constraints during their time in port.

Table 2-13. Tidal Limitations on Port of Tacoma Vessel Draft

Vessel Draft	Vessel Draft + 10% UKC	Hours in an Aggregate Tidal Cycle (12.4 hrs) with Required Channel Depth	% Time in an Aggregate Tidal Cycle with Required Channel Depth
40	44.0	12.4	100%
41	45.1	12.4	100%
42	46.2	12.4	100%
43	47.3	12.4	100%
44	48.4	12.4	100%
45	49.5	12.3	99%
46	50.6	12.1	97%
47	51.7	11.7	94%
48	52.8	11.1	90%
49	53.9	10.5	84%
50	55.0	9.8	79%
51	56.1	9.0	73%
52	57.2	8.1	66%
52.5	**57.8**	**7.6**	**61%**
53	58.3	7.0	56%
54	59.4	5.5	44%

The largest vessel in the design vessel class used in the analysis had a MXSLLD of 52.5 feet (Section 3.3.1). Pilots generally use a 10 percent UKC clearance rule for transiting the Blair Waterway. At its deepest draft, a vessel would require nearly 58 feet of water depth (52.5-foot draft, 5.25 feet UKC). Pilot practice nationwide and assumptions made for the SHNIP indicate the minimum UKC for PPX3 and PPX4 vessels to be at least 4.1 feet under FWP conditions. Given the tide cycle at Tacoma Harbor, which can fall to nearly -4 feet below MLLW, a fully-loaded 52.5-foot design draft vessel would require a channel depth of approximately -61 feet for 100 percent channel reliability. Table 2-14 provides channel reliability for the PPX4 design vessel by alternative, assuming 4.1-feet UKC clearance.

Table 2-14. Channel Reliability of Design Vessel by Alternative Depth

Alternative Depth (MLLW)	52.5' Design Draft Channel Reliability
-51	57%
-52	66%
-53	72%
-54	78%
-55	83%
-56	88%
-57	92%
-58	96%

Analysis of channel reliability reveals a disincentive for PPX3 and PPX4 vessel operators to load near MXSLLD under current channel dimensions. Doing so requires tide timing for both channel transit and dock loading. Vessels typically berth for at least 24 hours, so fully-loaded PPX3 and PPX4 vessels would likely violate their UKC thresholds in an aggregate tide cycle. Even if berth depths were lower than the channel depth, vessels are not likely to fully load given the difficulty of tide-timing and unreliability of sufficient channel depths in combination with dock congestion and tight service schedules.

The study assumes channel deepening would allow the current and future fleet to better optimize vessel loading practices by allowing vessels to transit at or near their MXSLLD. To capture the impact of loading, the analysis assumes vessel sailing drafts will shift approximately 0.7 feet on average for every foot of deepening until they are able to reach their MXSLLD. This assumption is only made for PPX3 and PPX4 vessels (Section 4.1.2.1).

2.7.2.3 Wind Conditions

Figure 2-14 provides the wind roses for the two closest wind stations to the Port of Tacoma: SEATAC International Airport and the Tacoma Narrows Bridge. Tacoma Harbor lies between these two sites. While there are likely differences in wind conditions between these stations and Tacoma Harbor, the prevailing trends are likely similar. The strongest and most frequent winds at Tacoma are oriented from the north and south. These winds can lead to significant crosswinds for vessels transiting the Blair Waterway, causing delays as vessels wait for acceptable conditions for channel transit.

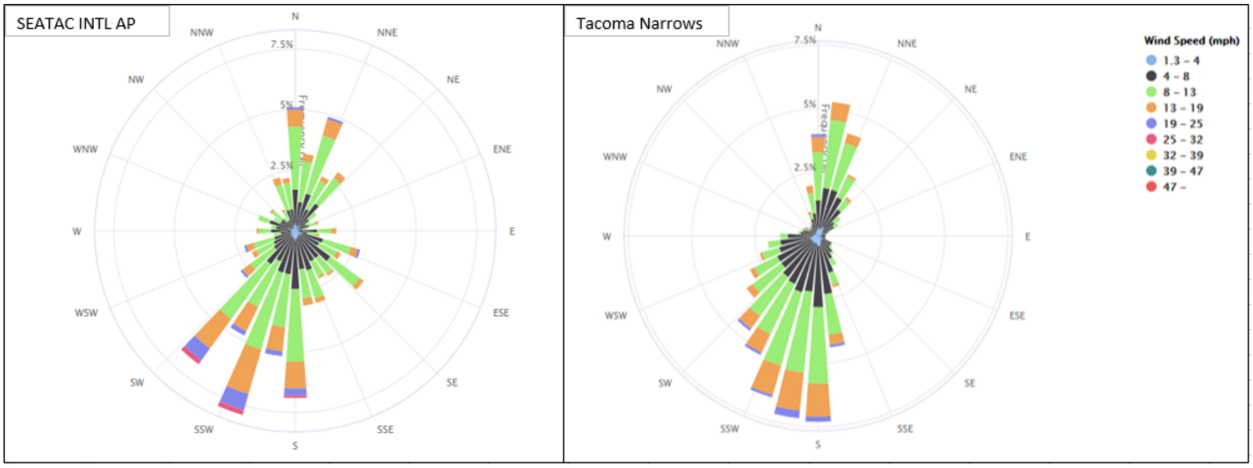


Figure 2-14. Wind Rose at SEATAC International Airport and Tacoma Narrows Bridge (1972-2018), NOAA

2.7.3 Sailing Practices

Vessel transit guidelines are documented for the PSP[9]. Below are general guidelines for Tacoma Harbor. These guidelines are not expected to change as a result of a deepening project. These general guidelines are advisory in nature only and are not intended to supersede the authority or judgment of the individual pilot or pilots. Every specific situation is unique with regard to the type and class of vessel, the existing weather, and numerous other variable conditions. All decisions rest with the discretion of the pilot(s) dispatched to the job.

VESSEL SPACING

1. It is recommended that all final berthing positions provide for a minimum of 10% of the vessel length in clearance to other vessels (including barges) or shoal areas.
2. For Vessels over 900 feet in length, it is recommended that all final berthing positions provide for a minimum of 100 feet clearance to other vessels (including barges) or shoal areas.

HORIZONTAL CLEARANCE

1. With the exception of the Duwamish River and Hylebos Waterway, 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. Net clearance means open water between vessels, gantry cranes, bunker barges/tugs/spill booms, fishing nets, shoals, or any other obstructions.
2. Vessels having a beam of 140 feet or wider should not pass a bunker barge while in operation when alongside a vessel in any of the Seattle/Tacoma waterways.

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:

[9] Puget Sound Pilots. "General Guidelines for Vessels Transiting Restricted Waterways or Ports". Revised May 1, 2017.

   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 vessel's midships section (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

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 the specific sail area of a vessel to the dispatcher 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)

BLAIR WATERWAY NORTH OF 11TH STREET

1. All vessels less than 900 feet in length should be dispatched with a minimum of two T4 class tugs except that one tug may be dispatched to a vessel with a 4% Bow Thruster.
2. All vessels 900 feet or greater in length should be dispatched with a minimum of two tugs, one T5 class, and one T4 class, except that one T5 class tug may be dispatched to a vessel with a 4% Bow Thruster departing when there are no other vessels or obstructions in the waterway.
3. Vessels greater than 110,000 GT should be dispatched with a minimum of two T5 and one T4 class tugs. For outbound vessels heading bow out with a 4% Bow Thruster, a minimum of two T5 class tugs may be acceptable provided there are no vessels berthed between the vessel and Commencement Bay.
4. Transit of vessels greater than 120,000 GT should be dispatched with a minimum of three T5 class tugs.

5. Transit of vessels greater than 145,000 GT shall be discussed with the President of Puget Sound Pilots well in advance of arrival. PSP will determine the appropriate tug package and any transit conditions/restrictions based on the vessel particulars and anticipated port conditions at the time.

BLAIR WATERWAY SOUTH OF 11TH STREET

1. Vessels with a beam of 100 feet or less should be dispatched with a minimum of two T4 class tugs.
2. Vessels exceeding 100 feet in beam should be dispatched with a minimum of two T5 class tugs, except that vessels having a 4% Bow Thruster may be dispatched with one T5 class and one T4 class tug.
3. Vessels exceeding 130 feet in beam should be dispatched with a minimum of two T5 and one T4 class tugs.
4. Vessels greater than 100,000 GT should be dispatched with a minimum of one T8 and two T5 class tugs.
5. Vessels greater than 120,000 GT should be dispatched with a minimum of two T8 class and one T5 class tugs.
6. Laden tankers exceeding 106 feet in beam should be dispatched with three tugs, two T5 class, and one T4 class tugs. Vessels with a Bow Thruster and twin screws may be dispatched with two T5 class tugs.
7. Second Pilot: Vessels exceeding 130 feet in beam will be dispatched with two pilots.
8. Vessels of unusual configuration, vessels greater than 155 feet in beam or 145,000 GT, and all tank vessels in excess of 750 feet in length may require daylight transit as well as additional tugs or pilots. The transit of these vessels must be discussed with the President of PSP well in advance of the intended transit date.

3 Future Conditions

This section outlines the key assumptions related to future conditions at Tacoma Harbor. The analysis assumes both the commodity and fleet forecasts will be the same in the FWOP and FWP Conditions.

3.1 Terminal Expansions

The NWSA created a 10-year strategic business plan in 2015. The plan's cornerstone is an investment in strategic terminals with sufficient berth length, water depth, storage acreage, and on-dock rail facilities to handle Post-Panamax vessel traffic. Two terminals were identified for strategic investment: T-5 in the Seattle Harbor and the General Central Peninsula development in the Tacoma Harbor, including Husky Terminal.

The study assumes the Port of Tacoma will continue to improve their facilities and backlands. These improvements are likely to include a reconfiguration of the backlands and various other terminal improvements. These projects will likely increase the efficiency of Husky Terminal and its overall capacity.

WUT will need to upgrade cranes to service PPX4 vessels efficiently in the future. Currently, the facility has 2 cranes capable of loading and unloading PPX4 vessels. The analysis assumes capacity constraints at Husky and growth in PPX3 and PPX4 vessel calls will necessitate crane upgrades at WUT. New cranes can take an average of two years to purchase and install. There is an adequate time prior to the project base year for WUT to upgrade. The purchase price for each new crane is approximately $12 million per crane up to six new cranes. This cost is not considered an associated cost of the project as it takes place regardless of a Federal project. The study team assumes that PPX4 vessels will call WUT with or without a Federal project. Section 5 discusses project sensitivity to crane upgrades at WUT.

PCT is currently capable of servicing PPX3 vessels, and no significant changes are expected to the terminal's backlands. The study team assumes PCT's capacity and operations will be similar to the current condition.

3.2 Commodity Forecast

3.2.1 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 prospects and the estimated cargo volume upon which future vessel calls are based. Under FWOP and FWP conditions, the same volume of cargo is assumed to move through Tacoma Harbor. However, a deepening project will allow shippers to load vessels more efficiently, leading to economies of scale for Post-Panamax vessels. This efficiency creates transportation cost savings, considered a National Economic Development (NED) benefit.

To minimize the impact of potential anomalies in trade volumes on long-term forecasts, the study uses five years of data (2014 through 2018) from the US Census Bureau's USA Trade Online tool to develop the containerized tonnage forecast baseline. The US Census data provides the most recent and detailed breakdown of commodities currently available.

3.2.1.1 Containerized Imports

Table 3-1 illustrates historical containerized imports moved through the Port of Tacoma from 2014 to 2018. International imports grew from 5.3 million in 2014 to 5.6 million metric tons in 2015 before falling back to a five-year low of 4.6 million metric tons in 2017. Tonnage rebounded to 5.1 million metric tons in 2018. The top containerized imports in terms of weight are furniture, machinery and equipment, iron and steel, toys, games, sports equipment and accessories, and motor vehicle parts. A high percentage of imports are either consumer goods or raw or intermediate goods manufactured into consumer goods. Section 2.2 only presents tonnage through 2017 to be consistent with the fleet existing condition data.

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

Year	Imports
2014	5,347,000
2015	5,622,000
2016	4,652,000
2017	4,607,000
2018	5,143,000
Average, 2014-2018	**5,074,000**

The import forecast uses the average import volume from 2014 through 2018, as presented in **Table 3-1**. This represents the most recent available data for Port of Tacoma and establishes an average import value over a five-year business cycle, as prescribed in IWR Report 10-R-4.

3.2.1.2 Containerized Exports

Table 3-2 summarizes historical containerized exports moved through the Port of Tacoma from 2014 to 2018. Average exports from 2014 through 2018 totaled 5.8 million metric tons. Overall international exports increased from 5.17 million metric tons in 2014 to 6.47 million metric tons in 2018. The top containerized exports based on tonnage are oilseeds, other agricultural products, primary wood products, and vegetable products.

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

Year	Exports
2014	5,165,000
2015	4,958,000
2016	6,423,000
2017	5,992,000
2018	6,468,000
Average, 2014-2018	**5,801,000**

The export forecast uses the average import volume from 2014 through 2018, as presented in Table 3-2. This represents the most recent available data for Port of Tacoma and establishes an average export value over a five-year business cycle, as prescribed in IWR Report 10-R-4.

3.2.2 Trade Forecast Methodology

The preceding section (Section 3.2.1) describes the methodology used to develop the import and export baseline. The following sections discuss the import and export long-term trade forecasts.

The forecast incorporates regional commodity growth rates from an IHS Global Insight forecast originally developed for the SHNIP economic analysis. The forecast applies the IHS Global Insight growth rates for each world region and the lowest commodity category (2, 4, or 6-digit) to the baseline tonnage.

When making global trade forecasts, IHS Global Insight employs macroeconomic models that contain all commodities with 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 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. Because international trade statistics collected by different countries usually have discrepancies and because no one source has complete data, they also use US Customs data and IMF Direction of Trade data to calibrate and supplement historical commodity trade data. IHS records data from different sources in different classification systems and units of measurements and converts data into thousands of current US dollars and 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, gross domestic product (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 US Bureau of Labor Statistics (BLS) 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.

3.2.3 Containerized Trade Forecast

The IHS Global Insight trade forecast included over 7,800 export and 10,500 import country-specific commodity growth rates through 2064. The analysis applies these growth rates to baseline commodity totals at Tacoma Harbor to estimate future throughput tonnage. This estimate is considered the unconstrained forecast because it does not account for the Port's capacity; instead, it estimates throughput tonnage at Tacoma Harbor, assuming no constraints. Analysis in Section 3.2.5 will estimate the constrained throughput forecast based on TEU throughput capacity at each terminal. Modeling will estimate benefits for every 5 years past the base year or until the port reaches capacity. Forecasts will be presented in 5-year intervals; however, the forecast includes growth rates for all years.

3.2.3.1 Import Forecast

Table 3-3 provides the baseline import tonnage and forecasted tonnage for every 5 years through 2045 and includes the CAGR between each model year. The analysis expects significant import growth through the study period, with overall tonnage doubling by 2040.

Table 3-3: Tacoma Harbor Forecast (Metric Tons)

Direction	Baseline	2030	2035	2040	2045
Import Tonnage	5,074,000	7,410,000	8,449,000	9,633,000	11,083,000
CAGR	-	3.5%	2.9%	2.8%	3.0%

Commodities like machinery, iron, steel, stone, clay, cement, sand, and other crude materials will benefit from a growing construction sector, while parts of motor vehicles, furniture, wood products, and electronics will benefit from strengthening consumer demand over the study period.

3.2.3.2 Export Forecast

Table 3-4 provides the baseline export tonnage and forecasted tonnage for every 5 years through 2045 and includes the CAGR between each model year. Export growth potential is even greater than import growth, with tonnage doubling by 2035.

Table 3-4. Tacoma Containerized Trade Forecast - Exports

Direction	Baseline	2030	2035	2040	2045
Export Tonnage	5,801,000	9,933,000	11,604,000	13,507,000	15,533,000
CAGR	-	4.6%	3.2%	3.1%	2.9%

According to IHS Global Insight, Asian countries will be demanding agriculture products and other raw commodities to meet population growth. Examples of high-volume, high-growth containerized commodities moving out of Tacoma are oilseeds, animal feed, fruits and vegetables, paper, and newspaper.

3.2.4 Containerized Forecast in TEUs

Using the containerized trade forecast for imports and exports and the average weight per loaded container (in terms of TEUs), a loaded container forecast was developed. Table 3-5 provides the loaded import and export TEU forecast with the weight per loaded container.

Table 3-5. Tacoma Loaded TEU Forecast – Import and Export

Direction	Weight per Loaded TEU	Baseline (2014-2018)	2030	2035	2040	2045
Import	6	781,000	1,140,000	1,300,000	1,482,000	1,705,000
Export	12	496,000	849,000	992,000	1,154,000	1,328,000
Total Loaded TEUs		**1,277,000**	**1,989,000**	**2,292,000**	**2,636,000**	**3,033,000**

The analysis assumes the percentage of empty TEUs to loaded TEUs will remain constant throughout the study period. Data received from Port of Tacoma for TEU trade from 2014 through 2018 informed the empty TEU estimate for this forecast (Table 3-6). The analysis applies these percentages to forecast empties through 2045 (Table 3-7).

Table 3-6. Tacoma Empty TEU Forecast – Import and Export (2014-2018)

Direction	Total Laden TEUs	Total Empty TEUs	% Empty
Import	4,784,000	505,000	11%
Export	3,309,000	1,230,000	37%
Total	8,093,000	1,735,000	21%

Table 3-7 provides total loaded and empty import and export TEUs. Import TEUs grow at a CAGR of 3.2 percent from a baseline volume of 795,000 TEUs to 1.9 million TEUs in 2045. Export TEUs grow at a CAGR of 3.8 percent from a baseline of 650,000 TEUs to 1.8 million TEUs in 2045.

