US Army Corps of Engineers®

OAKLAND HARBOR TURNING BASINS WIDENING, CA

NAVIGATION STUDY

DRAFT INTEGRATED FEASIBILITY REPORT & ENVIRONMENTAL ASSESSMENT

APPENDIX C:

Economics

List of Acronyms

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

OD	Origin-to-Destination
OMRR&R	Operations, Maintenance, Rehabilitation, Repair & Replacement
P&G	Principles & Guidelines
PIANC	Permanent International Association of Navigation Congresses
PNW	Pacific Northwest
PPX	Post-Panamax
PPX1	Post-Panamax Generation I
PPX2	Post-Panamax Generation II
PPX3	Post-Panamax Generation III
PPX4	Post-Panamax Generation IV
PX	Panamax
RECONS	Regional Economic System
RED	Regional Economic Development
RHA	Rivers and Harbors Act
SEA	Southeast Asia
SPX	Sub-Panamax
TEU	Twenty-Foot Equivalent Unit
TPI	Tons Per Inch Immersion
TSP	Tentatively Selected Plan
UKC	Underkeel Clearance
UPRR	Union Pacific Railroad
USDA	U.S. Department of Agriculture
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VOC	Vessel Operating Costs
WCUS	West Coast United States
WRDA	Water Resources Development Act
WTM	World Trade Model
XB	Extreme Breadth

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1. Introduction

This document presents the economic evaluations performed for the Oakland Harbor Turning Basin project. The current federally authorized channel depth of Oakland Harbor is -50 ft. mean lower low water (MLLW) in the Inner and Outer Harbor channels, with authorized channel widths of 800 and 900 ft., respectively. In September 2019, the U.S. Army Corps of Engineers (USACE) Oakland District was approved by the Office of Management and Budget to begin the multi-year feasibility study to determine if expanding the Turning Basins in the Inner and Outer Harbors is both economically beneficial and environmentally acceptable to the nation. The USACE San Francisco District together with the Deep Draft Navigation Planning Center of Expertise performed the economic analyses contained within this document in support of the feasibility study.

1.1. Study Purpose

The purpose of this study is to evaluate problems and opportunities, identified in Table 1-1, for improved navigation in Oakland Harbor and identify the plan that best satisfies the environmental, economic, and engineering criteria. The scope of this feasibility study involves analysis of existing conditions and requirements, identifying opportunities for improvement, preparing economic analyses of alternatives, identifying environmental impacts, and analyzing the National Economic Development (NED) plan.

Table 1-1. Problems and Opportunities

PROBLEMS	OPPORTUNITIES
• Navigation inefficiencies due to turning basin width limitations • Increased safety and environmental risks due to turning basins' width limitations	• Increase navigation efficiencies • Benefit the economy and realize economies of scale • Beneficially use dredged material • Increase navigation safety for all vessels • Reduce emissions and environmental risks

Potential navigation improvements include expansion of one, or both, of the Turning Basins. The purpose of these potential improvements is to increase the efficiency of cargo vessel operations on Post-Panamax containerships, which are already calling on the Port of Oakland and are projected to call on the port with increased frequency in the future. This study identifies and evaluates alternatives that would:

- Accommodate recent and anticipated future growth of containerized cargo and containership traffic;
- Improve the efficiency of operations for containerships within Oakland's Inner and Outer Harbors; and
- Allow larger and more efficient containerships to use the Port

1.2. Document Layout

Section 2 details the existing conditions at Oakland Harbor. Section 3 examines future without-and with-project conditions; it includes an evaluation and description of forecast trade, terminal upgrades, and the vessel fleet and operations at the harbor. Section 4 presents the transportation cost savings benefit analysis. In Section 5, sensitivities to the forecast are explored. Section 6 examines the multiport considerations. Section 7 includes updates to the economic evaluation for the Final Feasibility Report and Environmental Assessment, while Section 8 describes the socioeconomics of Oakland and the surrounding region.

2. Existing Conditions

The existing conditions are defined in this report as the conditions that exist today in the study area plus any changes that are expected to occur prior to project year one, anticipated in 2030, which is referred to as the base year. It is the year the project is expected to be operational and accrue benefits. The year 2019 is the most recent year for which complete data was obtained for containerized cargo volumes and is used as the baseline for the commodity forecast. The year 2019 data along with historical data dating back to at least year 2009 was considered the most reasonable data to use in the development of fleet and commodity forecasts described later in this appendix. The rationale for using this range of data is based on its completeness, relevancy, and ability to capture economic highs and lows during that timeframe. It should be noted that while this analysis is based on the most recent and complete data obtained, economic updates will be completed periodically. Future updates of the project's BCR will be required, consistent with USACE budget-development guidance.

2.1. Economic Study Area

The economic study area is the geographical area that will be used to project commodity flows for alternative analysis. To encompass any assumptions about how the project site will look in the future, any physical, socio-economic, economic, and policy conditions must be identified.

2.1.1. Physical Conditions

The federally authorized Oakland Harbor navigation project is located on the eastern side of the San Francisco Bay in the counties of Alameda and San Francisco, California, about 8 miles inside the Golden Gate Bridge, and consists of an Outer and Inner Harbor (Figure 2-1). The authorized project specifically includes deepening the following channels: Entrance Channel, Outer Harbor Channel, Inner Harbor Channel, the Outer Harbor Turning Basin, the Inner Harbor Turning Basin, and the Middle Harbor. The channels were deepened and are maintained to 50 ft. MLLW. The Outer Harbor is located immediately south of the San Francisco-Oakland Bay Bridge and provides access to the Port of Oakland's berthing areas, which serve container, break-bulk, and roll-on/roll-off deep-draft vessels. The Inner Harbor is also maintained to -50 ft. MLLW through Howard Terminal, which is approximately 2.5 miles from the Inner Harbor entrance. The deepening of the Inner and Outer Harbor from -42 to -50 ft. MLLW was completed in 2009. More information on the study area can be found in Section 1.4, Location and Description of the Study Area, of the main feasibility report.