Table 3-7. Tacoma Total TEU Forecast

Direction	Baseline (2014-2018)	2030	2035	2040	2045
Import Total	**867,000**	**1,265,000**	**1,443,000**	**1,645,000**	**1,893,000**
Loaded	781,000	1,140,000	1,300,000	1,482,000	1,705,000
Empty	86,000	125,000	143,000	163,000	188,000
Export Total	**679,000**	**1,163,000**	**1,358,000**	**1,580,000**	**1,818,000**
Loaded	496,000	849,000	992,000	1,154,000	1,328,000
Empty	183,000	314,000	366,000	426,000	490,000
Total TEUs	**1,546,000**	**2,428,000**	**2,801,000**	**3,225,000**	**3,711,000**
Loaded	1,277,000	1,989,000	2,292,000	2,636,000	3,033,000
Empty	269,000	439,000	509,000	589,000	678,000

3.2.5 Capacity Constrained Blair Waterway Container Forecast

The analysis assumes smaller capacity vessels (e.g., Sub-Panamax and Panamax ships) will continue to call the Sitcum Waterway, while the majority of Post-Panamax vessels will call the Blair Waterway. As a result, the forecast separates the Blair Waterway baseline tonnage from the existing, Sub-Panamax and Panamax tonnage handled on the Sitcum Waterway (approximately 2.11 percent of total import tonnage and 5.37 percent of total export tonnage). The study assumes throughput tonnage totals will continue to grow on both the Sitcum and Blair Waterways; however, this investigation focuses on Blair Waterway traffic only[10].

To reflect realistic expectations of future trade, the analysis estimates a capacity limit at Blair Waterway. The Terminal-by-terminal capacity limits determined in Section 2.4 indicate a maximum capacity of approximately 2.7 million TEUs for the Blair Waterway. This limits additional growth beyond 2035. Table 3-8 provides the constrained commodity forecast, including total TEUs. The study team holds the tonnage constant after 2035.

Table 3-8: Blair Waterway Capacity Constrained Forecast

Direction	Baseline	2030	2035
Import Tons	5,074,000	7,254,000	8,271,000
Export Tons	5,801,000	9,399,000	10,981,000
Total TEUs (Ld, UnLd)	1,347,300	2,326,300	2,683,300

3.3 Vessel Fleet Forecast

3.3.1 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" (CORPS 1984, 1995, 1999).

For the Blair Waterway, the economics and coastal hydraulics team, in consultation with the DDN-PCX and IWR, recommended the PPX4 containership class as the design vessel. This selection is meant to incorporate the full range of potential dimensions the largest, most frequently calling vessel will have over

[10] Forecasted tonnage quantities in this appendix refer to the Blair Waterway only, unless otherwise stated.

the study period. Vessel of this size are frequently used on Pacific Ocean routes, and similar vessels already call at WCUS Ports, including Seattle and LA/Long Beach. The Port of Tacoma is anticipating the use of these vessels in the future and has made a significant investment to do so. The specifications for the recommended design vessel class are as follows:

- 175 to 194 feet in beam
- 1,295 to 1,315 feet length overall (LOA)
- 47.6 to 52.5 feet MXSLLD
- Nominal TEU intake of approximately 15,500 to 19,200 TEUs
- Deadweight (DWT) rating of 155,000 to 205,000 metric tons

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 container (FCC) 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 (DWT) or nominal intake for standard-unit slot capacity (i.e., nominal TEUs).

Studies for Tacoma Harbor are primarily based on the anticipated service regime for future containerized movements with consideration of SPX, PX, current PPX and new PX, and new PPX hull designs or specifications. Previous PX 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 LOA via the existing lock system, while the new PX standard associated with the capacity of the new lock system allows for vessels up to 168 feet in breadth and 1,220 feet in length.

With respect to current and projected fleet service for deep-draft harbors such as Tacoma, post and new PX designs are divided into three general groupings, largely separated by beam and capacity for nominal TEU intake. Building trends for the first two groupings (PPX1 and PPX2, 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 DWT capacity, and typical homogeneous and nominal TEU ratings. What can be termed the PPX 3 class of containership (beams exceeding 150 feet through 168 feet) has only recently become better defined in terms of typical dimensions a project analyst would expect to encounter due in large part to the 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 on 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, the 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 PX specification, fleet service for harbors on WCUS such as Tacoma have the potential to be serviced by the new PPX classes of ships, especially where concerns for depth and limitation on air draft are not a constraint. 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 PPX4 (and above), PPX (with the definition of PPX based on the original lock specifications of the Canal), or new PPX based on the new locks in service as of 2016. The PPX4 class of containership have beams of 168 feet through 190 feet. Accordingly, this class of ship represents hulls exceeding the dimensions of the new lock system.

Studies for Tacoma Harbor involve the assessment and projection of fleet service to terminals in Blair Waterway. No bridges impose air draft limitations on these containerized cargo handling facilities within the harbor. The Blair Waterway is designed for one-way traffic only.

All terminals can feasibly accommodate PPX4-class vessels. Husky and WUT have the capacity to berth two PPX4 vessels simultaneously, while PCT could only accommodate one PPX4 vessel. PCT does not have plans to service PPX4 vessels; however, the Terminal services PPX3 vessels up to 14,000 TEU capacity. Therefore, the analysis limits the maximum vessel size at PCT to PPX3. However, PPX4 vessels will still use the Blair Waterway Turning Basin immediately adjacent to PCT, limiting the opportunity to design the turning basin for a smaller design vessel (PPX3).

The world fleet includes 453 PPX3 and PPX4 ships (i.e., vessels with at least 7,500 TEU capacity) in service, under construction, or on order with an average nominal capacity of 13,700 TEUs as of January 2018[11]. An additional 131 vessels within the PPX3 and PPX4 classes are currently on order, with an average capacity of 16,700 TEUs. The significant growth in average TEU capacity is largely due to the lack of vessels on order within the 7,500 to 9,999 TEU capacity range. This is due to the current overcapacity of vessels this size and the desire to achieve economies of scale using larger vessels. In the future, vessels with at least 10,000 TEU capacity are more likely to service Tacoma Harbor as the current fleet of vessels in the 7,500 TEU range are phased out and replaced by larger, deeper drafting, and more efficient PPX3 and PPX4 containerships.

3.3.2 World Fleet

MSI provided a world and regional fleet forecast for use on SHNIP. This forecast included anticipated cargo share by vessel class. Given the similarity in trade between Seattle and Tacoma, the SHNIP forecast was updated and used for this feasibility study. The forecasts were reviewed early in the study process and approved for use by NWS District planning and the DDNPCX[12]. The study team adapted the MSI fleet forecast developed by MSI to determine the future fleet calling at Tacoma Harbor. The methodology developed by MSI was linked to the commodity forecast to develop the final fleet forecast for Tacoma

[11] http://www.brsbrokers.com/assets/review_splits/BRS-Review2018-10-Containers.pdf
[12] MFR dated 30 Nov 2018

Harbor. Table 3-9 shows the fleet subdivision using common vessel labeling terminology and vessel specifications for design draft, beam, and LOA.

Table 3-9. Fleet Subdivisions on Draft, Beam, and LOA (in feet)

Vessel Fleet Subdivision (Containerships)	Dimension	From	To
Sub Panamax (SPX) (MSI size brackets: 0.1-1.3, 1.3-2.9k TEU)	**Beam**	Up to	98
	Draft	8.2	38.1
	LOA	222	813.3
Panamax (PX) (MSI size brackets: 1.3-2.9, 2.9-3.9, 3.9-5.2, 5.2-7.6k TEU)	**Beam**	98	106
	Draft	30.8	44.8
	LOA	572	970
Post-Panamax (PPX1) (MSI size brackets: 2.9-3.9, 3.9-5.2, 5.2-7.6, 7.6-12k TEU)	**Beam**	106	138
	Draft	35.4	47.6
	LOA	661	1045
Super Post-Panamax (PPX2) (MSI size brackets: 5.2-7.6, 7.6-12k TEU)	**Beam**	138	144
	Draft	39.4	49.2
	LOA	911	1205
Ultra Post-Panamax (PPX3) (MSI size brackets: 5.2-7.6, 7.6-12, 12k+ TEU)	**Beam**	144	168
	Draft	Up to	51.2
	LOA	Up to	1220
New Post-Panamax (PPX4) (MSI size brackets: 12k+ TEU)	**Beam**	175	194
	Draft	Up to	52.5
	LOA	1,295	1,315

By combining information from the commodity forecast with MSI's forecasted fleet capacity by vessel class, the study team was able to allocate a number of vessel calls by vessel class to Tacoma's future fleet. The number of transits, particularly those made by larger vessels, is a key variable in calculating the transportation costs used in evaluating project justification. 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. MSI's Container Shipping Planning Service (CSPS) model (Figure 3-1) determined the future world fleet forecast. The model 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.

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 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 fleet forecast and is provided as background information.

As larger vessels become a greater percentage of the world fleet, they are first deployed on the longest, most cost-efficient routes. These are typically services between Europe and Asia. As these vessels age and new vessels continue to enter service, these large vessels cascade to slightly less efficient routes (i.e., Transpacific services calling Tacoma Harbor). Vessels already on Transpacific services cascade to shorter and less efficient routes such as Transatlantic services. Over the study period, the average TEU capacity of vessels on Europe-Asia trade routes will continue to grow, causing a ripple effect of ship growth to Transpacific routes. Vessels with TEU capacity of at least 12,000 and up to 16,000 TEUs will become the workhorses of Transpacific routes over the study period (Section 3.3.2.4).

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 Charleston's study was then applied to Tacoma's forecasted tonnages in order to estimate future nominal TEU vessel capacity calling Tacoma. As the tonnage in Tacoma 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 Tacoma was determined, the future containers were allocated to various vessel classes. The allocation to vessel classes was based on MSI's examination of historical utilization of vessels and trends in vessel design and orders. Figure 3-1 summarizes the fleet forecast methodology.

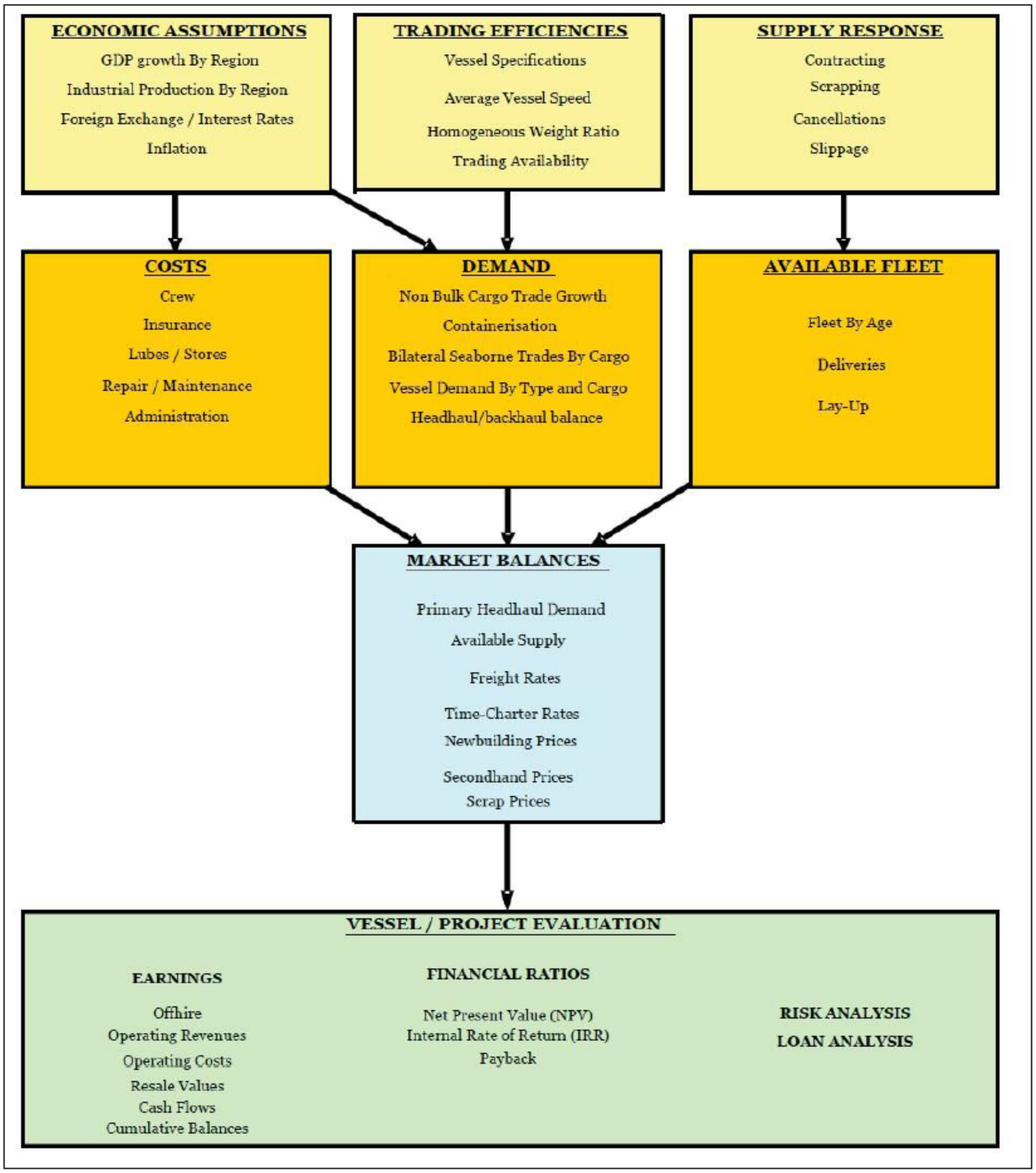


Figure 3-1. Schematic Overview of MSI's CSPS Model

3.3.2.1 World Fleet End of Period 2017

A projection of the World Fleet provides the necessary background for evaluating the future fleet forecast for Tacoma. The starting point for this projection was the world fleet by vessel class as projected by MSI from the Lloyd's Register-Fairplay database for the years 2016 and 2017[13]. The fleet is shown by TEU band in Table 3-10.

Table 3-10. World Fleet by TEU Band - 2016 and 2017

TEU Band	2016	2017
0.1 - 1.3k TEU	1,464	1,350
1.3 - 2.9k TEU	1,366	1,335
2.9 - 3.9k TEU	291	289
3.9 - 5.2k TEU	742	740
5.2 - 7.6k TEU	529	525
7.6 - 12k TEU	562	596
12k+ TEU	266	319
TOTAL	**5,220**	**5,154**

3.3.2.2 The "Order Book"

The "order book" is shorthand for the list of vessels contracted to be built 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 under construction. There are also option contracts, which secure the capacity of the shipyard but do not require the buyer to exercise the option to construct the vessel. Some contracts have committed financing; others do not. The challenge is to translate the number of vessels and types of contracts into future vessels coming into service at a specific time. This requires the knowledge and expertise of this market. Forecasts must be made for future contracts, vessel scrapping, and vessel deliveries[14]. 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 the LR-Fairplay fleet database. 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 contracting by TEU bands for FCC vessels[15] for the years 2000 to 2035.

[13] LR-Fairplay maintains the largest maritime databases covering ships, movements, owners and managers, maritime companies, ports and terminals.
[14] Factors such as economic conditions, price of steel, exchange rates, and a host of others can influence the forecasted world fleet.
[15] The term "fully cellular" refers to purpose-build vessels carrying ocean containers. The containers are generally stored in vertical slots on the ship.

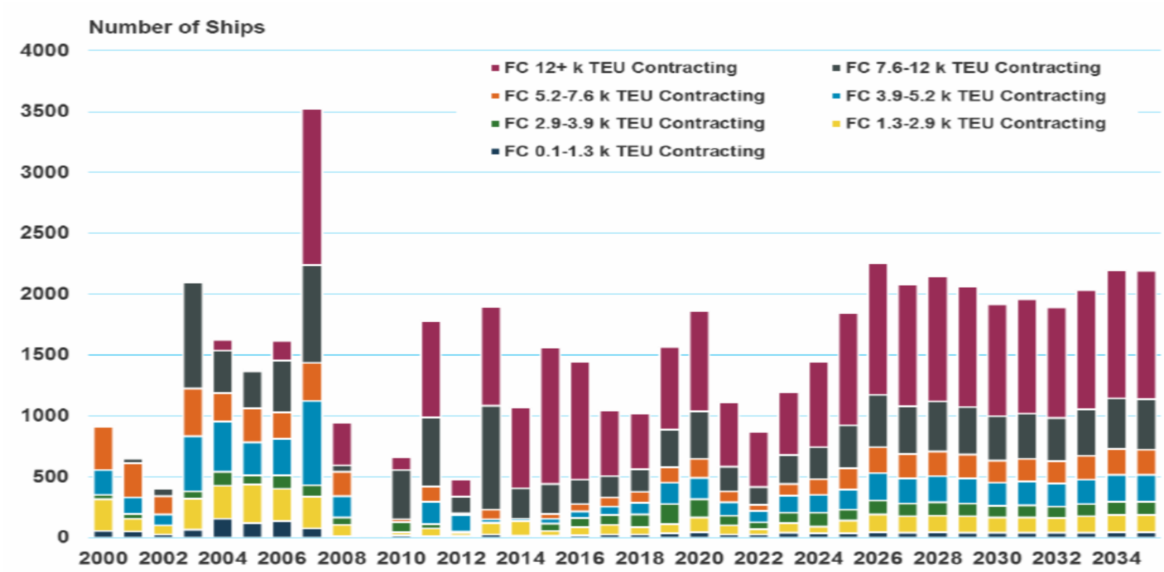


Figure 3-2. Containership Contracting, 2000-2035 (Source: MSI 2015)

3.3.2.3 Deliveries and Scrapping Assumptions

MSI modeled the relationship between annual contracting and annual deliveries by TEU band. Figure 3-3 depicts the forecast for deliveries by TEU band. The number of new vessel deliveries is expected to increase each year until 2030 and then taper to the end of the forecast period.