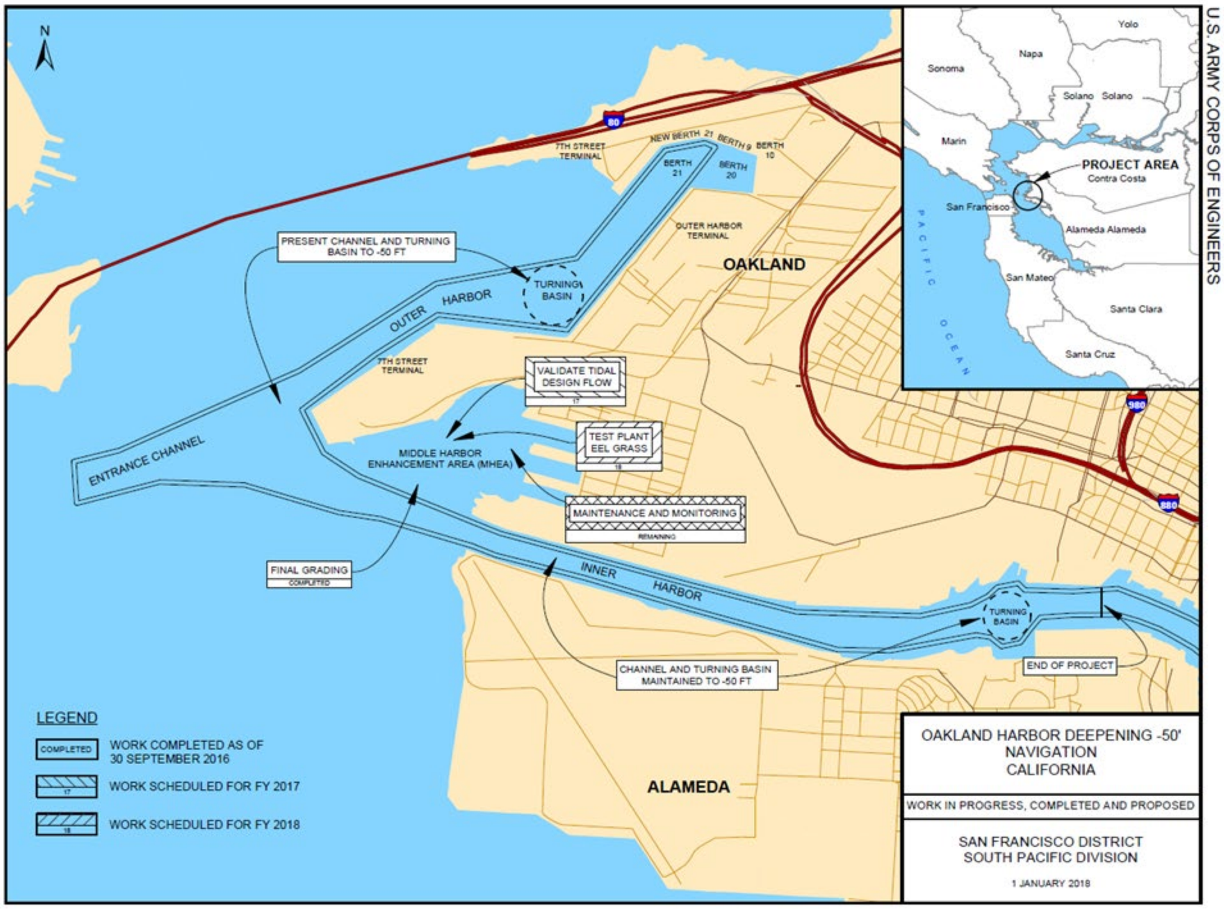

Figure 2-1. Federally Authorized Navigation Channel (Inner and Outer Harbors)

2.1.1.1. Facilities and Infrastructure

The Oakland Seaport is made up of 1,543 acres of waterfront land and nearby properties including container terminals, general purpose/cargo terminals, break-bulk cargo and refrigerated cargo and storage. There are four active container terminals in the Port of Oakland, as well as several other facilities. The Port of Oakland's four active container terminals, shown in Figure 2-2 are:

- TraPac Terminal
- Ben E. Nutter Terminal
- Oakland International Container Terminal (OICT)
- Matson Terminal

Figure 2-1. Oakland Harbor Map[1]

TraPac Terminal

The TraPac Terminal is a container terminal located in the northern end of the Outer Harbor, adjacent to the Outer Harbor Turning Basin. It is leased from the Port of Oakland by operator TraPac, Inc. The terminal size is 123 acres (50 hectares). This terminal includes four container berths with an overall length of 4,263 ft. Berths are all dredged to -50 ft. MLLW. This terminal includes seven Post-Panamax cranes and can accommodate large containerships with an outreach 13 to 18 boxes wide (144 ft.). There are typically 6 container vessel calls to this terminal per week, which keeps the terminal at or near its throughput capacity. Refer to Section 3.1 on future improvements to TraPac to accommodate ultra large containerships. Additionally, this terminal has refrigerated capacity with 860 reefer plugs.

Ben E. Nutter Terminal

The Ben E. Nutter Terminal is a container terminal located at the junction of the Entrance Channel and the Outer Harbor Channel, at the eastern edge of the port. It is operated by Everport Terminal Services, Inc., a subsidiary of Evergreen. The terminal size is 75 acres (30.5 hectares). This terminal includes two container berths with an overall length of 2,157 ft. Berths are currently -50 ft. MLLW. This terminal includes four cranes, all of which can accommodate large containerships with an outreach of 23 boxes wide (203 ft.). There are typically 3 container vessel

[1] Source: Oakland Seaport, oaklandseaport.com, accessed 8 September 2020

calls to this terminal per week. Additionally, this terminal has refrigerated capacity with 346 reefer plugs.

Oakland International Container Terminal (OICT)

The Oakland International Container Terminal (OICT) is a container terminal located on the north side of the Inner Harbor Channel near downtown Oakland. It is operated by Stevedoring Services of America Terminals, Inc. (SSA). The terminal size is 270 acres (109 hectares). This terminal has five berths with an overall length of 6,000 ft.. All berths are currently -50 ft. MLLW. This terminal typically sees 18-25 container vessel calls per week, utilizing all five berths simultaneously. This terminal includes ten Super Post-Panamax cranes, all of which can accommodate large containerships. OICT has recently raised and replaced its existing cranes to accommodate even larger containerships. OICT is adjacent to two Class I rail yards: Oakland International Gateway – Joint Intermodal Terminal (BNSF), and Railport Oakland (Union Pacific). Additionally, this terminal has refrigerated capacity with 1,503 reefer plugs designed for refrigerated containers.

Matson Terminal

The Matson Terminal is a container terminal located along the Inner Harbor Channel, adjacent to the Inner Harbor Turning Basin. It is also operated by SSA. The terminal size is 80 acres (32 hectares). This terminal has four berths that are -42 ft. MLLW, and four Post-Panamax cranes. This terminal is mainly used for domestic shipping to Alaska and Hawaii. Summary information for all Oakland Harbor container terminals is shown in Table 2-1.

Table 2-1. Oakland Harbor Container Terminals

Container Terminal	***Berth Numbers***	***Length***	***Water Depth (MLLW)***
TraPac Terminal	25-33	4,263.3 ft.	-50 ft.
Ben E. Nutter Terminal	35-38	2,157 ft.	-50 ft.
Oakland Int'l Container Terminal	55-56	2,400 ft.	-50 ft.
	57-59	3,600 ft.	-50 ft.
Matson Terminal	60-63	2,743 ft.	-42 ft.

2.2. Historic Commerce

The year 2019 is the most recent year for which complete data was available for containerized cargo volumes at the time of the analysis and is used as the baseline for the commodity forecast. The compilation of this complete data typically takes 18 months to 2 years. Utilizing this data for this study allows for more "normalized", pre-COVID pandemic data to drive long-term forecasts. Based on 2019 data, Oakland's cargo volume makes it the seventh busiest container port in the United States in terms of the number twenty-foot equivalent units (TEUs) handled and ranks San Francisco Bay among the three principal Pacific Coast gateways for U.S. containerized cargoes, along with San Pedro Bay in southern California and Puget Sound in the Pacific Northwest[2]. The Port of Oakland loads and discharges more than 99% of the containerized goods moving through Northern California (Port of Oakland, 2020). In 2019, about 78% of Oakland's trade was with Asia. Europe accounted for about 11%, Australia/New Zealand and Oceania accounted for about 2%, and other foreign economies accounted for about 2%. About 7% of Oakland's trade is domestic (primarily Hawaii). In 2019, over 19 million short tons of cargo moved through the port for import or export (USACE, 2022). Figure 2-3 below shows the levels of tonnage by major commodity between 2009-2019.

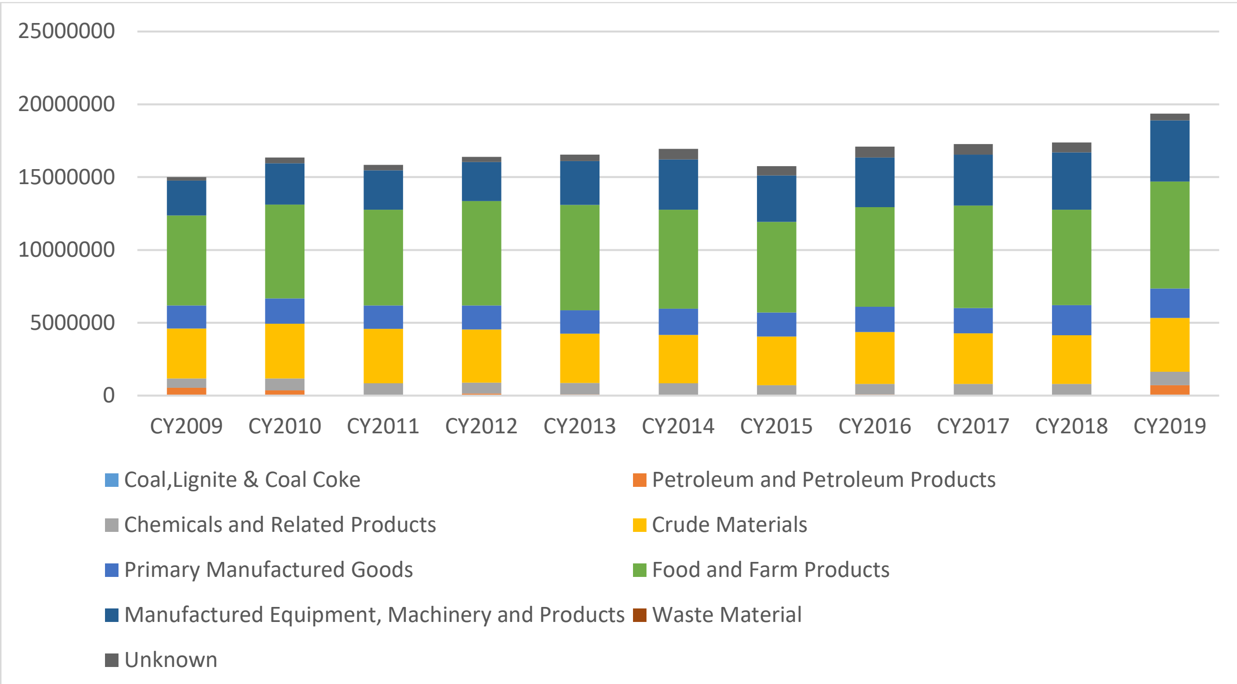

Figure 2-2. Oakland Distribution of Commodities, Metric Tons (Source: USACE WCSC, 2022)

Most of the commodities passing through the Port of Oakland include food and farm products, followed by crude materials (pulp/wastepaper and scrap metal) and manufactured equipment. Port volumes have been trending higher since the low point of the 2009 recession, with all-time highs reached in 2019. Flat trade growth in 2011 and a labor dispute in 2015 resulted in the only interruptions to this upward trend.

The Port's container vessel calls account for about 95% of total vessel calls in 2019 (Port of Oakland, 2020). Figure 2-4 provides a summary of the Port's commerce measured in TEUs from 2009 through 2020, closely mirroring tonnage volumes over the same time period.

[2] American Associated of Port (AAPA) data, 2019

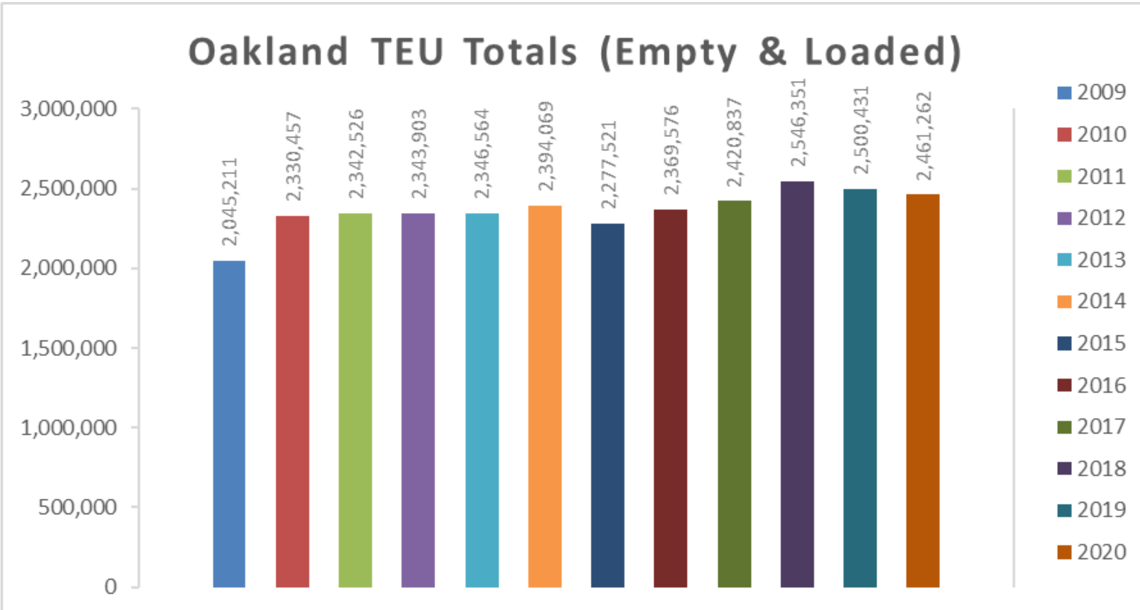

Figure 2-3.Oakland TEUs, Empty and Loaded, Years 2009-2020 (Source: Port of Oakland 2021)

There has been an almost even split of the TEU volumes between imports and exports since 2009. Imports have averaged around 1.1 million TEUs per year since 2009, and exports have averaged around 1.3 million TEUs per year, as shown in Figure 2-5. Machinery, toys and sports equipment, furniture and bedding, clothing, footwear, plastic, and iron/steel products were among the greatest value of imported commodities in 2018. High value export commodities included a variety of food products (grain, fish and seafood, preserved food, meat, fruit, dairy, vegetables, cereals, etc.), paper products, and wood products. California is a top national producer of fruit and nuts, fresh and frozen vegetables, and wine. Imports and exports in 2018 were valued at $28.1 billion and $19.2 billion, respectively, and about 45 percent of the trade value is with China alone (USACE, 2020). This larger volume in exports from Oakland is one reason that the Port has been able to maintain more steady throughput volumes during the trade conflict with China and other uncertainties surrounding Trans-Pacific trade.