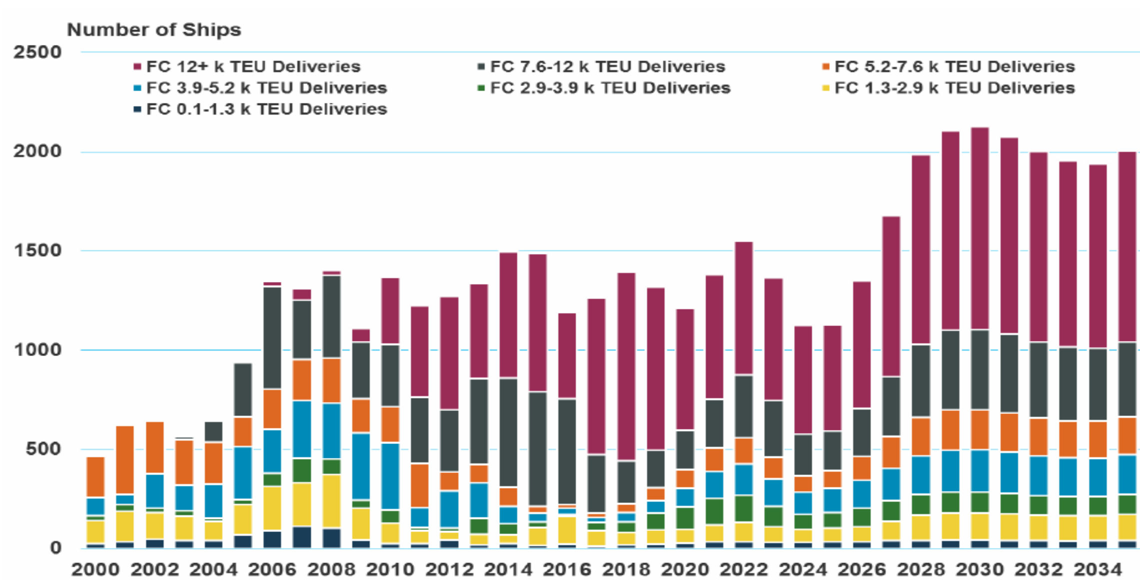


Figure 3-3. Containership Deliverables, 2000-2035 (Source: MSI 2015)

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 class.

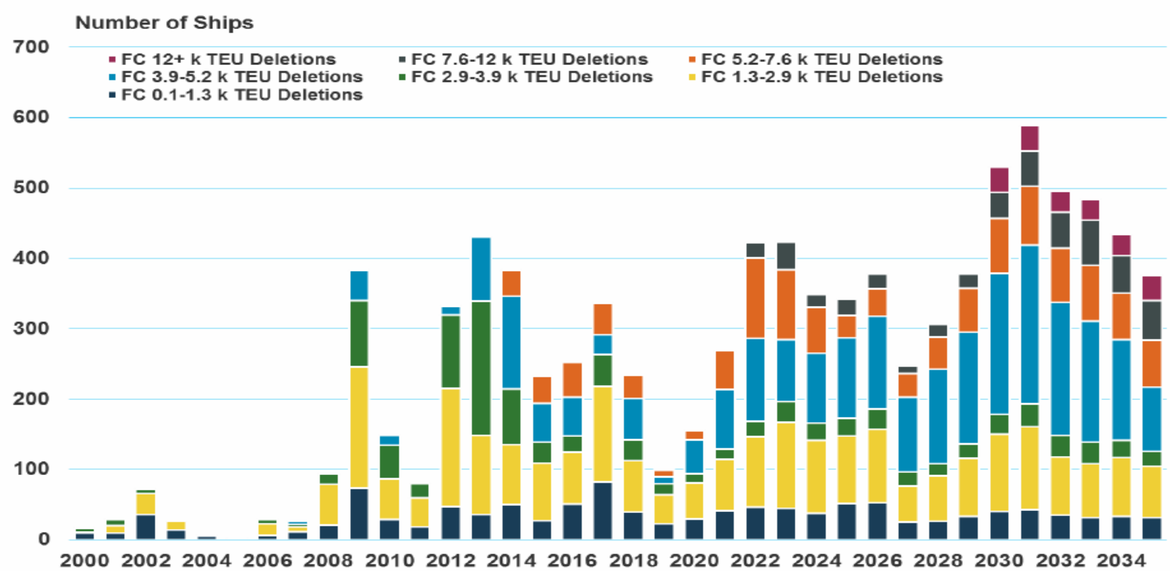


Figure 3-4. Containership Deletions, 2000-2035 (Source: MSI 2015)

3.3.2.4 World Fleet Forecast

With data for deliveries, scrapping, and the 2011 fleet calculated, the 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.

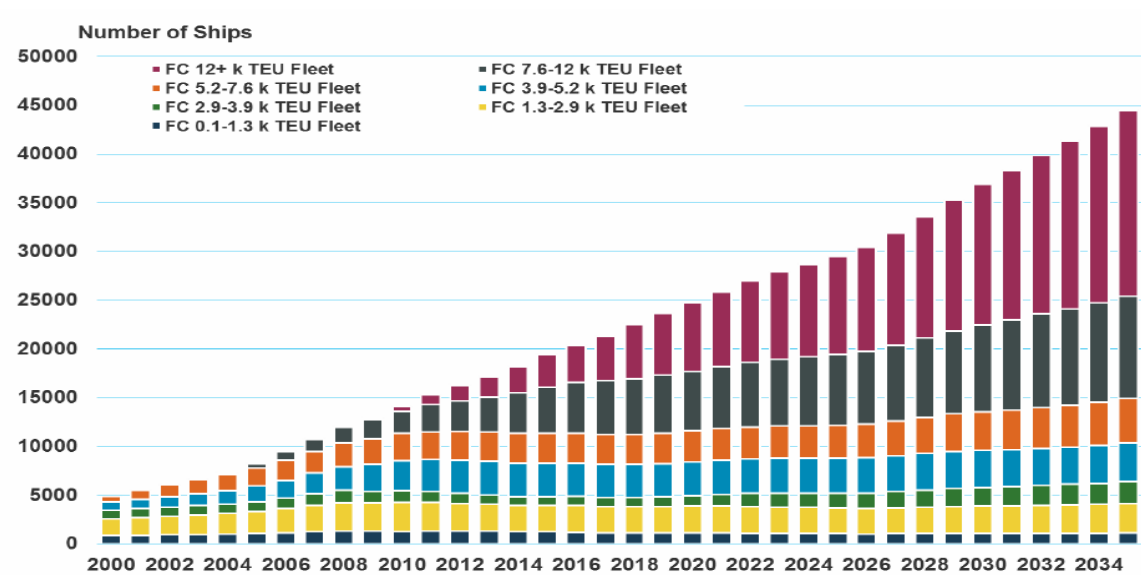
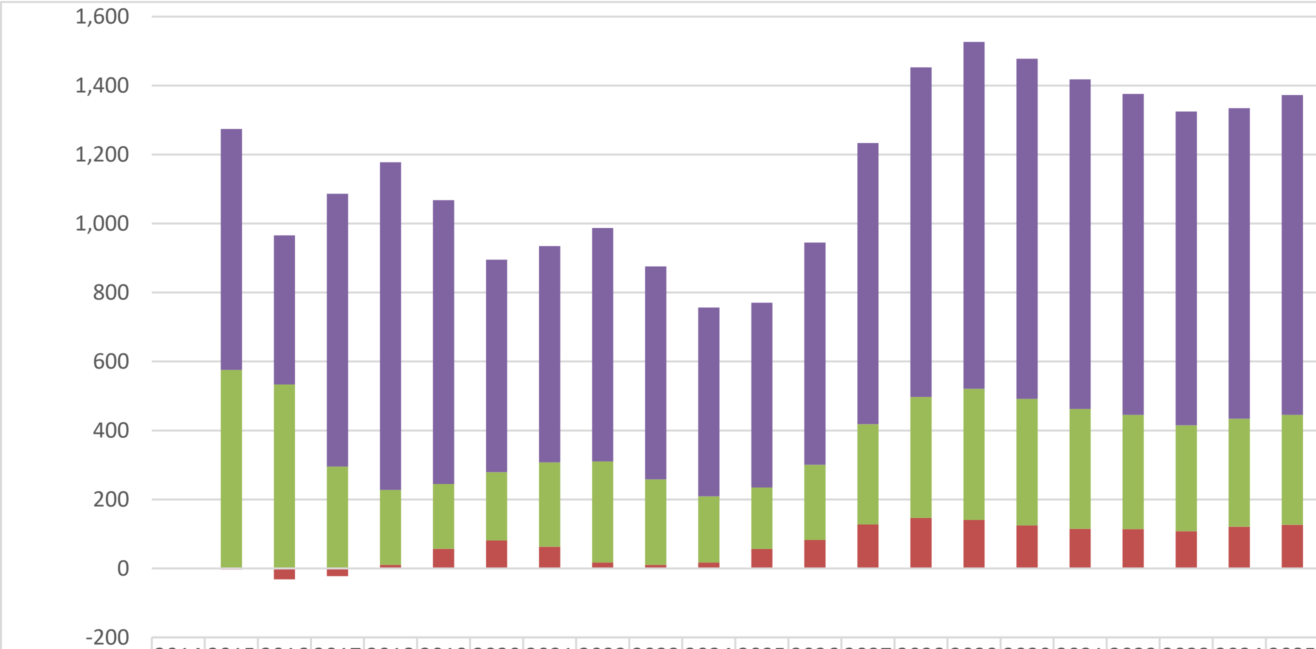


Figure 3-5. World Fleet, Historical and Forecasted FCC by TEU Band, 2000-2035 (Source: MSI 2015)

Figure 3-6 shows the net growth in selected PPX 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 Tacoma Harbor.



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
12+ k	0	698	432	791	950	823	616	627	677	617	547	536	644	815	956	1006	987	956	931	910	900	927
7.6-12 k	0	576	534	296	217	187	198	244	293	248	192	178	218	291	350	380	367	347	331	307	313	319
5.2-7.6 k	0	-4	-32	-22	11	57	81	63	17	10	17	56	82	128	147	141	125	115	114	108	121	126

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

3.3.3 Container Vessels Calling at Port of Tacoma

The quickly growing stock of vessels with capacity over 12,000 TEU will first deploy on the most economically optimal route, typically Asia-European services; however, the oversupply of large vessels will lead to cascading vessel deployment where shippers repurpose vessels on Asia-Europe services for use on Transpacific, Transatlantic, Asia-Middle East/Indian Subcontinent or Asia-Latin America trades. Traditionally, transpacific routes are first in line for these larger vessels.

3.3.3.1 Trade through North America and Port of Tacoma 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 WCUS based on historical distribution by trade route. The forecast is refined again to determine Tacoma's share of the fleet distribution.

Table 3-11 summarizes the historical percent share of total fleet capacity for Blair Waterway from 2008 through 2018. The table shows a shift from 5.2 to 7.6 thousand TEU capacity vessels to vessels with capacity of over 7.6 thousand TEUs. This is consistent with international order book trends, which show significant growth in orders for vessels with at least 7.6 thousand TEU capacity.

Table 3-11. Historical Share of Nominal Vessel Capacity Calling by TEU Band

Vessel Class	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0.1-1.3 k TEU	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1.3-2.9 k TEU	7%	7%	2%	0%	4%	5%	3%	5%	4%	2%	2%
2.9-3.9 k TEU	4%	7%	1%	0%	0%	0%	0%	0%	0%	0%	0%
3.9-5.2 k TEU	3%	19%	12%	3%	7%	11%	16%	14%	11%	10%	10%
5.2-7.6 k TEU	85%	68%	85%	97%	70%	50%	34%	38%	37%	71%	66%
7.6-12+ k TEU	0%	0%	0%	0%	19%	34%	48%	43%	48%	18%	22%

3.3.3.2 Forecasted Vessel Capacity Calling Port of Tacoma

The MSI forecast was used to estimate total annual nominal capacity calling at Tacoma for 2019 through 2035. The forecast was developed using the linear regression equation explained in Section 3.3.2. 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.

3.3.3.3 Forecasted PPX Share of Vessel Capacity

The forecasted capacity calling at Tacoma was allocated to PPX vessel classes according to MSI's forecast of capacity share, as shown in Table 3-12. The fleet forecast developed for SHNIP and adapted for Tacoma Harbor extends through 2035 when the analysis assumes the Port will reach capacity.

Table 3-12. Forecasted Share of Vessel Capacity

Vessel Class	2030	2035
7.6-12k TEU	33%	11%
12k+ TEU	65%	89%

Table 3-13 converts TEU size bands to vessel classes using Table 3-9 to estimate share of vessel capacity expected at Blair Waterway in model years 2030 and 2035.

Table 3-13: Forecasted Share of Vessel Capacity by Corps Vessel Class

Vessel Class	2030	2035
SPX	0%	0%
PX	0%	0%
PPX1	4%	3%
PPX2	9%	5%
PPX3	33%	16%
PPX4	54%	77%

3.3.3.4 Initial Forecast of Vessel Calls at Port of Tacoma

The PDT developed a fleet forecast using MSI projections as well as an internal analysis of the historical Port of Tacoma calls. Specifically, the study uses the MSI forecasted share of capacity by vessel class to distribute forecasted tonnage. The study then uses vessel loading assumptions (e.g., average loading percent empty containers, arrival drafts, and box weights) to determine the number of calling vessels. Section 4.1 provides a detailed description of loading assumptions.

Table 3-14 outlines the initial forecast of containerized vessels through the year 2035. 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**.**

Table 3-14. Without-Project Vessel Call Forecast for Port of Tacoma by Year

Vessel Class	2030 FWOP Calls	2035 FWOP Calls
PX	0	0
PPX1	49*	81*
PPX2	155	132
PPX3	229	189
PPX4	116	189
Total Vessel Calls	549	591

*Numbers presented represent the average number of calls populated through 5 iterations. Totals vary by iteration.

3.4 Alternatives Analysis

Initial screening of alternatives considered several action alternatives, which included improvements on both the Sitcum and Blair Waterway. Preliminary screening resulted in the removal of the Sitcum Waterway from consideration, leaving Blair Waterway channel deepening. Initial plan formulation considered incremental analysis of three channel segments within the Blair Waterway:

- Entrance to Husky (STA -5+00.00 to STA 41+85.18)
- Husky to WUT (STA 41+85.18 to STA 108+40.43)
- WUT to PCT (STA 108+40.43 to 137+24.11)

Segmenting offers the opportunity for cost savings by reducing the size and depth of the proposed project. However, feasibility-level ship simulation and pilot consultation emphasized the need for larger vessels berthing at WUT to use the Blair Waterway turning basin to maneuver safely under adverse weather conditions or low visibility. This required the PDT to eliminate any plan which does not provide a consistent design between WUT and PCT (e.g., different channel depths or widths between WUT and the Blair Turning Basin).

Additionally, engineering analysis at the Blair Waterway Turning Basin revealed an insignificant difference in the dredge quantities required to fit the turning basin to a PPX4 versus PPX3 design vessel. Expanding the footprint of the turning basin would likely require less than 10,000 cubic yards of dredged material. The cost difference between dredging the turning basin to -56 feet MLLW, the maximum draft required by PPX3 vessels, and -57 feet MLLW is less than $6 million, or 2.4 percent of the total project cost.

Designing the Blair Turning Basin based on a smaller design vessel (e.g., design vessel PPX3) would also require additional safety considerations for PPX4 vessels, which would not have access to an appropriately sized turning basin in the event of inclement weather or low visibility.

Preliminary screening resulted in the following alternatives for consideration:

Alternative 1 - No-Action Alternative. The No-Action Alternative is analyzed as the FWOP conditions for comparison with the action alternatives. Taking no action would mean continuing standard operations at the Port of Tacoma with no improvements to the Federal navigation channel. All physical conditions at the time of this analysis are assumed to remain with the exception of the planned terminal and facility upgrades. It is assumed current maintenance operations would be executed within the Federal navigation channel; this consists of periodic bathymetric surveys to evaluate any sediment accumulation above authorized depths (-51 MLLW) and intermittent maintenance dredging of the berths.

Alternative 2 - Blair Waterway Deepening. Within the range of depths analyzed for improving navigation, the Corps and Port determined the deepest channel depth alternative as -58 MLLW. Alternative 2 would be executed as follows:

- Deepen the entire Blair Waterway (STA -5+00.00 through STA 137+24.11) from an authorized depth of -51 MLLW to -58 MLLW plus two feet of overdepth
- Maintain the channel width from the mouth of the Blair Waterway to 11th Street at 520 feet
- Maintain the channel width from 11th Street to Lincoln Avenue at 520 feet
- Widen the channel at the 11th Street reach from 345 feet to 520 feet
- Widen the channel from Lincoln Avenue to the turning basin from 330 feet to 520 feet
- Deepen the turning basin from an authorized depth of -51 MLLW to -58 MLLW plus two feet of overdepth, and widen the turning basin from 1,300 feet to 1,600 feet

***Alternative 2a - Blair Waterway Deepening through Husky Terminal*.** Alternative 2a applies the same depths and widths as Alternative 2 to allow access for larger ships to Husky Terminal only (STA -5+00.00 to STA 41+85.18). The channel from the entrance to just past Husky Terminal would be deepened from the authorized depth of -51 MLLW to -58 MLLW with associated channel widening for design vessel navigation, ranging from 520 feet to 864 feet. Side slopes would be at a 2:1 ratio along the proposed channel.

***Alternative 2b - Blair Waterway Deepening to -57 MLLW*.** Alternative 2b is a depth increment of Alternative 2. This alternative consists of the NED channel depth as determined by the economic analysis. Associated channel widening and other improvements are consistent with Alternative 2.

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 Tacoma's Blair waterway. 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 Corps guidelines on transportation cost savings analysis[16].

4.1 Methodology

Channel improvement modifications result in reduced transportation costs by allowing a more efficient future fleet mix and less congestion when transiting the port. The HMST was designed to allow users to model these benefits. As the Blair Waterway is deepened, the reliability of the channel depth increases. The increased reliability is expected to encourage shippers to load larger vessels more efficiently, given the reduced constraint on the vessel's carrying capacity.

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 set up with the basic required variables. To estimate origin-to-destination (OD) cost saving benefits, the CLT, a module within the HMST, was used to generate a vessel call list based on the commodity forecast at the Port of Tacoma for a given year, Tacoma'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 51-foot limiting depth for each additional project depth, as described in Section 4.3. The Tentatively Selected Plan (TSP) 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.

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

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 in 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 schedule conflicts with other vessels 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.

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 the vessel can proceed to 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 may be able to move partially along the leg to an anchorage or mooring. If so, and if the vessel can use the anchorage, then HarborSym will direct the vessel to proceed along the leg to the anchorage and wait until it can proceed 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. 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.