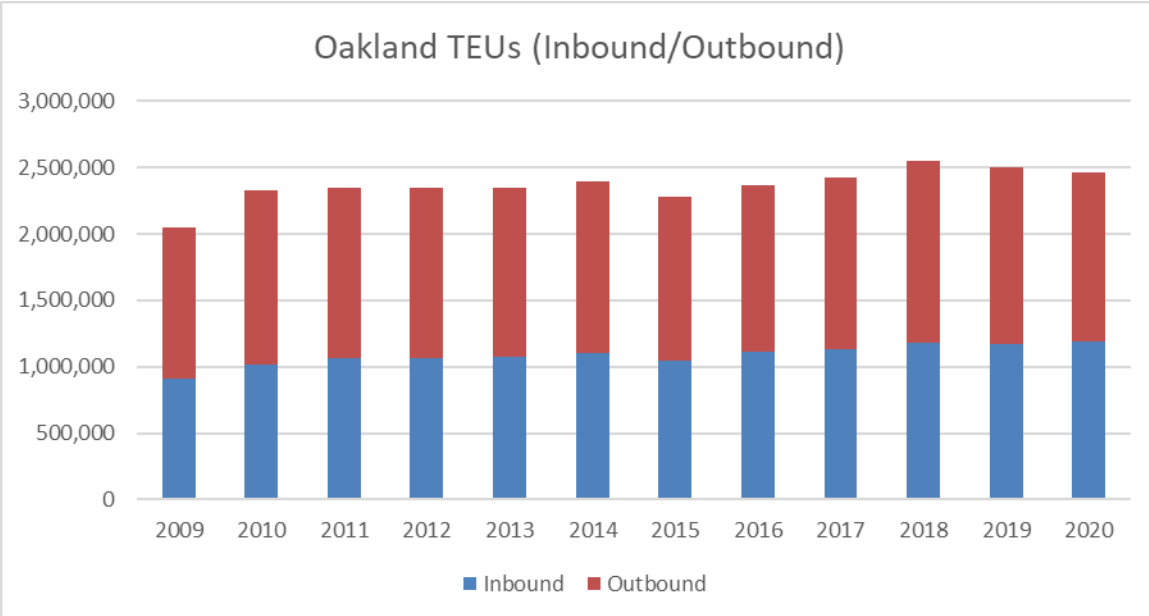

Figure 2-4.Oakland TEUs Inbound/Outbound, Years 2009-2020 (Source: Port of Oakland 2021)

2.2.1. Hinterland

The inland trade region served by a port is called its hinterland. The hinterland usually consists of several cargo hinterlands defined by the inland origins or destinations of specific commodities (NED Manual for Deep Draft Navigation). The Port of Oakland is a natural gateway to move import cargo, primarily Transpacific cargo from Asia, to the large population centers surrounding the Bay Area and beyond. Its proximity to the Central California agricultural markets also makes it a preferred export point of departure to maximize speed to international consumers. Oakland's international trade spans several countries in different world regions. However, it is highly concentrated in Asia, given its location as a West Coast gateway port. The following sections will identify hinterland clusters with respect to geography and transportation that account for most containerized cargoes. The hinterland should be described sufficiently so that secondary forecast data (e.g., population, income, employment) can be used or referenced in subsequent sections.

2.2.1.1. Imports

The Port of Oakland's top trading partner for both imports and exports is China, as shown in Table 2-2 and Table 2-4 below. Other top import origins are also listed in Figure 2-6 and outline the various production hinterlands for imported goods through Oakland.

Table 2-2. Oakland Imports by Origin Country, 2016-2019 (Source: U.S. Customs Bill of Lading data, 2020)

2016		2017		2018		2019	
Australia	1.67%	Australia	1.75%	Australia	1.55%	Australia	1.58%
Chile	1.22%	Chile	1.23%	Chile	1.13%	China	49.29%
China	48.94%	China	50.77%	China	51.96%	France	2.62%
France	2.77%	France	2.87%	France	2.75%	Germany	2.49%
Germany	2.60%	Germany	2.75%	Germany	2.51%	Hong Kong	4.33%
Hong Kong	6.09%	Hong Kong	5.49%	Hong Kong	5.38%	India	4.38%
India	3.53%	India	3.55%	India	3.85%	Indonesia	1.93%
Indonesia	2.97%	Indonesia	2.12%	Indonesia	1.71%	Italy	3.70%
Italy	3.83%	Italy	4.21%	Italy	3.92%	Japan	2.67%
Japan	2.83%	Japan	2.71%	Japan	2.50%	Malaysia	2.38%
Malaysia	1.90%	Malaysia	1.99%	Malaysia	2.01%	New Zealand	1.17%
New Zealand	1.42%	New Zealand	1.35%	New Zealand	1.24%	Philippines	1.17%
Philippines	1.15%	South Korea	3.11%	South Korea	3.16%	South Korea	3.68%
South Korea	3.17%	Spain	1.27%	Spain	1.42%	Spain	1.44%
Taiwan	7.91%	Taiwan	7.43%	Taiwan	6.98%	Taiwan	7.44%
Thailand	3.03%	Thailand	3.21%	Thailand	3.31%	Thailand	3.78%
Vietnam	4.96%	Vietnam	4.19%	Vietnam	4.62%	Vietnam	5.95%

According to data from the Census Bureau, in 2018, the top imported commodities at Oakland from Asian nations like China, Taiwan, and India were, in descending order, furniture, glassware, sound/TV equipment, plastics, and iron/steel. Imports from Europe, Australia, and South/Central America centered around, in descending order, wine, coffee, and wood[3]. These are primarily consumer goods, as opposed to manufacturing inputs, and depend on the available population around Oakland to buy them and facilitate trade flows. According to bill of lading data, approximately 75 percent of all imports are distributed within the state of California, as shown in Table 2-3 below. Some discrepancies do exist with bill of lading data and other reports due to uncertainties in final destinations based on consignee location or listed destinations and

[3] Port-level Imports, U.S. Census Bureau, Economic Indicators Division. Usatrade.census.gov. Accessed 02 December 2020.

missing data.