When a vessel leaves the system, the model records the total tonnage, export tonnage, and import tonnage transferred by the call, as well as total transportation costs associated with the vessel's time in the port. The cost per ton can be calculated at the call level (divide the total cost by total tonnage).

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 at the vessel class and call level. The model can thus deliver a high level of detail on individual vessel, class, and commodity volumes and transportation 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 estimated 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:

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

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:

$$At\ Sea\ Cost\ Allocation\ Fraction = 0.5 * (Import\ tons/Tonnage\ on\ board\ at\ arrival) + 0.5 * (Export\ tons/Tonnage\ on\ board\ at\ departure)$$

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 Tacoma 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 Tacoma Harbor study.

The base year for the model was 2030. A model run was performed for 2030 and 2035. The analysis assumes the Blair Waterway reaches capacity prior to 2035, and the MSI fleet forecast does not extend past 2035; therefore, the analysis holds benefits constant after 2035.

Each model run consisted of 50 iterations. The number of iterations was determined to be sufficient when comparing the average time of the fleet in the system. Figure 4-1 shows minimal variation in the moving average vessel time in the system for the OD model runs by the 50th iteration. For the base condition OD model run in 2030, the average total vessel time in the system after 50 iterations was 23,239 hours, with a standard deviation of 50 hours.

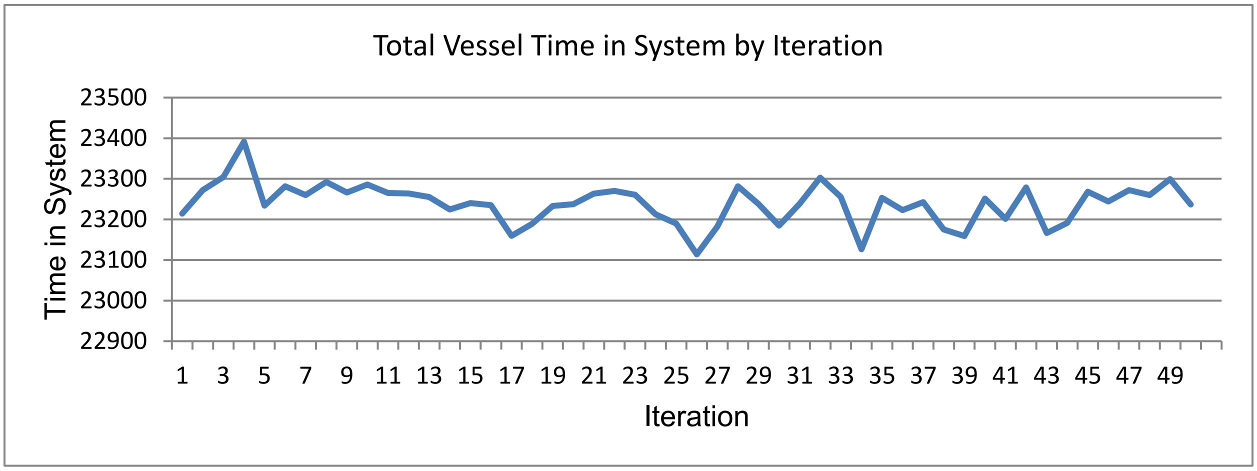


Figure 4-1. HarborSym Iterations - Hours

Physical and Descriptive Harbor Characteristics. These data inputs include the specific network of Tacoma 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. Error! Reference source not found.

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 ten trade routes calling on Tacoma Harbor in 2018.

Numerous container services call Tacoma Harbor (Table 2-9). All services have destinations in Asia and WCUS. Section 2.5 describes the carriers and trade lanes included in this analysis. Given constantly changing alliances on trans-Pacific trade routes, all services originating in Asia which access the WCUS 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 the minimum, most likely, and maximum sailing distances in nautical miles to prior port, next port, and total remaining sailing distance. The analysis used the average distance of each route to develop an aggregated "Asia" route.

Table 4-1. HarborSym Route Groups

Route Group	Minimum Total Distance (nautical miles)	Most Likely Total Distance (nautical miles)	Maximum Total Distance (nautical miles)
Asia	11,930	13,832	16,439

Table 4-2. HarborSym Commodity Transfer Rates for Containers

Dock Name	Min	Most Likely	Max
Blair Containers (Husky, WUT, PCT)	710	717	925

The analysis also considered prior and next port depths, summarized in Table 4-4 for the current services calling the Port of Tacoma. As shippers deploy larger containerships on transpacific services, rotations will continue to evolve to meet international demand, which will consider evolving shipping alliances and port limitations. Analysis of Asian container services showed few loading constraints for previous and next ports, with ports on current services having depths already in excess of the maximum evaluated depth for the study (-58'MLLW).

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

Service	Previous Ports	Depth (ft)	Next Ports	Depth (ft)
PNW3	Ningbo	56	Vancouver	52
PSW8	Oakland	50	Kaohsiung	49
PN1	Tokyo	49	Vancouver BC	52
PN2	Yantian	52	Vancouver BC	52
PS8	Los Angeles	55	Busan	59
PN2	Busan	59	Vancouver BC	52
PS1	Long Beach	55	Busan	59
WSL	Everett	40	Vancouver BC	52
WSL-1	Vancouver	52	Hitachinaka	49
WSL-2	Prince Rupert	61	Tomakomai	35

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 (VOC) spreadsheets and Economic Guidance Memorandum (EGM) 15-04 (dated 28 September 2015), Deep-Draft Vessel Operating Costs FY 2016. Economical or slow-steam speeds at sea and associated costs were included in the evaluation. VOCs 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. VOCs are not shown 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 Exemption 4 of the Freedom of Information Act, 5 U.S.C. § 552 .

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

Reach	PX		PPX1/PPX2		PPX3/PPX4	
	Light	Loaded	Light	Loaded	Light	Loaded
Entrance to Anchorage	3	3	3	3	3	3
Entrance/Anchorage to Blair Waterway	3	3	3	3	3	3
Turning Basin	3	3	3	3	3	3

Table 4-5. Containerized Vessel Operations

Speed (knots)	PX	PPX1	PPX2	PPX3	PPX4
Vessel Speed at Sea, Min	19.0	21.0	20.6	20.0	16.1
Vessel Speed at Sea, Most Likely	20.0	21.5	20.9	20.7	18.4
Vessel Speed at Sea, Max	20.5	21.6	21.1	21.0	20.7

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

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, net registered tons, gross registered tons, deadweight tons, capacity, LOA, beam, draft, flag, tons per inch immersion (TPI) factor, ETTC, and the route group for which it belongs.

4.1.2 Containerized Vessel Call List

The study team used the CLT to allocate forecasted commodity volume onto vessels. 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, the model generates a fleet of vessels able to call the port. This fleet includes the maximum possible vessel calls based on the user provided availability information. Second, the commodity forecast 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 Tacoma 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, a tentative arrival draft is determined for each generated vessel based on user-provided cumulative distribution functions (CDFs). A random draw is made from the CDF, and the arrival draft is initially set to this 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 + UKC + 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.

Next, the CLT conducts a Loading Factor Analysis (LFA) given the physical characteristics of each generated vessel. LFA explores the relationships between a ship's 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.

$$Vessel\ operating\ cost\ per\ 1000\ miles\ is\ calculated\ as\ 1000\ miles\ divided\ by\ the\ applied\ speed$$

$$times\ the\ hourly\ at\ sea\ cost$$

$$= (\ 1000\ miles\ /\ Applied\ Speed)\ X\ Hourly\ Cost$$

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 containers

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

Shares of vessel capacity are then calculated as:

$$\begin{aligned} Cargo\ Share\ =\ &Average\ Lading\ Weight\ per\ Loaded\ TEU\ by\ Route\ (tonnes) \\ &/Total\ weight\ per\ loaded\ container\ in\ tonnes \end{aligned}$$

$$\begin{aligned} &Laden\ Container\ Share \\ &\quad = Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes) \\ &\quad /Total\ weight\ per\ loaded\ container\ in\ tonnes \end{aligned}$$

$$\begin{aligned} &Empty\ Container\ Share \\ &\quad = ((Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)) \\ &\quad * (Percent\ Empty\ TEUs\ ))\ /\ Total\ weight\ per\ loaded\ container\ in\ tonnes) \end{aligned}$$

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 set between the vessel's maximum (loaded) to minimum (empty) sailing draft. At each sailing draft, the total tonnage carried is calculated using the 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).

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 Sailing Draft Distribution

There are a number of data required by the CLT in addition to the commodity forecast (Section 3.2) and the vessel fleet (Section 3.3). Vessel sailing draft distributions are critical for determining the benefits of channel deepening. In the CLT, vessel drafts are used to determine how much cargo a vessel carries and, thus, how many trips are required to satisfy a commodity forecast. The model allows deeper sailing drafts with channel deepening, leading to higher cargo volumes per transit, less required vessel calls, and a reduction in total transportation costs. Vessels with a maximum sailing draft of less than 49 feet (SPX, PX, PPX1, and PPX2) have at least 90 percent channel reliability at maximum sailing draft under the FWOP condition (Table 2-13); therefore, the analysis kept these vessel classes' sailing drafts constant under all channel depth scenarios. Figure 4-2, Figure 4-3, and Figure 4-4 provide the normalized arrival draft CDFs for PX, PPX1, and PPX2 vessels, respectively. The CDFs were developed by evaluating the arrival drafts of the container class vessels calling on the harbor from 2012 to 2016[17].

[17] Represents the most recent available data at time of analysis. Subsequent year data was made available after primary analysis was complete. This data validates assumptions used in the analysis.

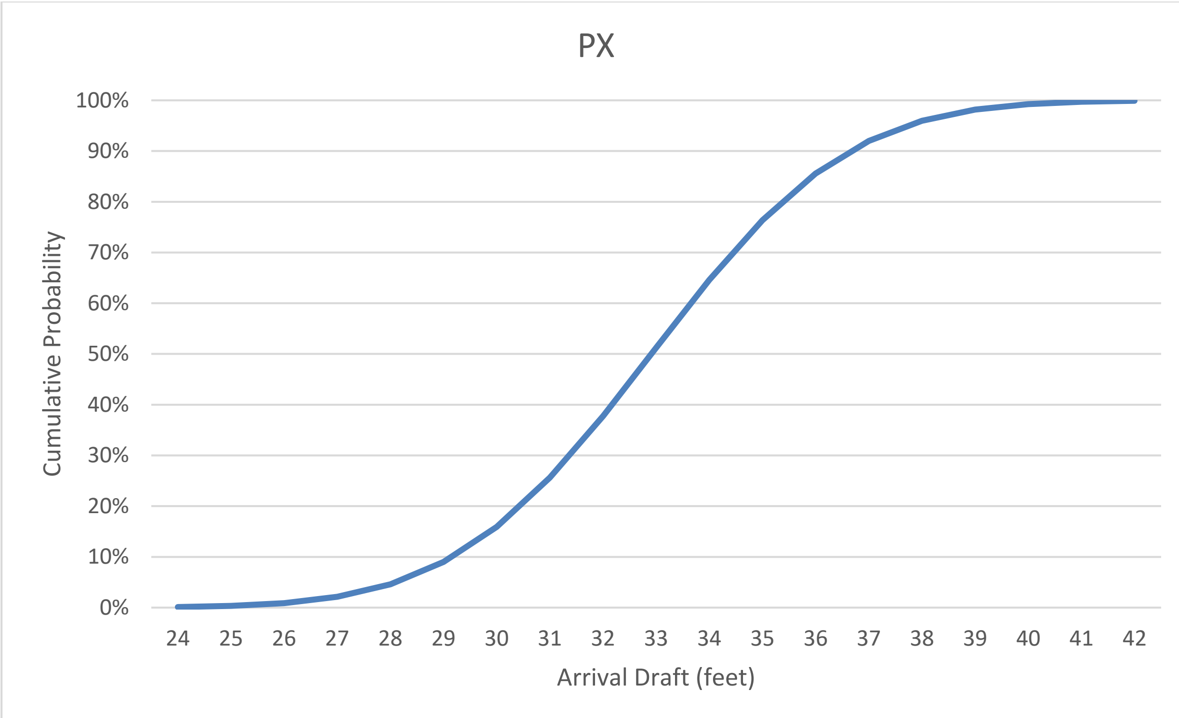


Figure 4-2: PX Normalized CDF

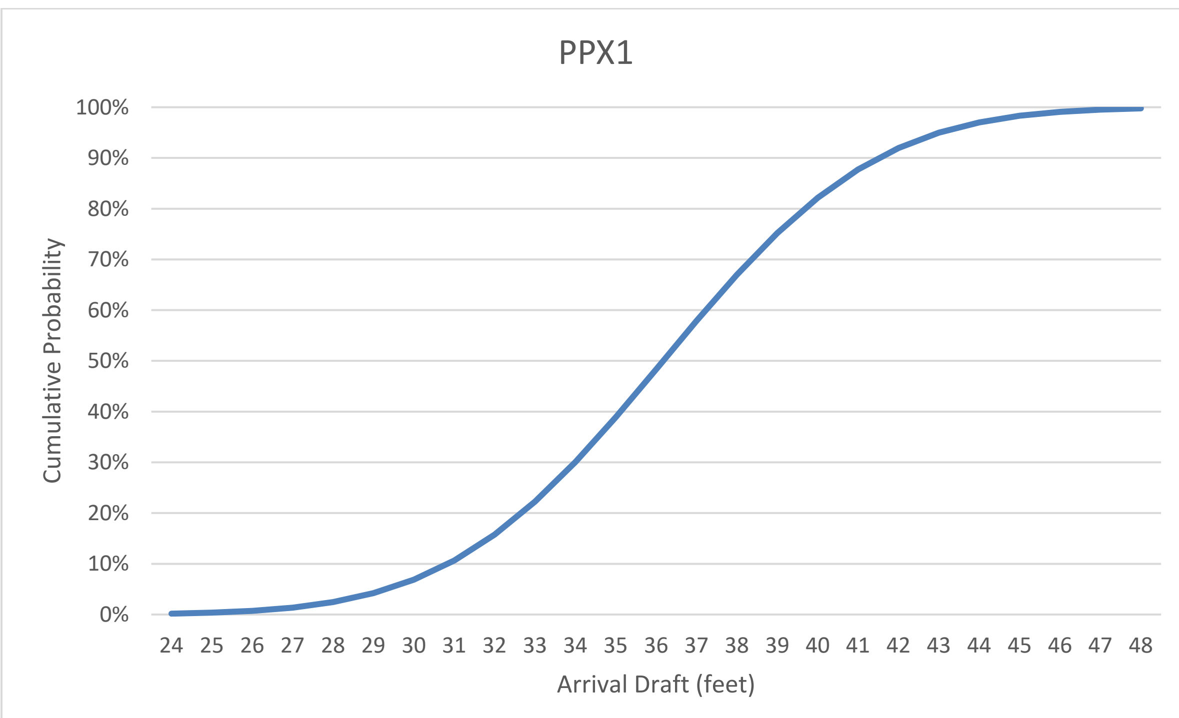


Figure 4-3: PPX1 Normalized CDF

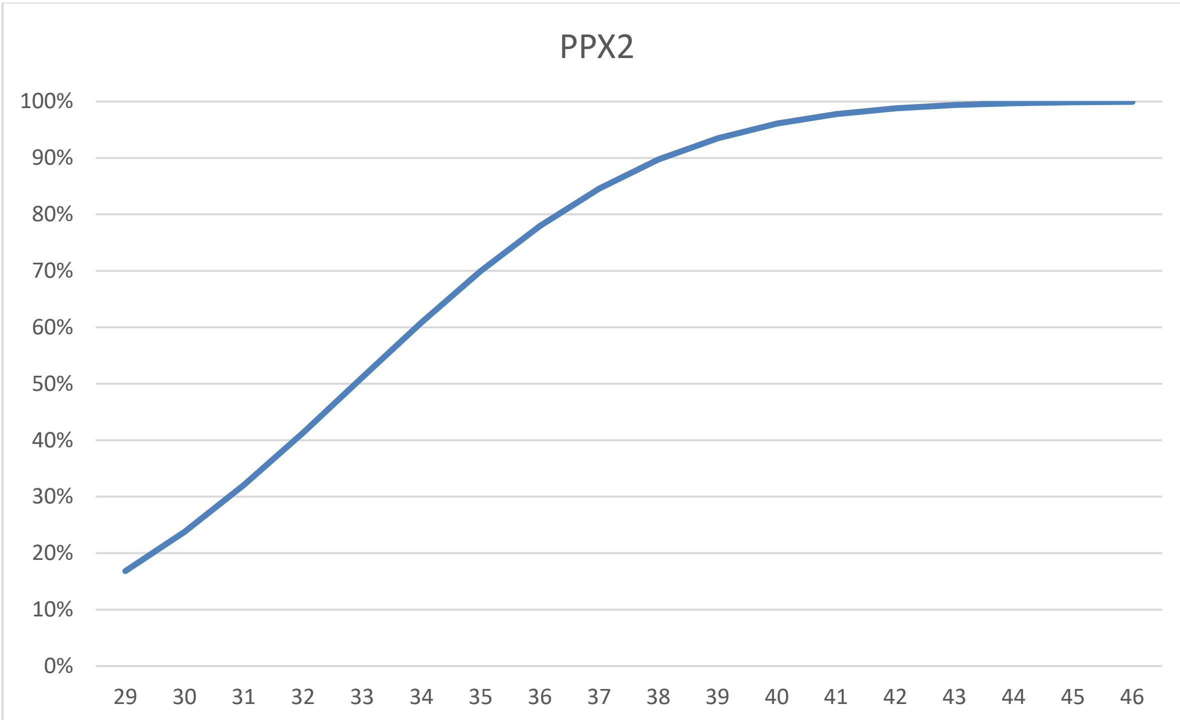


Figure 4-4: PPX2 Normalized CDF

The with-project (-52' MLLW through -58' MLLW) sailing draft CDFs for PPX3 and PPX4 vessels were developed with the assistance of the IWR. The analysis assumes for each additional foot of channel depth, and the average container vessel will load to an additional 0.6 to 0.8 feet deeper (0.7 feet on average). PPX3 class vessels and larger only began arriving on a regular service at Tacoma Harbor recently. As a result, there are insufficient draft observations for a CDF; therefore, the analysis uses all WCUS PPX3 and PPX4 arrival draft observations from 2013 through 2017[18]. These are applicable to Tacoma Harbor, given the overlap in shipping companies and services operating along the West Coast. In fact, most routes calling Tacoma include stops at other WCUS ports.