Table 2-3. Oakland Imports by Destination State, 2016-2019 (Source: U.S. Customs Bill of Lading Data, 2020)

2016		2017		2018		2019	
California	76.73%	California	79.33%	California	76.78%	California	77.46%
Colorado	2.39%	Colorado	1.93%	Colorado	1.46%	Colorado	1.82%
Illinois	2.98%	Illinois	2.93%	Connecticut	1.00%	Connecticut	1.08%
Nevada	3.41%	Nevada	3.43%	Florida	1.26%	Florida	1.31%
New Jersey	1.83%	New Jersey	1.70%	Georgia	1.52%	Georgia	1.31%
New York	2.37%	New York	2.30%	Illinois	2.88%	Illinois	2.54%
Outside U.S.	1.17%	Texas	4.26%	Nevada	3.19%	New Jersey	1.75%
Texas	5.58%	Utah	2.07%	New Jersey	1.87%	Nevada	2.44%
Utah	1.84%	Washington	2.04%	New York	2.33%	New York	2.44%
Washington	1.70%			Texas	3.47%	Texas	3.11%
				Utah	1.93%	Utah	2.15%
				Washington	2.32%	Washington	2.58%

The Port is backed by a network of local roads and interstate freeways, warehouses, and two Class I railroads – Burlington Northern Santa Fe Railway Company (BNSF) and Union Pacific Railroad (UP) – that, together, link the port to regional and national markets for containerized goods. These containerized goods are primarily moved by truck from the port directly to their warehousing and distribution locations, while goods destined for the Midwest, South and East Coast are typically moved by rail. Figure 2-6 below illustrates the freight flows by mode in 2018.

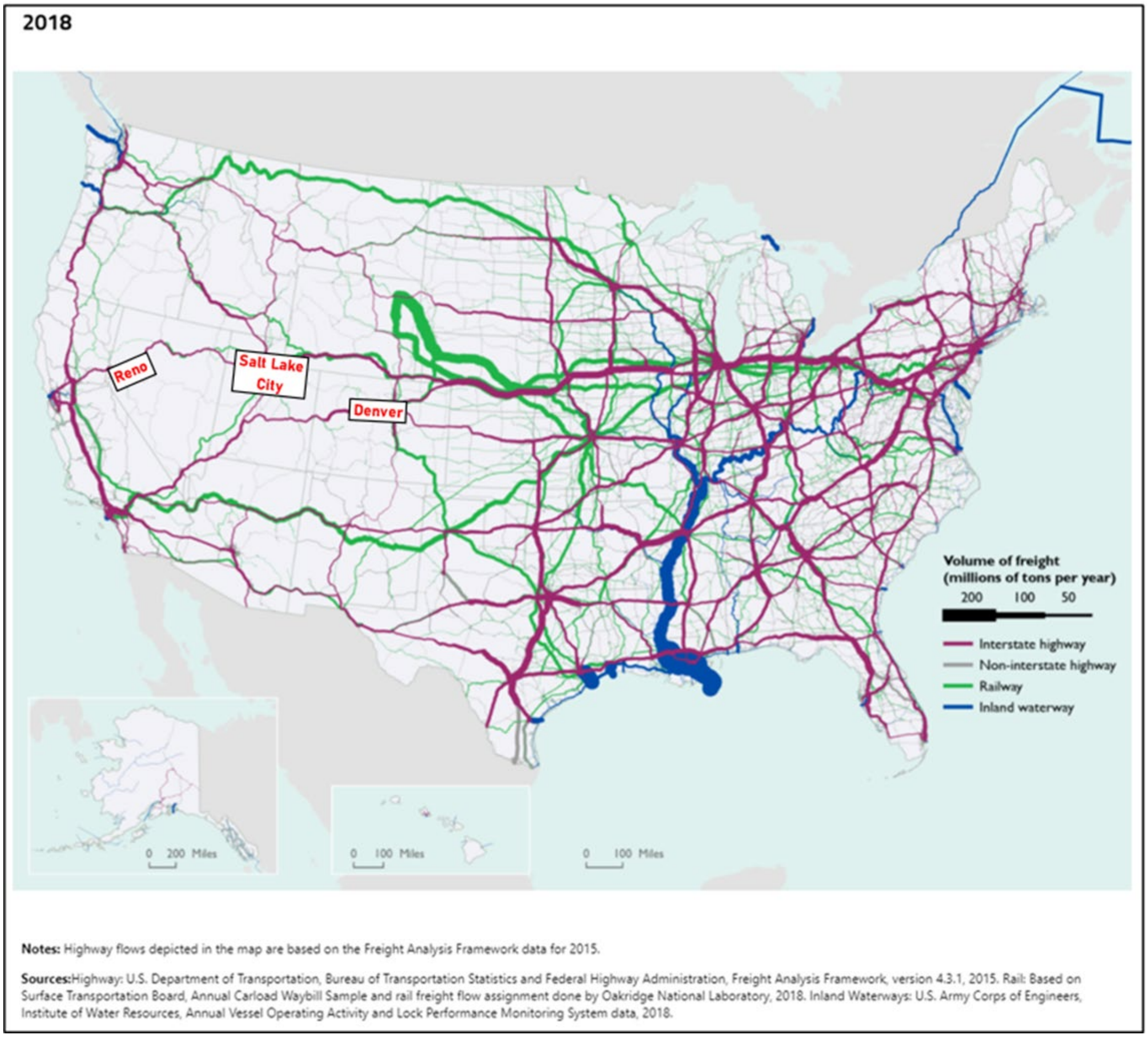

Figure 2-5. Freight Flows by highway, railroad, and waterway, Source: U.S. Department of Transportation, Bureau of Transportation Statistics, Freight Facts and Figures (Washington, DC: 2020)

Transload warehouse and distribution centers (DCs) are an integral component of the international supply chain. The concentration, capabilities and location of warehouse and distribution centers in relation to a port can influence importers', exporters', and container shipping lines' cargo routing and port selection decisions. Warehouse and distribution centers not only provide storage for goods received from and/or delivered to the Port, but also add much needed flexibility for importers. Upon arrival, goods are transported from the terminal to nearby warehouses or distribution centers, where they are stored or consolidated, cross-docked, or transloaded (removing contents of international marine containers and repackaged in 53-foot domestic containers) for delivery to local or regional DCs or directly to retail stores. Additionally, these facilities provide value-added services such as labeling, re-packaging, order pick-and-pack fulfillment and computerized inventory control to supplement the regular or just-in time delivery needs of the importer. According to the Port, 98 percent of all imports are received within 300 miles of Oakland, but 25-30 percent are transloaded at DCs and moved farther inland. For example, they estimate that 10 percent is moved to the Tahoe/Reno area, 10 percent to the Denver area, and 10 percent to the Utah area[4].

The consumption hinterland for imported containerized goods for the Port of Oakland encompasses the population centers along major interstate highways in northern California, Nevada, Utah, and Colorado. The primary hinterland, representing most of the import volumes, extends from Redding in northern California to King County in the south, which is roughly equidistant from the ports of Oakland and those in San Pedro Bay. Figure 2-7 below illustrates both the primary and marginal consumption hinterlands. The area in green highlights the primary consumption hinterlands for Oakland, and the port's estimates for domestic transloading stops in Reno, Salt Lake City, and Denver represent more marginal hinterlands due to their smaller volumes transported.