Shipping companies use consistently available channel depths to make vessel loading decisions; consequently, shippers would likely avoid loading vessels to any draft beyond 49 feet at Tacoma Harbor at the current channel depth, which would allow 84 percent reliability in an aggregate tidal cycle for a 49-foot sailing draft (Table 2-13). With each additional foot of channel depth, the analysis assumes PPX3, and PPX4 vessels will load 0.7 feet deeper on average. Additional channel depth allows shippers to consistently load vessels deeper. An unrestricted PPX4 vessel may load as deep as 52.5 feet, requiring up to 58 feet of water depth for safe transit. In an aggregate tidal cycle, 57 feet of depth would be available for less than 8 hours or 66 percent (Table 2-13). With 58-feet of channel depth, shippers could expect approximately 96 percent channel reliability for a fully-loaded PPX4 vessel with a sailing draft of 52.5 feet. Figure 4-5 and Figure 4-6 provide the CDFs for PPX3 and PPX4 vessels by channel depth, respectively.

18 Detailed arrival draft curve data was only available through 2017 at the time of analysis. Subsequent years draft data have verified assumptions used for this study.

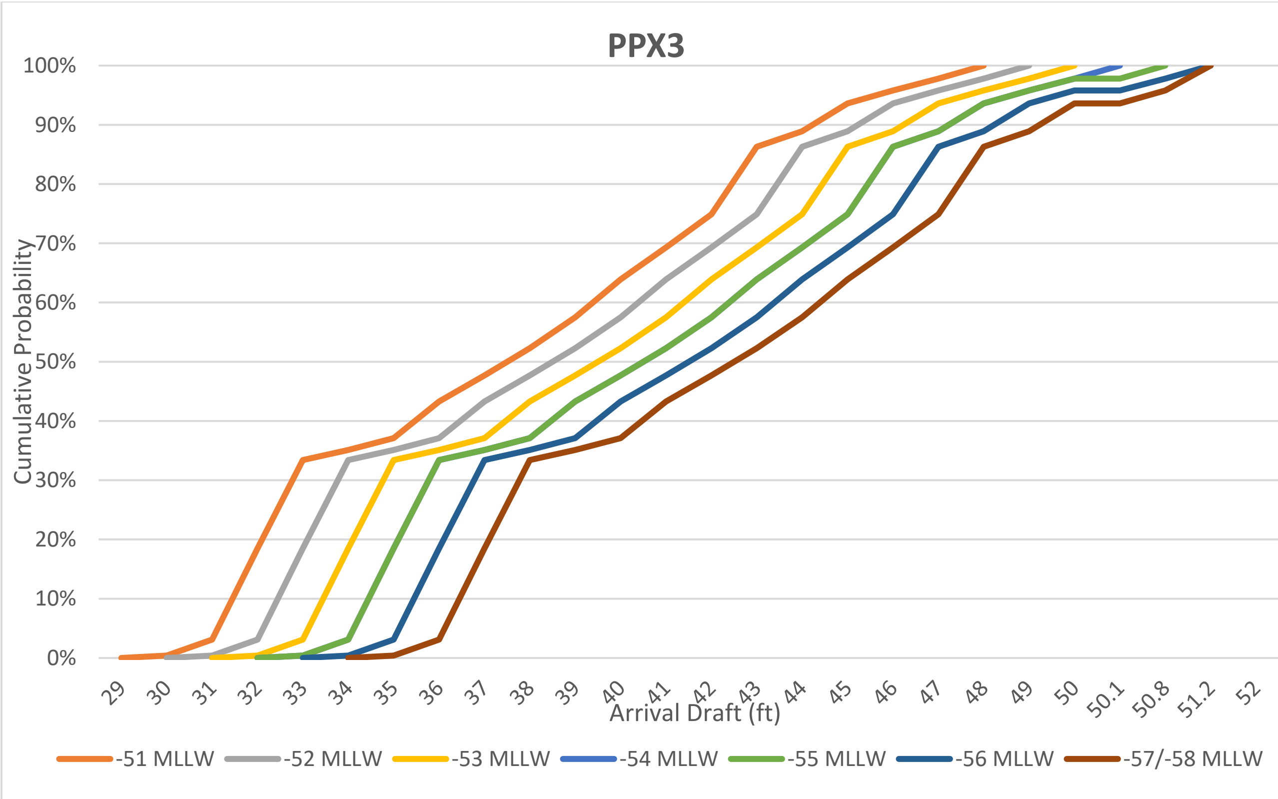


Figure 4-5. PPX3 Arrival Draft by Channel Depth

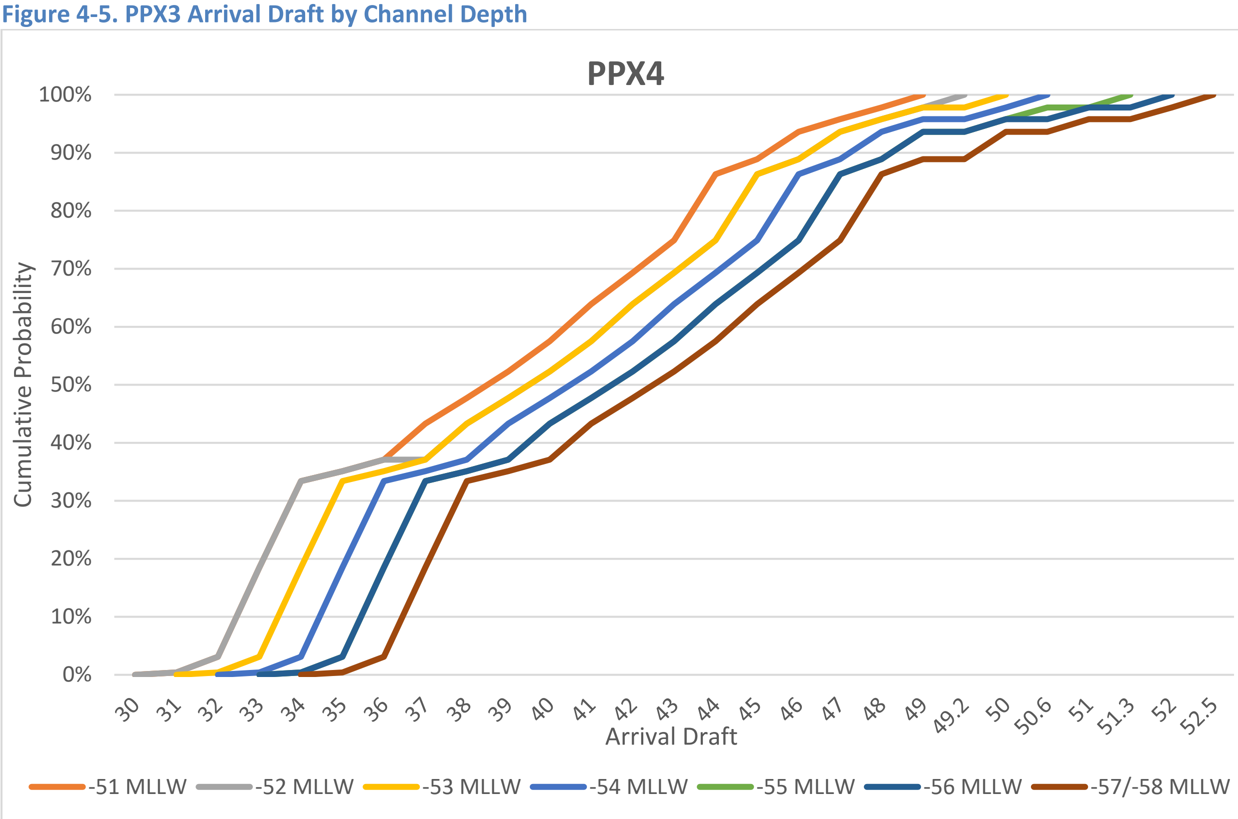


Figure 4-6. PPX4 Arrival Draft by Channel Depth

4.1.2.3 Load Factor Analysis

Table 4-6 provides the vessel class assumptions used in the load factor analysis (LFA)[19], such as average lading weight per TEU (see Section 2.2.2), 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). The analysis uses the historical cargo share estimate of 38 percent based on NNOMPEAS Post-Panamax cargo data at Tacoma Harbor from 2013 through 2017[20]. The study assumes this cargo share will remain constant through the study period given Tacoma Harbor's strategic location and role as a "last out" port of call, where carriers maximize their export loads to realize cost efficiencies as vessels make the long transit across the Pacific. Cargo share is a key input into the at-sea cost allocation detailed in Section 4.1.1.1.

Table 4-6. Vessel Class Inputs

Class	Lading Wt. per TEU	Container Wt. per TEU	Empty TEU Allotment	Vacant Slot Allotment	Allowance for Ops. (% of DWT)	Variable Ballast (% of DWT)	Import/ Export Cargo Share
SPX	11.72	2	17.3%	6.15%	7.1%	14.9%	38%
PX	11.72	2	17.3%	6.15%	7.1%	14.9%	38%
PPX1	11.72	2	17.3%	6.15%	7.1%	14.9%	38%
PPX2	11.72	2	17.3%	6.15%	7.1%	14.9%	38%
PPX3	11.72	2	17.3%	6.15%	7.1%	14.9%	38%
PPX4	11.72	2	17.3%	6.15%	7.1%	14.9%	38%

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

Class	LOA	Beam	Max SLLD	Capacity (DWT)	Applied Draft	TEU Rating	TPI	UKC	Sinkage	% Class
SPX CL 7	571	87	31.3	20,643	31.00 to 31.99	1,447	87.1	2.7	0.2	2
SPX CL 10	576	92	34.6	24,812	34.00 to 34.99	1,778	96.3	2.7	0.2	14
SPX CL 11	603	92	35.6	25,370	35.00 to 35.99	1,895	97.1	2.7	0.2	4
SPX CL 13	676	99	37.6	33,887	37.00 to 37.99	2,470	117.7	2.7	0.2	80
PX CL 4	846	106	41.2	50,070	41.00 to 41.99	3,841	162.7	2.8	0.2	28.3
PX CL 5	907	106	42.5	56,792	42.00 to 42.99	4,125	176.7	2.8	0.2	28.4
PX CL 6	887	104	43.4	54,885	43.00 to 43.99	3,993	170.4	2.8	0.2	43.3
PPX1 CL 2.00	928	131	41.4	75,623	41.00 to 41.99	5,534	214.7	3	0.3	14
PPX1 CL 4.00	900	130	44.4	78,284	44.00 to 44.99	4,912	208	3	0.3	4
PPX1 CL 5.00	935	131	46	78,618	46.00 to 46.99	5,793	215.1	3	0.3	21
PPX1 CL 5.40	965	132	46.1	80,504	46.00 to 46.99	6,295	225.4	3	0.3	19

[19] 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.

[20] Detailed vessel loading data was only available through 2017 at the time of analysis. Subsequent years data released after preliminary evaluation validates assumptions used in this study.

Class	LOA	Beam	Max SLLD	Capacity (DWT)	Applied Draft	TEU Rating	TPI	UKC	Sinkage	% Class
PPX1 CL 5.30	981	132	46.1	110,448	46.00 to 46.99	6,441	230.7	3	0.3	2
PPX1 CL 5.25	984	132	46.1	75,898	46.00 to 46.99	6,505	230.9	3	0.3	33
PPX1 CL 5.15	992	132	46.2	102,179	46.00 to 46.99	6,600	233.7	3	0.3	7
PPX2 CL 7.00	1,106	143	42.7	104,549	42.00 to 42.99	9,148	290.3	3	0.3	3.4
PPX2 CL 9.00	1,018	143	46.1	103,865	46.00 to 46.99	7,200	260.3	3.1	0.3	19.3
PPX2 CL 10.00	1,090	142	47.6	104,657	47.00 to 47.99	8,212	284.9	3	0.3	39.8
PPX2 CL 10.67	1,099	143	47.6	105,458	47.00 to 47.99	8,528	289.2	3	0.3	3.4
PPX2 CL 10.30	1,114	144	47.7	92,875	47.00 to 47.99	8,916	293.5	3	0.3	18.2
PPX2 CL 10.15	1,127	145	47.7	96,687	47.00 to 47.99	9,294	300.3	3	0.3	15.9
PPX3-1	984	158	48.6	112,729	48.00 to 48.99	9,365	394	4.1	0.3	20
PPX3-2	1,106	158	50.9	119,510	50.00 to 50.99	10,100	394	4.1	0.3	30
PPX3-3	1,202	158	51.2	148,542	51.00 to 51.99	13,102	394	4.1	0.3	50
PPX4-1	1,305	185	52.5	158,200	52.00 to 52.99	15,550	453	4.5	0.3	5
PPX4-2	1,299	176	52.5	186,470	52.00 to 52.99	16,022	453	4.5	0.3	12
PPX4-3	1,310	194	52.5	195,118	52.00 to 52.99	18,340	453	4.5	0.3	45
PPX4-4	1,312	193	52.5	218,000	52.00 to 52.99	20,150	453	4.5	0.3	38

Table 4-8 shows the maximum sailing draft for each vessel class at which vessel cargo capacity is maximized given LFA vessel class inputs and vessel subclass inputs presented in Table 4-6 and Table 4-7.

Table 4-8. Maximum Depth by Vessel Class

Vessel Class	Depth at Which Vessel Cargo Capacity is Maximized (Max Sailing Draft)
SPX	37.6
PX	43.4
PPX1	46.1
PPX2	47.7
PPX3	48.6 - 51.2
PPX4	52.5

4.1.2.4 Containerized Vessel Calls

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

Table 4-9. Average Vessel Calls by Vessel Class and Channel Depth/Alternative (5 iterations)

	FWOP	Alt 2: -52' MLLW	Alt 2: -53' MLLW	Alt 2: -54' MLLW	Alt 2: -55' MLLW	Alt 2: -56' MLLW	Alt 2: -57' MLLW	Alt 2: -58' MLLW
2030								
SPX	0	0	0	0	0	0	0	0
PX	0	0	0	0	0	0	0	0
PPX1	49	25	4	0	0	0	0	0
PPX2	155	155	153	132	107	80	54	54
PPX3	229	229	229	229	229	229	229	229
PPX4	116	116	116	116	116	116	116	116
Total	549	525	502	477	452	425	399	399
2035								
SPX	0	0	0	0	0	0	0	0

	FWOP	Alt 2: -52' MLLW	Alt 2: -53' MLLW	Alt 2: -54' MLLW	Alt 2: -55' MLLW	Alt 2: -56' MLLW	Alt 2: -57' MLLW	Alt 2: -58' MLLW
PX	0	0	0	0	0	0	0	0
PPX1	81	55	29	5	0	0	0	0
PPX2	132	132	132	132	107	79	50	50
PPX3	189	189	189	189	189	189	189	189
PPX4	189	189	189	189	189	189	189	189
Total	591	565	539	513	485	457	425	425

4.1.2.5 Tacoma Share of World Fleet

The previous table provided the number of vessel calls by vessel class for the Port of Tacoma for 2030 and 2035. The following tables show the estimated number of vessels out of the world fleet required to meet the Tacoma fleet forecast. The analysis assumes an average service consists of 6 vessels with at least one vessel calling weekly based on vessel counts for 2017 services. The equivalent vessel numbers are a result of dividing the number of vessel calls in the previous tables by 52 weeks and multiplying by 6 vessels per service. The percent of world fleet values is derived by 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 4-10, the historical share of the world fleet calling Tacoma at Blair Waterway remained between 0.5 percent and 1 percent of the total world fleet. As of 2017, Tacoma Harbor vessel calls at Blair Waterway composed 0.8 percent of the world fleet of vessels with the greatest share of PPX2 vessels (3.9 percent of the world fleet).

Table 4-10. Tacoma Share of World Fleet by Vessel Class, 2008-2017

Tacoma % World Fleet	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
SPX	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.2%	0.3%	0.3%	0.1%
PX	0.6%	0.9%	0.3%	0.0%	0.3%	0.5%	0.8%	0.7%	0.6%	0.3%
PPX1	7.6%	3.9%	3.6%	4.0%	3.3%	2.9%	1.9%	2.0%	1.5%	3.5%
PPX2	0.5%	1.4%	1.5%	1.7%	4.2%	6.4%	7.6%	7.9%	7.7%	3.9%
PPX3	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%	0.4%	1.0%	0.0%
PPX4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	**0.9%**	**0.7%**	**0.5%**	**0.5%**	**0.7%**	**0.9%**	**1.0%**	**1.0%**	**1.0%**	**0.8%**

Table 4-11 presents the estimated future percent of the world fleet calling Tacoma in the Blair Waterway. The analysis assumes Tacoma's share of the world fleet at Blair Waterway remains at or under 1 percent. This assumption relies on a fleet transition to PPX3 and PPX4 vessels with maximum world fleet share of up to 2.9 percent of PPX3 vessels in 2030 and 1.9 percent of PPX4 vessels in 2035. Consideration of this projection is discussed further as a consideration for sensitivity analysis in Section 5. The analysis confirms the projected vessel calls for the Port of Tacoma 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 4-11. Estimate Future Percent of World Fleet Calling Tacoma Once per Week

Alternative and Vessel Class	2030		2035	
	Vessels	% World Fleet	Vessels	% World Fleet
FWOP				
SPX	0	0.0%	0	0.0%
PX	0	0.0%	0	0.0%
PPX 1	49	0.5%	81	0.6%
PPX 2	155	5.3%	132	4.4%
PPX 3	229	3.1%	189	2.1%
PPX 4	116	1.7%	189	2.0%
Total	549	1.0%	591	1.0%
-52’ MLLW				
SPX	0	0.0%	0	0.0%
PX	0	0.0%	0	0.0%
PPX 1	25	0.2%	55	0.4%
PPX 2	155	5.3%	132	4.4%
PPX 3	229	3.1%	189	2.1%
PPX 4	116	1.7%	189	2.0%
Total	525	0.9%	565	0.9%
-53’ MLLW				
SPX	0	0.0%	0	0.0%
PX	0	0.0%	0	0.0%
PPX 1	4	0.0%	29	0.2%
PPX 2	153	5.2%	132	4.4%
PPX 3	229	3.1%	189	2.1%
PPX 4	116	1.7%	189	2.0%
Total	502	0.9%	539	0.9%
-54’ MLLW				
SPX	0	0.0%	0	0.0%
PX	0	0.0%	0	0.0%
PPX 1	0	0.0%	5	0.0%
PPX 2	132	4.5%	130	4.3%
PPX 3	229	3.1%	189	2.1%
PPX 4	116	1.7%	189	2.0%
Total	477	0.9%	513	0.8%
-55’ MLLW				
SPX	0	0.0%	0	0.0%
PX	0	0.0%	0	0.0%
PPX 1	0	0.0%	0	0.0%
PPX 2	107	3.6%	107	3.6%
PPX 3	229	3.1%	189	2.1%
PPX 4	116	1.7%	189	2.0%

Alternative and Vessel Class	2030		2035	
	Vessels	% World Fleet	Vessels	% World Fleet
Total	452	0.8%	485	0.8%
-56’ MLLW				
SPX	0	0.0%	0	0.0%
PX	0	0.0%	0	0.0%
PPX 1	0	0.0%	0	0.0%
PPX 2	80	2.7%	79	2.6%
PPX 3	229	3.1%	189	2.1%
PPX 4	116	1.7%	189	2.0%
Total	425	0.8%	457	0.7%
-57’/-58’ MLLW				
SPX	0	0.0%	0	0.0%
PX	0	0.0%	0	0.0%
PPX 1	0	0.0%	0	0.0%
PPX 2	54	1.8%	50	1.7%
PPX 3	229	3.1%	189	2.1%
PPX 4	116	1.7%	189	2.0%
Total	399	0.7%	428	0.7%

4.2 Origin-Destination Transportation Cost Savings Benefits by Project Depth

Transportation cost benefits were estimated using the HarborSym Economic Reporter, a tool developed by IWR to summarize HarborSym results from multiple simulations and present benefit-cost analysis summaries. 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) value.

Transportation costs were estimated for a 50-year period of analysis for the years 2030 through 2079. Transportation costs were estimated using HarborSym for the years 2030 and 2035. The transportation costs were held constant beyond 2035. 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 to Base Year 2030 at the current FY 2020 Federal Discount rate of 2.75 percent using the transportation cost and savings information shown in Table 4-12 and Table 4-13. Estimates were determined for each alternative project depth.

Table 4-12 provides the annual transportation costs in total and for the at-sea and in-port portions for the Blair Waterway (Alternative 2). The table consists 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 Tacoma. The second subtable shows the in-port proportion of total transport costs, 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 92 to 93 percent of total costs. The transportation cost saving benefit is provided in Table 4-13 and with the same three subtables. The HarborSym model interpolates values between 2025 and 2030 to provide an annual benefit estimate.

Table 4-12. Origin-Destination Annual Transportation Cost ($1,000s)

Annual O-D At-Sea and In-Port Transportation Cost Allocated to Port ($1,000s)[1]							
Year	No Action	Alt 2 -52 MLLW	Alt 2 -53 MLLW	Alt 2 -54 MLLW	Alt 2 -55 MLLW	Alt 2 -56 MLLW	Alt 2 -57 and -58 MLLW
2030	**$597,576**	**$572,724**	**$550,537**	**$528,536**	**$507,330**	**$486,594**	**$467,775**
2031	$611,069	$586,148	$563,662	$541,686	$520,157	$499,243	$479,840
2032	$624,561	$599,572	$576,787	$554,837	$532,984	$511,891	$491,905
2033	$638,054	$612,997	$589,911	$567,987	$545,810	$524,539	$503,969
2034	$651,546	$626,421	$603,036	$581,137	$558,637	$537,188	$516,034
2035-2074	**$665,039**	**$639,845**	**$616,160**	**$594,288**	**$571,464**	**$549,836**	**$528,099**
Annual O-D In-Port Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	Alt 2 -52 MLLW	Alt 2 -53 MLLW	Alt 2 -54 MLLW	Alt 2 -55 MLLW	Alt 2 -56 MLLW	Alt 2 -57 and -58 MLLW
2030	**$29,535**	**$29,804**	**$29,983**	**$30,056**	**$30,131**	**$30,177**	**$30,246**
2031	$30,641	$30,902	$31,081	$31,178	$31,263	$31,321	$31,394
2032	$31,747	$32,001	$32,179	$32,301	$32,394	$32,465	$32,542
2033	$32,853	$33,099	$33,278	$33,423	$33,526	$33,610	$33,690
2034	$33,959	$34,198	$34,376	$34,545	$34,658	$34,754	$34,837
2035-2074	**$35,065**	**$35,296**	**$35,474**	**$35,667**	**$35,790**	**$35,899**	**$35,985**
Annual O-D At-Sea Transportation Cost Allocated to Port ($1,000s)							
Year	No Action	Alt 2 -52 MLLW	Alt 2 -53 MLLW	Alt 2 -54 MLLW	Alt 2 -55 MLLW	Alt 2 -56 MLLW	Alt 2 -57 and -58 MLLW
2030	**$568,041**	**$542,920**	**$520,555**	**$498,480**	**$477,199**	**$456,418**	**$437,529**
2031	$580,428	$555,246	$532,581	$510,508	$488,894	$467,922	$448,446
2032	$592,814	$567,572	$544,607	$522,536	$500,589	$479,426	$459,363
2033	$605,201	$579,898	$556,634	$534,564	$512,284	$490,930	$470,280
2034	$617,588	$592,223	$568,660	$546,592	$523,979	$502,433	$481,197
2035-2074	**$629,974**	**$604,549**	**$580,686**	**$558,620**	**$535,674**	**$513,937**	**$492,114**
[1] Costs rounded to the nearest $100,000.							

Table 4-13. Origin-Destination Annual Transportation Cost Savings Benefits by Channel Depth (1,000s)

Annual O-D At-Sea and In-Port Transportation Cost Saving Benefits ($1,000s)[1,2]						
Year	**Alt 2 -52 MLLW**	**Alt 2 -53 MLLW**	**Alt 2 -54 MLLW**	**Alt 2 -55 MLLW**	**Alt 2 -56 MLLW**	**Alt 2 -57 and -58 MLLW**
2030	**$24,852**	**$47,039**	**$69,040**	**$90,246**	**$110,982**	**$129,801**
2031	$24,920	$47,407	$69,382	$90,912	$111,826	$131,229
2032	$24,989	$47,775	$69,724	$91,578	$112,670	$132,657
2033	$25,057	$48,143	$70,067	$92,243	$113,514	$134,084
2034	$25,125	$48,511	$70,409	$92,909	$114,359	$135,512
2035-2074	**$25,194**	**$48,879**	**$70,751**	**$93,575**	**$115,203**	**$136,940**
Annual O-D In-Port Transportation Cost Saving Benefits ($1,000s)						
Year	**Alt 2 -52 MLLW**	**Alt 2 -53 MLLW**	**Alt 2 -54 MLLW**	**Alt 2 -55 MLLW**	**Alt 2 -56 MLLW**	**Alt 2 -57 and -58 MLLW**
2030	**-$269**	**-$447**	**-$521**	**-$596**	**-$642**	**-$711**
2031	-$261	-$440	-$537	-$621	-$680	-$753
2032	-$254	-$432	-$554	-$647	-$718	-$795
2033	-$246	-$425	-$570	-$673	-$757	-$837
2034	-$239	-$417	-$586	-$699	-$795	-$879
2035-2074	**-$231**	**-$410**	**-$603**	**-$725**	**-$834**	**-$921**
Annual O-D At-Sea Transportation Cost Saving Benefits ($1,000s)						
Year	**Alt 2 -52 MLLW**	**Alt 2 -53 MLLW**	**Alt 2 -54 MLLW**	**Alt 2 -55 MLLW**	**Alt 2 -56 MLLW**	**Alt 2 -57 and -58 MLLW**
2030	**$25,121**	**$47,786**	**$69,561**	**$90,842**	**$111,623**	**$130,512**
2031	$25,182	$47,846	$69,920	$91,553	$112,623	$131,982
2032	$25,243	$48,207	$70,278	$92,225	$113,389	$133,451
2033	$25,303	$48,567	$70,637	$92,917	$114,271	$134,921
2034	$25,364	$48,928	$70,995	$93,609	$115,154	$136,391
2035-2073	**$25,425**	**$49,288**	**$71,354**	**$94,300**	**$116,037**	**$137,861**
[1] Costs rounded to the nearest $100,000. [2]Transportation costs computed using FY16 VOCs from EGM 17-04 in coordination with DDN-PCX.						

Table 4-14 provides estimated AAEQ transportation costs and cost savings benefits.

Table 4-14. Origin-Destination AAEQ Transportation Cost and Cost Savings Benefits by Alternative Depth ($Thousands)

Alternative/Depth	O-D AAEQ Transportation Cost ($1,000s)[1]	O-D AAEQ Transportation Cost Savings ($1,000s)[1]
Alt 1: -51 MLLW (FWOP)	$657,998	----
Alt 2: -53' MLLW	$632,840	$25,158
Alt 2: -53' MLLW	$609,312	$48,687
Alt 2: -54' MLLW	$587,425	$70,573
Alt 2: -55' MLLW	$564,771	$93,227
Alt 2: -56' MLLW	$543,236	$114,762
Alt 2: -57' MLLW and -58' MLLW	$521,803	$136,195
[12]Transportation costs computed using FY16 VOCs from EGM 17-04 in coordination with DDN-PCX.		

Table 4-15 summarizes AAEQ cost statistics, including risk and uncertainty.

Table 4-15. Origin-Destination AAEQ Cost Statistics by Alternative and Depth ($Thousands)

Statistic	No Action	Alt 2: -52 MLLW	Alt 2: -53 MLLW	Alt 2: -54 MLLW	Alt 2: -55 MLLW	Alt 2: -56 MLLW	Alt 2: -57 MLLW and -58 MLLW
Mean	$657,998	$632,840	$609,312	$587,425	$564,771	$543,236	$521,803
Std Dev	$7,471	$6,516	$5,681	$5,602	$6,239	$5,946	$5,935
Median	$659,048	$633,032	$611,648	$588,760	$565,531	$544,199	$521,756
Min	$644,696	$620,965	$598,685	$576,302	$551,144	$528,856	$507,977
Max	$673,088	$645,591	$618,172	$597,258	$573,841	$553,781	$533,068
Range	$28,392	$24,626	$19,487	$20,956	$22,698	$24,925	$25,091
Confidence of Mean +/-	$2,071	$1,806	$1,575	$1,553	$1,729	$1,648	$1,645
Note: Transportation costs computed using FY16 VOCs from EGM 17-04 in coordination with DDN-PCX.							

Table 4-16 provides the OD cost saving benefits by vessel class for each alternative depth.

Table 4-16. Origin-Destination AAEQ Transportation Cost Saving Benefits by Vessel Class ($Thousands)

Alternative Depth	PPX1		PPX2		PPX3		PPX4		Total AAEQ Benefits
	Cost Savings	%	Cost Savings	%	Cost Savings	%	Cost Savings	%	
-52 MLLW	$10,384	41.3	$6,195	24.6	$9,481	37.7	-$903	-3.6	$25,158
-53 MLLW	$15,126	48.3	$6,957	14.3	$22,392	46.0	-$1,540	-3.2	$48,648
-54 MLLW	$22,472	49.0	$8,820	12.7	$34,480	49.7	-$2,244	-3.2	$69,334
-55 MLLW	$31,374	33.7	$19,502	20.9	$45,155	48.4	-$2,803	-3.0	$93,227
-56 MLLW	$31,374	27.3	$32,110	28.0	$54,816	47.8	-$3,538	-3.1	$114,762
-57/-58 MLLW	$31,374	23.0	$44,988	33.0	$63,922	46.9	-$4,090	-3.0	$136,195
Note: Transportation costs computed using FY16 VOCs from EGM 17-04 in coordination with DDN-PCX.									

Finally, an estimate of the cost per ton by alternative and vessel class is provided in Table 4-17**,** showing significant cost savings from increased loading efficiency for PPX3 and PPX4 vessels.

Table 4-17: Cost per Ton Allocated to Tacoma Harbor by Vessel Class and Alternative ($Thousands)

Year	Depth	PPX1	PPX2	PPX3	PPX4
2030	FWOP	$28	$39	$37	$34
	-52' MLLW	$27	$37	$35	$33
	-53' MLLW	$27*	$36	$34	$31
	-54' MLLW	N/A	$36	$32	$30
	-55' MLLW	N/A	$37	$30	$29
	-56' MLLW	N/A	$36	$29	$29
	-57' MLLW and -58' MLLW	N/A	$37	$28	$28
2035	FWOP	$28	$37	$27	$33
	-52' MLLW	$28	$36	$26	$32
	-53' MLLW	$27	$36	$25	$31
	-54' MLLW	$26	$36	$23	$30
	-55' MLLW	N/A	$36	$22	$29
	-56' MLLW	N/A	$37	$22	$28
	-57' MLLW and -58' MLLW	N/A	$37	$21	$27

*Allocated cost per ton can fall for PPX1 and PPX2 vessels as more tonnage is loaded on PPX3 and PPX4 vessels as there is less overall tonnage left to load and, therefore, a lower cost allocation (**Section 4.1.1.1**).

4.3 Alternative 2 Benefit-Cost Analysis

The benefit-cost analysis presented in this section is for each channel depth (-51 feet MLLW through -58 feet MLLW) considered for Alternative 2. Costs have been annualized using the FY20 discount rate (2.75 percent) and the October 2019 price level. Economic costs include project first costs (construction cost), associated local service facility improvements (LSF), interest during construction (IDC), and 50-year operations, maintenance, rehabilitation, repair, and replacement (OMRR&R) dredging expenses. Slope stability costs are required at -55 feet MLLW and below.

Table 4-18 presents alternative costs, including IDC, OMRR&R, and local service facility improvement cost assumptions. Preconstruction, engineering, and design (PED) is assumed to be 29.5 percent of construction costs, and construction management (CM) is assumed to be 15 percent of construction costs. Estimated first costs include the cost to construct the proposed depth, including contingency, PED, and CM costs presented at current price levels (October 2019). IDC is based on an assumed one-year to four-year construction duration, depending on the alternative, calculated to the midpoint of construction. Total economic costs represent implementation costs and include project first costs, IDC, and local service facility costs.

Table 4-18. Alternative Costs ($1,000s, Oct 2019 prices, 2.75% discount rate)

Alt.	Project First Costs	IDC	LSF	Total Economic Cost	Total OMRR&R	AAEQ Cost
-52 MLLW	$135,496	$1,863	$4,148	$141,507	$9,265	$5,373
-53 MLLW	$163,360	$4,523	$4,740	$172,623	$9,265	$6,525
-54 MLLW	$180,886	$5,009	$5,362	$191,256	$9,265	$7,216
-55 MLLW	$202,967	$8,501	$110,805	$322,273	$9,265	$12,069
-56 MLLW	$222,254	$9,309	$111,450	$343,013	$9,265	$12,837
-57 MLLW	$242,274	$10,147	$112,101	$364,523	$9,265	$13,634
-58 MLLW	$264,690	$14,913	$112,753	$392,356	$9,265	$14,665

Table 4-19 presents the transportation cost saving benefit analysis for Alternative 2. The -57 MLLW depth provides the greatest total net benefits (the NED depth). Total AAEQ benefits of $136,195,000 outweigh AAEQ costs of $13,634,000 for a net AAEQ benefit of $122,561,000 and a BCR of 10.0.

Table 4-19. Alternative 2 Benefit-Cost Summary (Oct 2019 prices, 2.75% discount rate)

Project Depth	Total AAEQ Costs	Total AAEQ Benefits[1]	Total Net Benefits	Incremental Net Benefits	BCR
-52 MLLW	$5,373,000	$25,158,000	$19,785,000	$0	4.7
-53 MLLW	$6,525,000	$48,687,000	$42,161,000	$22,376,000	7.5
-54 MLLW	$7,216,000	$70,573,000	$63,357,000	$21,196,000	9.8
-55 MLLW	$12,069,000	$93,227,000	$81,159,000	$17,802,000	7.7
-56 MLLW	$12,837,000	$114,762,000	$101,926,000	$20,767,000	8.9
-57 MLLW	**$13,634,000**	**$136,195,000**	**$122,561,000**	**$20,635,000**	**10.0**
-58 MLLW	$14,665,000	$136,195,000	$121,530,000	($1,031,000)	9.3
[1]Transportation costs computed using FY16 VOCs from EGM 17-04 in coordination with DDN-PCX.					

4.3.1 Alternative 2a Benefit-Cost Analysis

The study also developed a benefit-cost summary for Alternative 2a: Blair Waterway Deepening through Husky. Initial plan formulation identified three potentially separable channel segments: (1) Entrance to Husky, (2) Husky to WUT, and (3) WUT to PCT. For the purposes of the economic analysis, only “Entrance to Husky” represents a separable segment. Per ship simulation, vessels calling WUT will use the Blair Turning Basin, which extends all the way to the PCT berth. As a result, any deepening past Husky must continue through the Turning Basin to be considered a complete plan.

To estimate the benefits of only deepening to Husky Terminal, the analysis assumes each terminal’s share of transportation cost savings corresponds to its share of total cargo (Table 4-20).

Table 4-20: Cargo Share by Terminal (2030)

Terminal	Cargo/Transportation Cost Savings Share
Husky	37%
WUT	32%
PCT	31%

Table 4-21 summarizes the results of the incremental benefit-cost summary. The analysis looks at the benefits of channel deepening up to Husky Terminal.