[4] Discussions with Port of Oakland Marketing Department, October 2020

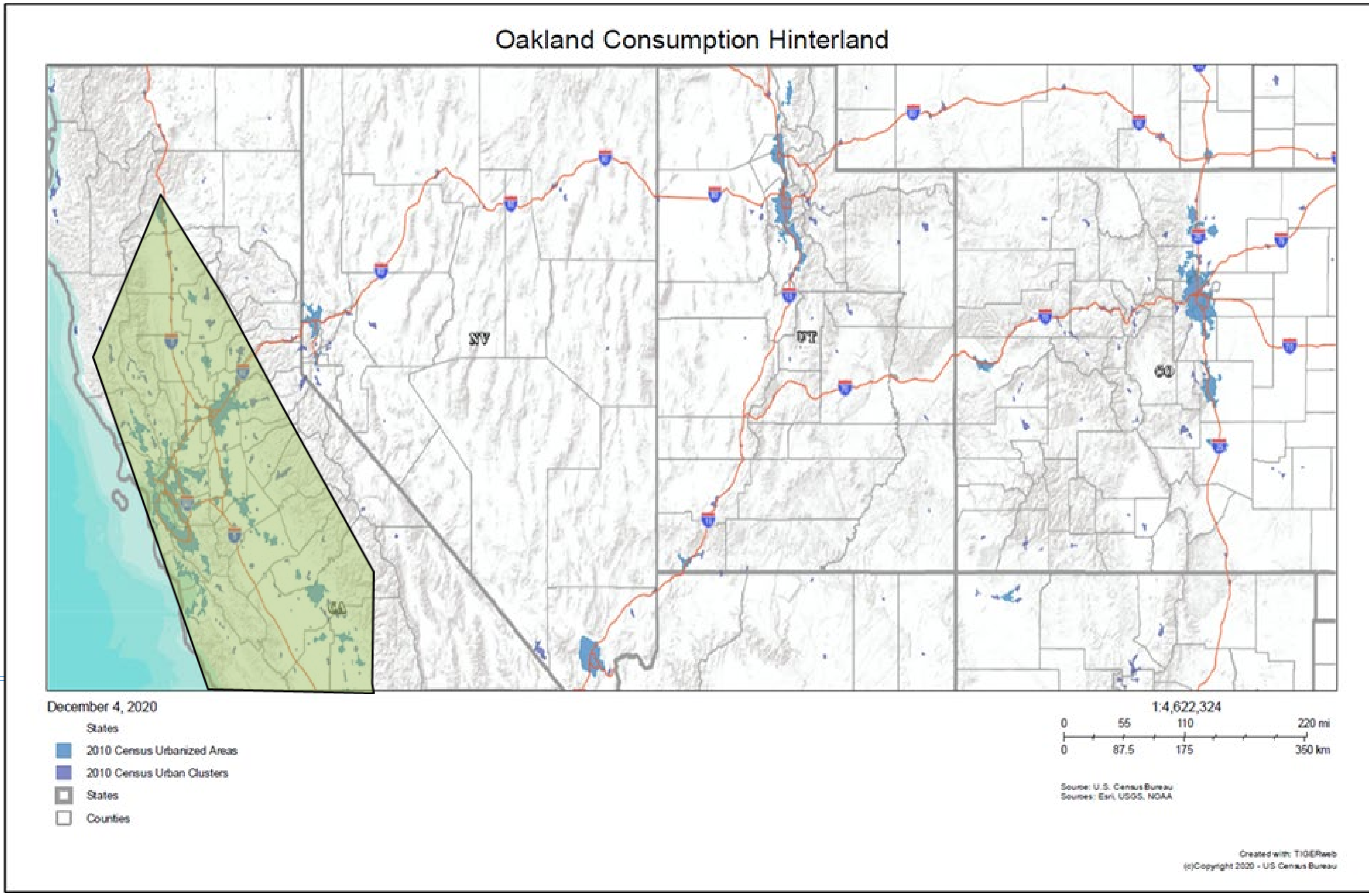

Figure 2-6. Port of Oakland Consumption Hinterland for Imports

2.2.1.2. Exports

Oakland is a final port of call on the U.S. West Coast for many services prior to their return leg to Asia. Its proximity to California agricultural markets also makes it a preferred point of departure to maximize speed to international consumers. These factors make it a desirable export gateway for domestic producers. Table 2-4 below shows export destinations by country. China, Japan, and South Korea, with their large populations and developed economies, lead this list. The top five exported commodities in 2018 were, in descending order: Wood Pulp/Scrap paper, Fruits and Nuts, Meat, Iron and Steel, and Beverages/Spirits/Vinegar

Table 2-4. Oakland Exports by Destination Country, 2016-2019 (Source: U.S. Customs Bill of Lading Data, 2020)

2016		2017		2018		2019	
Country	% of TEUs	Country	% of TEUs	Country	% of TEUs	Country	% of TEUs
Belgium	1.32%	Australia	2.00%	Australia	1.51%	Australia	1.68%
China	32.28%	Belgium	1.36%	Belgium	1.30%	Belgium	1.25%
Germany	2.35%	China	35.63%	China	35.52%	China	21.90%
Hong Kong	4.24%	Germany	1.72%	Hong Kong	3.94%	Germany	2.17%
India	1.07%	Hong Kong	4.93%	India	2.83%	Hong Kong	4.42%
Japan	14.20%	India	2.62%	Indonesia	2.36%	India	2.90%
Philippines	1.23%	Japan	19.65%	Japan	16.20%	Italy	1.27%
Singapore	1.01%	Netherlands	1.72%	Malaysia	1.31%	Japan	19.27%
South Korea	8.56%	Philippines	1.54%	Netherlands	1.83%	Malaysia	1.91%
Spain	0.78%	South Korea	10.87%	Philippines	1.47%	Netherlands	2.38%
Taiwan	1.28%	Spain	1.58%	Singapore	1.27%	Singapore	2.37%
Thailand	0.69%	Taiwan	7.14%	South Korea	11.25%	South Korea	15.51%
United Arab Emirates	1.56%	Thailand	1.52%	Spain	1.29%	Spain	2.26%
United Kingdom	1.02%	United Arab Emirates	2.24%	Taiwan	7.88%	Taiwan	13.27%
Vietnam	1.12%	United Kingdom	1.88%	Thailand	1.83%	United Kingdom	1.63%
		Vietnam	3.61%	United Arab Emirates	1.31%	Unknown	2.62%
				United Kingdom	1.93%	Vietnam	3.18%
				Vietnam	4.97%		

As shown in Table 2-5 below, approximately 70% of exports departing Oakland originate in California. The port is well-connected to California locations by road and most containerized goods arrive at the port for export by truck. The recently completed CoolPort upgrades at the

Port complex further accommodate the large fresh food service from California agricultural exporters by truck. Other export origins, such as Texas and those in the Mid-West and East Coast arrive via one of the two Class I railroads to the port.