Table 4-21: Alternative 2a Benefit-Cost Summary (Oct 2019 prices, 2.75% discount rate)

Project Depth	AAEQ Costs*	AAEQ Benefits	Net Benefits	Incremental Net Benefits	BCR
-52 MLLW	$1,162,000	$9,308,000	$8,146,000	$-	8.0
-53 MLLW	$1,325,000	$18,014,000	$16,689,000	$8,543,000	13.6
-54 MLLW	$1,487,000	$26,112,000	$24,625,000	$7,936,000	17.6
-55 MLLW	$2,539,000	$34,494,000	$31,955,000	$7,330,000	13.6
-56 MLLW	$2,729,000	$42,462,000	$39,733,000	$7,778,000	15.6
-57 MLLW	**$2,920,000**	**$50,392,000**	**$47,472,000**	**$7,739,000**	**17.3**
-58 MLLW	$3,112,000	$50,392,000	$47,280,000	$(192,000)	16.2
[1]Transportation costs computed using FY16 VOCs from EGM 17-04 in coordination with DDN-PCX. *Costs include monitoring, equipment, slope stability, and real estate costs for the entire channel					

The NED depth for each channel segment is -57 feet MLLW (Table 4-21). Additionally, the alternative which maximizes net economic development benefits is Alternative 2. Alternative 2 at -57 feet MLLW is the NED plan.

4.3.2 Alternative 2b Benefit-Cost Analysis

Alternative 2b is a depth increment of Alternative 2. This alternative consists of the NED channel depth as determined by the economic analysis. Associated channel widening and other improvements are consistent with Alternative 2. Alternative 2b was selected as the recommended plan. Costs and benefits have been updated to the most recent price level and discount rate. Table 4-22 presents the updated project costs for Alternative 2b, which includes beneficial use of dredged material at the Saltchuk Beneficial Use Site.

Table 4-22: Alternative 2b Cost Estimate (October 2021 price level, 2.25% discount rate)

Project First Costs	IDC	LSF	Total Economic Cost	Total OMRR&R	AAEQ Cost
$295,328,000	$13,541,000	$112,101,000	$425,405,000	$9,510,000	$14,259,000

Table 4-23 summarizes the benefit-cost analysis completed for Alternative 2b. Only costs of Alternative 2b have been updated to reflect the most recent available construction costs and risks. Alternative 2b is the NED plan.

Table 4-23: Alternative 2b Benefit-Cost Summary

Project Depth	Total AAEQ Costs[1]	Total AAEQ Benefits[2]	Total Net Benefits	BCR
-57 MLLW	$14,259,000	$152,715,000	$138,456,000	10.7
[1]October 2021 Price Level, FY22 Discount Rate (2.25%) [2]Transportation costs computed using FY19 VOCs from EGM 20-04 in coordination with DDN-PCX.				

4.3.3 Channel Design Optimization

The analysis presented in Section 3.3.3.4 assumes PPX3, and PPX4 vessels can transit the Blair Waterway in the FWOP condition; however, channel width would pose significant limitations on the transit of PPX4 vessel in particular. The analysis assumes significant delays and operational inefficiencies associated with these channel width restrictions.

Alternative 2, the recommended plan, includes expansion of the channel footprint beyond the existing boundary to accommodate the design vessel. Table 4-24 provides the preliminary estimates of quantities required to expand the channel footprint from the existing outline to the proposed channel for Alternative 2.

Table 4-24: Estimated Dredge Quantities Required for Expanded Channel Footprint

Channel Segment	Dredge Quantity to Reach Recommended Footprint (cubic yards)
Entrance to Husky	31,000
Husky to WUT	138,000
WUT to PCT	9,000
Full Waterway	**178,000**

The economic evaluation does not include a quantitative justification for the channel expansion other than including the expansion costs in all FWP conditions. These additional costs are low compared to the overall project costs (quantities represent less than 10 percent of total). These features would be easily justified given the high benefits associated with the fleet transition (e.g., transition from PPX2 to PPX3 and PPX4). Additionally, the study team will continue to optimize the channel footprint through the feasibility and design phases of this investigation.

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.

5.1 Model Uncertainty

Port and individual operations are subject to change based on various conditions, including weather, congestion, labor availability, schedule, pilot practices, and other factors leading to variability. The HarborSym model included variations or ranges for many of the variables involved in the vessel costs, loading, distances, speeds, etc. Figure 5-1 plots the range of transportation costs computed by the HarborSym model for each depth alternative. The distribution shows the variation in the total transportation costs; however, there is no overlap in total transportation cost between alternatives.

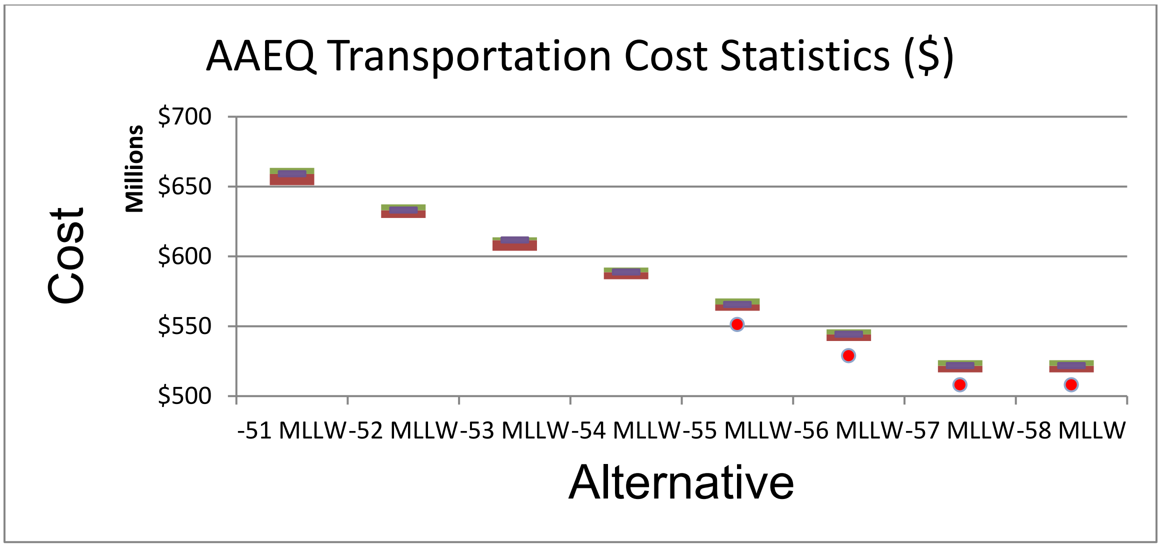


Figure 5-1: HarborSym Range of Transportation Costs

5.2 Commodity and Fleet Uncertainty

The long-term trade forecast assumes a compound average annual growth of 3.5 percent through 2035. While the study assumes long-term positive GDP growth will drive continued increases in containerized trade, future trade volumes are difficult to predict with certainty as they are subject to the ups and downs of the business cycle, individual commodity markets, and political influence. US-China tariff actions taken between 2018 and 2019, for example, add uncertainty to any transpacific trade forecast, especially in the short and medium-term. Trade with China represents approximately 33 percent of all containerized tonnage moved through Tacoma Harbor over the past decade.

The Tacoma Harbor fleet forecast assumes PPX3, and PPX4 vessels will comprise a larger percentage of calls and carry a larger share of total cargo over the study period. This assumption is based on an analysis of containerized vessel order books and firms' preference for the economies of scale and lower unit transportation costs realized by larger, more efficient vessels (Section 3.3). However, vessel scrap rates and deployment are firm-level decisions based on operating costs, fleet availability, trade volume, landside infrastructure constraints, scheduling, and other exogenous factors. As a result, forecasting the fleet distribution at Tacoma Harbor over the study period involves significant uncertainty. More importantly, the share of cargo carried on PPX3 and PPX4 vessels, the benefitting classes of containerships for this project, is subject to change.

5.2.1 Scenarios Analysis

Three scenarios were evaluated to compare against the outputs of the analysis presented in Section 4, referred to as the "Reference" scenario. These scenarios included the following:

- Scenario 1: No commodity or fleet growth from 2013-2016 average;
- Scenario 2: Reduced commodity and fleet growth between 2013-2016 average and Base Year (2030); and
- Scenario 3: No commodity or fleet growth past Base Year (2030).

Table 5-1 compares the commodity forecast used in the evaluation presented in Section 4 to the alternate growth scenarios developed for this sensitivity analysis.

Table 5-1. Commodity Forecast by Growth Scenario (1,000s of metric tons)

Growth Scenario	Direction	Baseline	2030	2035	2040	2045
Scenario 1	Import	5,074	5,074	5,074	5,074	5,074
	Export	5,801	5,801	5,801	5,801	5,801
	Total	10,875	10,875	10,875	10,875	10,875
Scenario 2	Import	5,074	6,013	6,419	6,852	7,410
	Export	5,801	9,292	9,487	9,687	9,933
	Total	10,875	15,305	15,906	16,539	17,343
Scenario 3	Import	5,074	7,254	7,254	7,254	7,254
	Export	5,801	9,399	9,399	9,399	9,399
	Total	10,875	16,653	16,653	16,653	16,653
Reference (Section 4)	Import	5,074	7,254	8,271	8,271	8,271
	Export	5,801	9,399	10,981	10,981	10,981
	Total	10,875	16,653	19,252	19,252	19,252

Table 5-2 summarizes the CAGR for each growth scenario. Scenario 1 shows no growth past the 2013 through 2016 average. Scenario 2 commodity growth is roughly equal to 50 percent of the reference case. Scenario 3 assumes equivalent growth to the reference case through 2030 before holding throughput constant.

Table 5-2: CAGR by Growth Scenario

Growth Scenario	2030	2035	2040	2045
Scenario 1	0.0%	0.0%	0.0%	0.0%
Scenario 2	1.6%	1.7%	1.7%	2.1%
Scenario 3	4.0%	0.0%	0.0%	0.0%
Reference (Section 4)	4.0%	2.9%	0.0%	0.0%

Table 5-3 presents the FWOP vessel fleet forecast given each commodity growth scenario. The results closely follow the commodity growth forecasts from Table 5-1.

Table 5-3: FWOP Vessel Fleet Forecast by Growth Scenario

Growth Scenario	Vessel Class	2030	2035	2040	2045
Scenario 1	PPX1	27	27	27	27
	PPX2	44	44	44	44
	PPX3	203	203	203	203
	PPX4	124	124	124	124
	Total	406	406	406	406
Scenario 2*	SPX	14	10	5	0
	PX	24	16	8	0
	PPX1	132	104	77	49
	PPX2	138	144	149	155
	PPX3	111	150	190	229
	PPX4	54	75	95	116
	Total	472	498	523	549
Scenario 3	PPX1	49	49	49	49
	PPX2	155	155	155	155
	PPX3	229	229	229	229
	PPX4	116	116	116	116
	Total	549	549	549	549
Reference (Section 4)	PPX1	49	81	81	81
	PPX2	155	132	132	132
	PPX3	229	189	189	189
	PPX4	116	189	189	189
	Total	549	591	591	591

*Scenario 2 values for 2030, 2035, and 2040 are interpolated.

5.3 Results

Each growth scenario was run through HarborSym using the same loading assumptions described in Section 4. Table 5-4 presents the results of each growth scenario in comparison to the reference case. All alternatives result in positive net benefits except under Scenario 1. Scenario 2 and Scenario 3 support -57 feet MLLW as the NED plan. Under each scenario, adjustments to the commodity and fleet forecast results in a relatively constant change to all alternatives. This means -57 feet MLLW will likely be the NED plan under all growth scenarios with the exception of very low and no growth scenarios (e.g., Scenario 1).

Table 5-4: Benefit-Cost Summary by Growth Scenario

Growth Scenario	Alternative Depth	AAEQ Costs	AAEQ Benefits	Net Benefits	BCR
Scenario 1	-52' MLLW	$5,373,000	$408,000	($4,965,000)	0.08
	-53' MLLW	$6,525,000	$757,000	($5,768,000)	0.12
	-54' MLLW	$7,216,000	$1,194,000	($6,022,000)	0.17
	-55' MLLW	$12,069,000	$1,505,000	($10,564,000)	0.12
	-56' MLLW	$12,837,000	$1,893,000	($10,944,000)	0.15
	-57' MLLW	$13,634,000	$2,219,000	($11,415,000)	0.16
	-58' MLLW	$14,665,000	$2,219,000	($12,446,000)	0.15
Scenario 2	-52' MLLW	$5,373,000	$21,339,000	$15,966,000	3.97
	-53' MLLW	$6,525,000	$41,395,000	$34,870,000	6.34
	-54' MLLW	$7,216,000	$59,932,000	$52,716,000	8.31
	-55' MLLW	$12,069,000	$79,256,000	$67,187,000	6.57
	-56' MLLW	$12,837,000	$97,579,000	$84,742,000	7.60
	-57' MLLW	$13,634,000	$115,987,000	$102,353,000	8.51
	-58' MLLW	$14,665,000	$115,987,000	$101,322,000	7.91
Scenario 3	-52' MLLW	$5,373,000	$24,852,000	$19,479,000	4.63
	-53' MLLW	$6,525,000	$47,039,000	$40,513,000	7.21
	-54' MLLW	$7,216,000	$69,040,000	$61,824,000	9.57
	-55' MLLW	$12,069,000	$90,246,000	$78,178,000	7.48
	-56' MLLW	$12,837,000	$110,982,000	$98,145,000	8.65
	-57' MLLW	***$13,634,000***	***$129,801,000***	***$116,168,000***	9.52
	-58' MLLW	$14,665,000	$129,801,000	$115,137,000	8.85
Reference Case	-52' MLLW	$5,373,000	$25,158,000	$19,785,000	4.7
	-53' MLLW	$6,525,000	$48,687,000	$42,161,000	7.5
	-54' MLLW	$7,216,000	$70,573,000	$63,357,000	9.8
	-55' MLLW	$12,069,000	$93,227,000	$81,159,000	7.7
	-56' MLLW	$12,837,000	$114,762,000	$101,926,000	8.9
	-57' MLLW	***$13,634,000***	***$136,195,000***	***$122,561,000***	***10.0***
	-58' MLLW	$14,665,000	$136,195,000	$121,530,000	9.3

Future sensitivity analyses may test the sensitivity of loading analysis assumptions. The study team assumed each foot of additional channel depth leads to vessels loading 0.7 feet deeper on average. This assumption is applied to all vessels in the benefitting vessel classes (PPX3 and PPX4). How vessel classes change operating behavior based on project features is a critical assumption in all deep draft navigation studies; however, there is uncertainty surrounding this input. While testing this assumption on a national scale is outside the scope of the study, testing the impact of changes to this assumption could improve the robustness of the findings.

5.3.1 Breakeven Analysis

The following breakeven analysis determines the minimum fleet transition required for project justification. This analysis further demonstrates the project's sensitivity to the fleet transition.

The results of the breakeven analysis indicate a low threshold for the project justification and the relatively low risk of fleet transition.

The study team estimates the minimum fleet transition possible by looking at the number of benefitting PPX3 vessels required to justify a -56 MLLW depth, then justifying the incremental depth from -56 MLLW to -57 MLLW using PPX4 vessels. This method should result in an estimate of the smallest fleet in terms of capacity possible for project justification. The study team uses the following assumptions to complete the breakeven analysis:

- Exports are the primary benefit driver
- Each benefitting PPX3 or PPX4 vessel adds export volume by loading 0.7 feet deeper
- Benefitting PPX3 and PPX4 vessels pull tonnage from PPX1 vessels
- Benefits equal the product of total PPX1 calls reduced and average total PPX1 transportation costs allocated to Tacoma Harbor

The analysis does not incorporate additional in-port costs associated with a more fully-loaded PPX3 and PPX4 vessel. However, these costs are relatively minor compared to the at-sea cost savings (less than 5 percent). With fewer PPX3 and PPX4 calls and no change in the commodity forecast, more PPX1 and PPX2 calls will be necessary for operation. Additional dock and channel congestion would like lower overall capacity and increase in-port costs for all vessels.

Using average parcel size by vessel class and average total voyage cost allocated to Tacoma Harbor for PPX1 vessels, the study team estimates a breakeven average annual call volume of 62 benefitting PPX3 vessels to justify -56 MLLW and approximately 5 benefitting PPX4 vessels to justify the incremental cost between -56 MLLW and -57 MLLW. This represents a 70 percent drop in benefitting PPX3 vessel calls and an 80 percent drop in benefitting PPX4 calls. The breakeven analysis shows the threshold for justification is well below the forecasted fleet transition, indicating relatively low project risk associated with the fleet transition.

5.4 Local Service Facility Assumptions

The study team assumes Port of Tacoma will upgrade cranes at WUT to service PPX4 vessels. WUT already operates two super-post-Panamax cranes; however, the terminal is unlikely to receive consistent PPX4 calls without additional crane upgrades. If PPX3 vessels are the largest, most consistently calling vessels at WUT over the study period, plan selection would change.

PPX3 vessels have an approximately 1-foot shallower design draft than PPX4 vessels. Consequently, there would be minimal benefit to deepening beyond -56 feet MLLW past Husky Terminal. However, -56 feet MLLW would be justified. A quick check of this assumption can be made using the estimated $5.20 in AAEQ cost savings per ton loaded on PPX3 vessels in the -56 feet MLLW depth alternative compared to the FWOP. Assuming all PPX4 tonnage would need to be loaded onto PPX3 vessels at WUT, the analysis would estimate an additional 2.1 million tons on PPX3 vessels at WUT. Assuming $5.20 AAEQ cost savings per ton in the -56 feet MLLW condition leads to approximately $10.9 million in AAEQ benefits at WUT for PPX3 vessels alone. If total costs for dredging from Husky to the Turning Basin equals costs of dredging to the entire channel to -56 feet MLLW ($12,837,000 AAEQ) minus total costs of dredging Husky only ($2,920,000), then total project costs equal $9,917,000 AAEQ. This is enough benefit to justify the costs of deepening to -56 feet MLLW from Husky to the Turning Basin without including PPX3 benefits realized by vessels calling PCT, which would likely increase total benefits by as much as 30 percent based on cargo share by Terminal (Table 4-20).