Table 2-5. Oakland Exports by Origin State, 2016-2019 (Source: U.S. Customs Bill of Lading Data, 2020)

2016		2017		2018		2019	
State	% of TEUs	State	% of TEUs	State	% of TEUs	State	% of TEUs
California	65.67%	California	73.21%	California	55.13%	California	69.30%
Colorado	1.92%	Colorado	2.20%	Colorado	1.53%	Colorado	2.21%
Fleet Post Office Cargo	1.96%	Fleet Post Office Cargo	2.81%	Fleet Post Office Cargo	1.80%	Florida	1.19%
Illinois	3.15%	Illinois	3.10%	Illinois	3.70%	Illinois	1.92%
Indiana	0.51%	Kansas	2.84%	Kansas	2.42%	Kansas	3.93%
Kansas	2.12%	New Jersey	2.25%	New Jersey	3.70%	Nevada	1.13%
New Jersey	2.66%	New York	3.98%	New York	3.20%	New Jersey	3.29%
New York	3.71%	Oregon	1.16%	Outside U.S.	3.03%	New York	3.67%
Oregon	0.99%	Outside U.S.	2.72%	South Dakota	1.21%	Unknown	1.27%
Outside U.S.	2.47%	South Dakota	1.42%	Texas	13.99%	Outside U.S.	3.96%
South Dakota	1.16%	Texas	2.75%	Virginia	8.79%	South Dakota	1.66%
Texas	2.60%	Washington	1.55%	Washington	1.51%	Texas	2.86%
Washington	1.41%					Virginia	1.76%
						Washington	1.86%

Oakland's domestic production hinterlands are varied, but center around its immediate California market. The top two commodities exported through the Port in 2018 were recycled paper/cardboard, and fruits/nuts[5]. Both are exported via container. The description of their origins and destinations are below.

Scrap paper is the Port's largest export commodity, accounting for approximately 27 percent of the tonnage and container volume[6]. Scrap paper is "produced" and packaged for export by Bay Area material recovery facilities (MRF) that collect municipal and commercial recycling for sorting and export. So, the regional population of the San Francisco Bay Area "produces" this commodity, which is then collected and exported by MRFs. As Figure 2-8 below shows, the Bay

[5] U.S. Census Bureau, Port Level Exports, Economic Indicators Division, usatrade.census.gov, accessed 02 December 2020.

[6] *Ibid.*

Area is home to three of the top four producing MRFs on the West Coast, with two more in the top 10 nearby in Sacramento. The MRF with the largest exports of wastepaper on the West Coast is in San Francisco, and ships more than thirty large containers six days a week.[7]

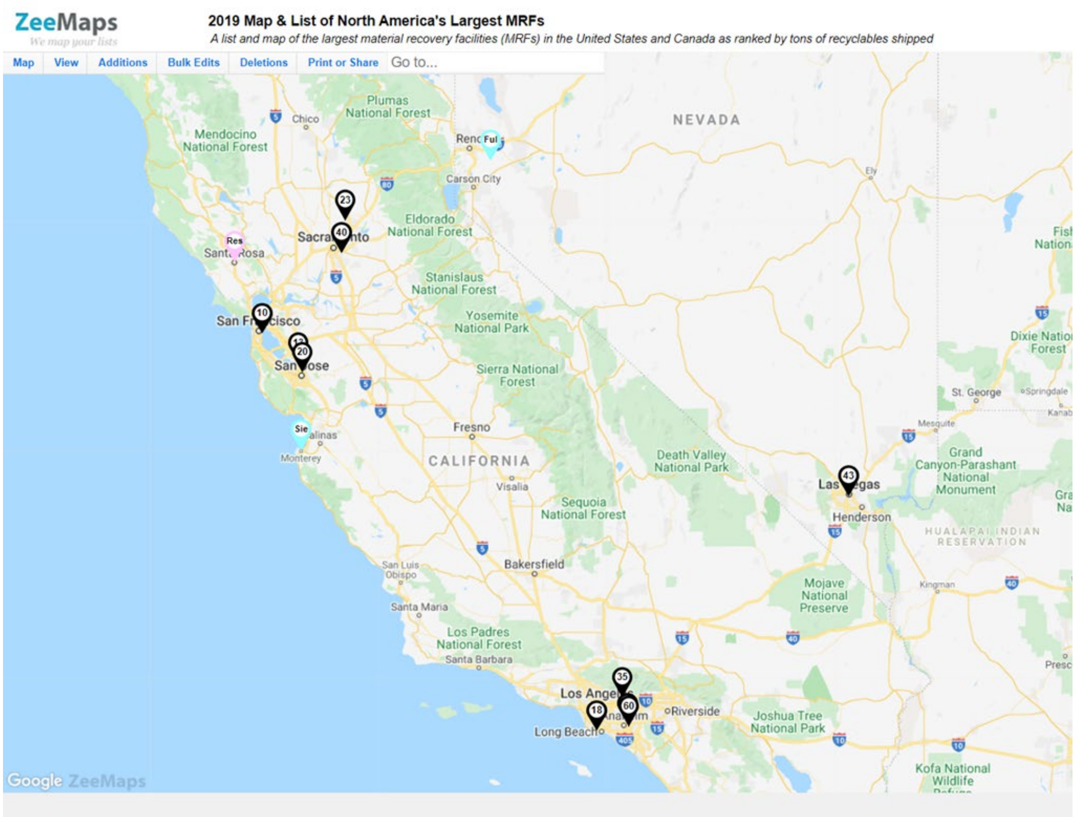

Figure 2-7. 2019 Map of California MRF's and North American Rankings by tons of recyclables shipped; Source: "Seismic Shifts: List and Maps of North America's Largest MRF's," Recycling Today, September 2019.

Even though the environment for U.S. scrap paper exports has been challenging over the last 3 years, the Port of Oakland has managed to increase their exports over that time. Pressures, such as a rising U.S. dollar, the U.S.- China trade standoff, and China's tougher quality standards for foreign scrap products, have made it more difficult for U.S. scrap exporters. However, Oakland has substituted exports to China with trade to other Asian countries, like Taiwan, Vietnam, and India[8].

The second major export commodity from Oakland is agricultural products. California is the largest agricultural producer among U.S. states. In 2018, California received almost double the crop revenue of the second closest state, Iowa[9]. As shown in Figure 2-9 below, it is a center of crop production, and produces a significant share of livestock, dairy, and poultry products.

[7] Company website, www.recology.com, accessed 08 December 2020.
[8] "Scrap paper still flowing out of SF Bay Area," Recycling Today, online edition, December 12, 2018.
[9] California Agricultural Statistics Review, 2018-2019, California Department of Food and Agriculture, p.3.