6 Multiport Analysis

The multiport competition was assessed qualitatively for this study as it relates to shifting of cargo from one port to another port based on factors such as deepening of a harbor. The recommended plan includes a deeper channel to more efficiently operate larger containerships. Larger containerships alone do not drive growth for the harbor. Many factors may influence the growth of a particular harbor: landside development and infrastructure, location of DCs for imports, source locations for exports, population and income growth and location, port logistics and fees, business climate and taxes, carrier preferences, labor stability, and volatility, and business relationships. Harbor depth is just one of many factors involved in determining growth and market share for a particular port. The economic analysis was conducted with the historical Tacoma cargo share remaining the same in both the FWOP and FWP conditions. Under the NWSA, the Ports of Seattle and Tacoma cooperate on container operations to meet the demands of the the region and nation. The analysis assumes that in the long-run, the Ports of Tacoma and Seattle will handle relatively similar portions of overall trade through the region. Over the study period, both Ports are likely to run into capacity constraints as trade volume continues to grow. As a result, the NWSA will have limited ability to favor one Port over the other in the long-term, and cargo shares will likely remain stable. This means that if, for example, Seattle Harbor was not deepened, the benefits of the recommended plan at Tacoma Harbor would not significantly change. Both terminals would still need to handle relatively similar commodity throughput, and there would be limited opportunity to shift cargo to or from Seattle Harbor.

Year-to-year cargo may vary in the future as investments are made in port facilities and supporting infrastructure, and long-term leases are renewed or changed at individual terminals. However, the NWSA's share of cargo is expected to grow in the future based on GDP growth for the WCUS and associated hinterland based on the information provided in IHS Global Insight's commodity forecast conducted in 2015. To restate the multiport considerations in another way, the justification of the recommendation for this study is not based on cargo shifting to Tacoma. The analysis assumes Tacoma receives the same share of regional cargo volumes with or without the deepening of the Blair Waterway.

7 Socioeconomic and Regional Analysis

The parameters used to describe the demographic and socioeconomic environment include recent trends in population growth for thirteen counties making up the immediate economic study area, private sector employment, and wage earnings by sector for Washington State and the three counties within the Seattle-Tacoma-Bellevue Metropolitan Statistical Area (MSA): 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 Tacoma metro area and Pierce Counties, whose communities may be impacted by the project.

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 and an estimated 7.5 million residents in 2017. Between 1990 and 2010, Washington's population increased by 38 percent from 4.9 million to 6.7 million (Table 7-1). Washington's growth was greater than the national growth over the same historical period. The City of Tacoma and Pierce County experienced population growth rates of over this time frame greater than King County and the national growth rate. The Seattle-Tacoma-Bellevue metro area is ranked 15th in total population among US MSAs.

Table 7-1. Population Trends, 1990 to 2010

Geographical Area	Population				Growth Rate (1990-2017)
	1990	2000	2010	2017, est.	
Tacoma	176,644	193,603	198,397	213,418	20%
King County	1,507,319	1,737,034	1,931,249	2,188,649	45%
Pierce County	586,203	700,820	795,225	876,764	50%
Seattle-Tacoma-Bellevue MSA	2,559,164	3,043,878	3,439,809	3,867,046	51%
Washington State	4,866,692	5,894,121	6,724,540	7,405,743	52%
United States	248,709,873	281,421,906	308,745,538	325,719,178	31%

Source: US Census, 2013-2017 American Community Survey (ACS)

7.1.2 Employment

Washington employment in 2017 totaled 2.7 million (excluding public employees), with average annual wages of $62,000, as shown in Table 7-2. In 2017 over 550 thousand people were employed in federal, state, and local government. Within the private sector, Health care and social assistance (15 percent), Retail trade (14 percent), Manufacturing (10 percent), and Accommodation and food services (10 percent) make up 50 percent of total industry employment, with over 1.3 million total employees.

Of the private sector industries, information sector employees are paid the highest in average annual earnings at $172,500, followed by employees within the management of companies and enterprises sector.

Table 7-2. Private Sector Employment, 2017

NAICS Code	NAICS Sector	Annual Average Employment	Total Annual Wages ($1,000s)	Average Wage per Employee
11	Agriculture, forestry, fishing and hunting	105,181	$3,276,969	$31,156
21	Mining, quarrying, and oil and gas extraction	2,494	$177,407	$71,138
22	Utilities	4,738	$440,916	$93,055
23	Construction	187,247	$11,468,777	$61,249
31-33	Manufacturing	280,368	$21,389,100	$76,290
42	Wholesale trade	131,686	$10,099,449	$76,693
44-45	Retail trade	378,004	$19,861,120	$52,542
48-49	Transportation and warehousing	96,171	$5,577,303	$57,994
51	Information	125,798	$21,701,793	$172,513
52	Finance and insurance	93,682	$8,498,340	$90,715
53	Real estate and rental and leasing	50,776	$2,618,757	$51,575
54	Professional and technical services	194,675	$17,915,457	$92,027
55	Management of companies and enterprises	44,224	$4,948,057	$111,886
56	Administrative and waste services	165,883	$8,040,706	$48,472
61	Educational services	42,327	$1,627,804	$38,458
62	Health care and social assistance	409,236	$20,852,008	$50,954
71	Arts, entertainment, and recreation	50,933	$1,635,337	$32,107
72	Accommodation and food services	274,207	$6,249,332	$22,791
81	Other services, except public administration	97,492	$3,784,766	$38,822
99	Unclassified	20	$1,160	$57,278
All	Average	2,735,142	$170,164,559	$62,214

*Source: BLS Quarterly Census of Employment and Wages, 2017

7.1.3 Median Household Income

Median household incomes for Pierce County in 2017 are shown in Table 7-3. Tacoma median household income is 16 percent below the state median while the Seattle-Tacoma-Bellevue MSA median income is over 124 percent of the state median income largely due to the higher wage areas in Seattle and Bellevue.

Table 7-3. Median Household Income for Selected Areas, 2017

Geography	Median Household Income, 2017	% State Median Household Income
Tacoma City	$55,506	84%
King County	$83,571	126%
Pierce County	$63,881	97%
Seattle-Tacoma-Bellevue MSA	$82,133	124%
Washington State	$66,174	100%
United States	$57,652	87%
Source: US Census, 2013-2017 American Community Survey		

The unemployment rate for the Tacoma – Lakewood area was 5.4 percent in 2017, 0.6 percent higher than the state average. The unemployment rate in the Seattle-Tacoma-Bellevue MSA was 3.8 percent in 2017, 1 percent below the state average. Table 7-4 summarizes unemployment statistics for the study area.

Table 7-4. Unemployment for Selected Areas, 2017

Geographical Area	Unemployment Rate
Tacoma – Lakewood	5.4%
Seattle-Tacoma-Bellevue MSA	3.8%
Washington State	4.8%
United States	4.35%
Source: BLS	

7.1.4 Social Characteristics

This section describes the social characteristics of the Seattle-Tacoma-Bellevue MSA, which includes Pierce County, King County, and Snohomish County. Most Port related infrastructure is located in the City of Tacoma. Social characteristics assessed in this section include population, race, age, education, income, poverty, and unemployment.

7.1.4.1 Population Trends

The population trends from 1980 through 2017 for the Seattle-Tacoma-Bellevue metro area are shown in Table 7-1. The Seattle-Tacoma-Bellevue MSA experienced a much higher rate of population growth than the national average, with a 51 percent increase in population from 1990 to 2017. The Tacoma metro area experienced slower population growth than the region overall with 20 percent population growth between 1990 and 2017, with a net population increase of nearly 37,000 residents.

7.1.4.2 Racial Composition

As shown in Table 7-5, Pierce County, King County, and Washington have lower percentages of minority populations than the United States for all races, with the exception of American Indian, Asian and Pacific populations.

Table 7-5. Racial Composition by Geographical Area, 2017

	King County		Pierce County		WA	US
Race	**No.**	**%**	**No.**	**%**	**%**	**%**
White	1,402,793	66.2%	624,094	73.8%	76.7%	73.0%
Black	130,594	6.2%	56,640	6.7%	3.7%	12.7%
American Indian	14,276	0.7%	10,257	1.2%	1.3%	0.8%
Asian	350,616	16.6%	51,582	6.1%	8.1%	5.4%
Pacific	16,522	0.8%	12,172	1.4%	0.6%	0.2%
Other race	73,630	3.5%	24,966	3.0%	4.1%	4.8%
Two or more races	129,688	6.1%	65,482	7.7%	5.5%	3.1%
Hispanic or Latino	200,545	9.5%	87,702	10.4%	12.3%	17.6%

Source: US Census (American Community Survey, 2017)

7.1.4.3 Age Distribution

The age characteristics of the Seattle metro area are shown in Table 7-6. King and Pierce Counties have lower median ages than the state of Washington and the United States. In 2017, the median age was 37.2 for King County and 36.0 for Pierce County compared to 37.8 for the nation.

Table 7-6. Age Characteristics, 2017

	King County		Pierce County		WA	US
Age Group	**No.**	**%**	**No.**	**%**	**%**	**%**
Under 18	439,068	20.70%	201,572	23.80%	22.50%	22.90%
18-64	1,415,231	66.80%	534,641	63.30%	63.10%	62.20%
65 or above	263,820	12.50%	108,980	12.90%	14.40%	14.90%
Median Age	37.2		36.0		37.6	37.8

Source: US Census (American Community Survey, 2017)

7.1.4.4 Income and Poverty

The US Census Bureau 2013-2017 American Community Survey income and poverty data for the Tacoma area and the state of Washington are summarized in Table 7-7. Pierce County had lower median household incomes than the state and national median income. Poverty levels for Pierce County are the same as the national average.

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

Regional Income and Poverty Data, 2012	King County	Pierce County	Washington State
Median Household Income	$83,571	$63,881	$66,174
Per Capita Income	$46,316	$31,157	$34,869
Total for whom poverty status is determined	2,089,582	828,520	7,037,413
Persons Below Poverty Level	212,509	101,328	859,950
Percent of Persons Below Poverty Level	10.20%	12.20%	12.20%
Persons Below 50% of Poverty Level	101,374	48,192	394,852
Percent of Persons Below 50% Poverty Level	4.85%	5.82%	5.61%
Source: US Census Bureau, 2013-2017 American Community Survey			

7.2 Regional Economic Development Analysis

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

The Corps 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 Corps Recreation, Navigation, and Formally Utilized Sites Remedial Action Program (FUSRAP). Contributions are measured in terms of economic output, jobs, earnings, and/or value added.

These reports provide estimates of the economic impacts of the Civil Works Budget Analysis for Tacoma Harbor. 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 Corps'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 built specifically for Corps 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.

The navigation construction expenditures associated with the Tacoma Harbor are $295,328,000. This amounts to the total project cost less LSF. LSF is not included in the Regional analysis as it is not a federally cost-shared feature and would have a unique regional economic impact compared to navigation construction expenditures. The RECONS model estimates the local impact area will capture $221,608,000 of the total expenditure. The state impact area (Washington State) and nation capture $241,308,000 and $279,119,000, respectively. Direct expenditures associated with the project also generate additional economic activity, often called secondary or multiplier effects. RECONS measures jobs supported in full-time equivalent (FTE) jobs, defined as one full-time job for one year. Jobs supported by this project would only last over the construction period, and actual employment impact and duration will vary by function.

The Civil Works expenditure of $295,328,000 supports approximately 1,400 full-time equivalent job years over the construction period, $127,707,000 in labor income, and $193,634,000 in value added in the local impact area. More broadly, these expenditures support approximately

2,700 full-time equivalent jobs over the construction period, $216,076,000 in labor income, and $337,323,000 in value added to the nation.

Table 7-8 summarizes the results of the regional analysis by impact area. Table 7-9, Table 7-10 and Table 7-11 present the detailed impacts for the local impact area, state, and nation, respectively. The model assumes the local impact area captures 75 percent of the total project expenditure, and 57 percent of the output generated. The model assumes the proposed project generates $314 million in direct and secondary impacts.

Table 7-8: Overall Impact Summary

Area	Local Capture ($000)	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
Local					
Direct Impact		$221,608	810	$85,969	$121,891
Secondary Impact		$119,292	586	$41,738	$71,743
Total Impact	$221,608	$340,900	1,396	$127,707	$193,634
State					
Direct Impact		$241,308	891	$90,278	$130,203
Secondary Impact		$133,701	672	$44,824	$77,133
Total Impact	$241,308	$375,009	1,563	$135,102	$207,336
US					
Direct Impact		$279,119	1,072	$105,463	$149,782
Secondary Impact		$354,413	1,620	$110,613	$187,540
Total Impact	$279,119	$633,531	2,692	$216,076	$337,323

* Jobs are presented in annual full-time equivalence (FTE).

Table 7-9: Local Impact Summary

	Local Impacts	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$26,582	136	$11,480	$14,914
105	All other food manufacturing	$729	2	$99	$123
156	Petroleum refineries	$3,846	1	$131	$700
205	Cement manufacturing	$1,914	3	$307	$780
217	Iron and steel mills and ferroalloy manufacturing	$653	1	-$0	$19
254	Valve and fittings, other than plumbing, manufacturing	$842	2	$164	$413
271	All other industrial machinery manufacturing	$119	0	$31	$35
334	Switchgear and switchboard apparatus manufacturing	$210	0	$77	$82
363	Ship building and repairing	$22,190	76	$8,100	$9,604
395	Wholesale trade	$9,058	29	$3,124	$6,057
399	Retail - Building material and garden equipment and supplies stores	$1,513	11	$658	$1,031
408	Air transportation	$149	0	$36	$73
409	Rail transportation	$322	1	$107	$216
410	Water transportation	$181	0	$23	$51
411	Truck transportation	$1,219	6	$440	$525
413	Pipeline transportation	$110	0	$29	$45
437	Insurance carriers	$4,853	10	$1,199	$2,437
449	Architectural, engineering, and related services	$2,951	26	$2,169	$1,971
455	Environmental and other technical consulting services	$13,808	113	$10,767	$11,371
462	Office administrative services	$2,676	19	$637	$1,754
507	Commercial and industrial machinery and equipment repair and maintenance	$43,284	1186	$20,809	$32,547
535	Employment and payroll of federal govt, non-military	$37,142	190	$25,583	$37,142
5001	Private Labor	$47,257	0	$0	$0
	Direct Impact	**$221,608**	**810**	**$85,969**	**$121,891**
	Secondary Impact	**$119,292**	**586**	**$41,738**	**$71,743**
	Total Impact	**$340,900**	**1,396**	**$127,707**	**$193,634**

* Jobs are presented in full-time equivalence (FTE)

Table 7-10: State Impacts Summary

	State Impacts	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$26,582	144	$11,480	$14,914
105	All other food manufacturing	$838	2	$114	$141
156	Petroleum refineries	$15,195	2	$729	$3,838
205	Cement manufacturing	$1,914	3	$307	$780
217	Iron and steel mills and ferroalloy manufacturing	$784	1	$12	$42
254	Valve and fittings, other than plumbing, manufacturing	$857	2	$167	$420
271	All other industrial machinery manufacturing	$235	1	$62	$70
334	Switchgear and switchboard apparatus manufacturing	$372	1	$136	$145
363	Ship building and repairing	$25,804	92	$9,419	$11,168
395	Wholesale trade	$9,058	30	$3,124	$6,057
399	Retail - Building material and garden equipment and supplies stores	$1,585	12	$689	$1,080
408	Air transportation	$149	0	$36	$73
409	Rail transportation	$322	1	$107	$216
410	Water transportation	$181	0	$23	$51
411	Truck transportation	$1,219	7	$440	$525
413	Pipeline transportation	$110	0	$30	$46
437	Insurance carriers	$4,853	10	$1,199	$2,437
449	Architectural, engineering, and related services	$2,951	28	$2,169	$1,971
455	Environmental and other technical consulting services	$13,808	122	$10,767	$11,371
462	Office administrative services	$2,706	20	$645	$1,774
507	Commercial and industrial machinery and equipment repair and maintenance	$46,132	209	$22,178	$34,689
535	Employment and payroll of federal govt, non-military	$38,395	205	$26,446	$38,395
5001	Private Labor	$47,257	0	$0	$0
	Direct Impact	**$241,308**	**891**	**$90,278**	**$130,203**
	Secondary Impact	**$133,701**	**672**	**$44,824**	**$77,133**
	Total Impact	**$375,009**	**1,563**	**$135,102**	**$207,336**

* Jobs are presented in full-time equivalence (FTE)

Table 7-11: National Impact Summary

	US Impacts	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$26,582	150	$11,480	$14,914
105	All other food manufacturing	$5,068	13	$753	$958
156	Petroleum refineries	$17,737	3	$851	$5,752
205	Cement manufacturing	$2,005	3	$321	$817
217	Iron and steel mills and ferroalloy manufacturing	$5,414	5	$486	$999
254	Valve and fittings, other than plumbing, manufacturing	$5,256	13	$1,208	$2,577
271	All other industrial machinery manufacturing	$1,850	6	$523	$644
334	Switchgear and switchboard apparatus manufacturing	$2,710	7	$992	$1,058
363	Ship building and repairing	$31,361	115	$11,447	$13,573
395	Wholesale trade	$9,059	31	$3,124	$6,058
399	Retail - Building material and garden equipment and supplies stores	$1,587	13	$690	$1,082
408	Air transportation	$149	0	$36	$73
409	Rail transportation	$325	1	$108	$218
410	Water transportation	$181	0	$24	$54
411	Truck transportation	$1,726	9	$622	$743
413	Pipeline transportation	$492	1	$375	$354
437	Insurance carriers	$5,168	11	$1,277	$2,819
449	Architectural, engineering, and related services	$2,954	30	$2,514	$1,973
455	Environmental and other technical consulting services	$20,675	183	$16,123	$17,027
462	Office administrative services	$2,954	25	$712	$1,936
507	Commercial and industrial machinery and equipment repair and maintenance	$50,211	249	$24,277	$37,755
535	Employment and payroll of federal govt, non-military	$38,397	205	$27,520	$38,397
5001	Private Labor	$47,257	-	$0	$0
	Direct Impact	**$279,119**	**1,072**	**$105,463**	**$149,782**
	Secondary Impact	**$354,413**	**1,620**	**$110,613**	**$187,540**
	Total Impact	**$633,531**	**2,692**	**$216,076**	**$337,323**

* Jobs are presented in full-time equivalence (FTE)

8 References

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