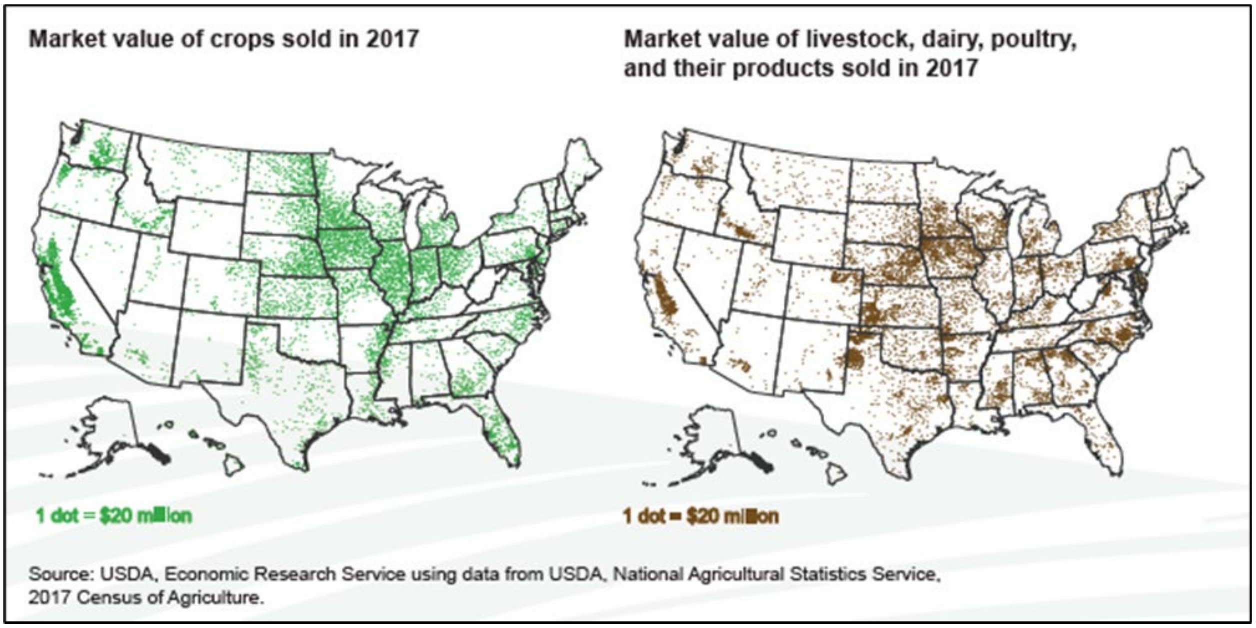

Figure 2-8. Snapshot of U.S. agricultural production by market value, USDA 2017

In 2018, California exported approximately 26 percent of its agricultural production by volume. In dollar terms, California's agricultural exports reached $21.02 billion. Significantly, California is the nation's sole exporter of many agricultural commodities, supplying 99 percent or more of the following: almonds, artichokes, dates, prunes, figs, garlic, kiwifruit, olives and olive oil, pistachios, raisins, table grapes, and walnuts. According to the USDA's National Agricultural Statistics Service, in 2019, California produced 59 percent of the nation's fruit and tree nuts, valued at over $21 billion[10]. Almonds are a large part of this crop and make up a large amount of overall U.S. farm exports. Over 60 percent of almonds produced in the U.S. were exported between 2015-2018[11]. Figure 2-10 below shows the top ten export destinations for California's leading agricultural commodities according to the University of California's Agricultural Issues Center.

[10] *Citrus Fruits 2018 Summary* and *Noncitrus Fruit and Nuts 2018 Summary,* USDA, National Agricultural Statistics Service, ers.usda.gov, accessed 02 December 2020.
[11] USDA, Economic Research Service using USDA, Foreign Agricultural Service, Production, Supply and Distribution Database.

California's Top 10 Agricultural Export Markets, 2018			
Rank	Country	Export Value $1 Million	Leading Exports
1	European Union	3,373	Almonds, Pistachios, Wine
2	Canada	3,193	Wine, Lettuce, Almonds
3	China/Hong Kong	2,252	Pistachios, Almonds, Dairy and Products
4	Japan	1,557	Almonds, Rice, Beef and Products
5	Korea	1,011	Oranges and Products, Almonds, Beef and Products
6	Mexico	907	Dairy and Products, Table Grapes, Almonds
7	India	816	Almonds, Cotton, Pistachios
8	Vietnam	485	Almonds, Beef and Products, Pistachios
9	United Arab Emirates	365	Almonds, Walnuts, Pistachios
10	Taiwan	307	Table Grapes, Beef and Products, Almonds

Source: University of California, Agricultural Issues Center

Figure 2-9. California's Top 10 Agricultural Export Markets in 2018; Source: California Agricultural Statistics Review 2018-2019, p.8.

The Port of Oakland is a natural gateway for agricultural exports from the region. At Oakland, fruits and nuts made up over 20 percent of total exports by volume in 2018[12]. Figure 2-11 below shows the top 10 agricultural counties in California, in terms of production value in dollars, and their locations on a map. Those counties listed on the table in yellow are considered primary production hinterlands for the Port of Oakland for containerized agricultural products. Those in red would be primary hinterlands for the San Pedro Ports (Los Angeles and Long Beach) given their shorter distance than Oakland. Those counties in orange would be an overlapping hinterland for either Oakland or San Pedro Bay ports. These counties are tied to the Port of Oakland and those in San Pedro Bay by interstates and state highways. Many of the counties listed are bisected by major highways to help facilitate agricultural commerce north or south.

[12] U.S. Census Bureau, *Port Level Exports*, Economic Indicators Division, usatrade.census.gov, accessed 02 December 2020.

Top 10 Agricultural Counties

County	Total Value and Rank ($1,000) 2017		2018		Leading Commodities
Fresno	7,024,915	3	7,911,893	1	Almonds, Pistachios, Livestock (Unspecified), Grapes (Table)
Kern	7,254,004	1	7,469,670	2	Grapes (Table), Almonds, Pistachios, Milk
Tulare	7,050,855	2	7,213,141	3	Milk, Oranges (Navel) , Grapes (Table), Cattle & Calves
Monterey	4,425,425	4	4,258,628	4	Strawberries, Lettuce, Broccoli, Wine Grapes
Stanislaus	3,648,192	5	3,569,989	5	Almonds, Milk, Chickens, Nursery
Merced	3,409,518	6	3,254,144	6	Milk, Almonds, Chickens, Cattle
San Joaquin	2,527,966	7	2,594,221	7	Almonds, Grapes (Wine), Milk, Walnuts
Kings	2,058,715	10	2,351,983	8	Milk, Pistachios, Cotton (Pima), Cattle & Calves
Imperial	2,065,599	9	2,226,030	9	Cattle, Alfalfa Hay, Vegetables, Other Hay
Ventura	2,099,889	8	2,103,232	10	Strawberries, Lemons, Celery, Raspberries

Source: California County Agricultural Commissioners' Reports

Figure 2-10. Port of Oakland containerized agricultuural production hinterlands

2.2.1.3. Overlapping Hinterlands

Hinterlands can be described in many ways. “The primary hinterland is the area which primarily receives cargo from a given port. An overlapping (or competitive) hinterland is an area from which two or more ports derive their cargoes and a given commodity could flow to any port depending on rate, service

and other characteristics. Hinterlands are not always fixed and can be fluid depending upon changing conditions (USACE, 2010).” As an example, USACE’s Port of Long Beach Deep (POLB) Draft Navigation study (2020) describes its hinterland this way:

> “*The catchment area (geographic area from which the Port attracts a population that uses its services) for the San Pedro Bay Ports (Port of Long Beach and Port of Los Angeles) includes a local catchment area, comprising of area located*

within California, and an extended catchment area, including Colorado, New Mexico, Utah, Arizona, Nevada, and California (Figure 2-12).

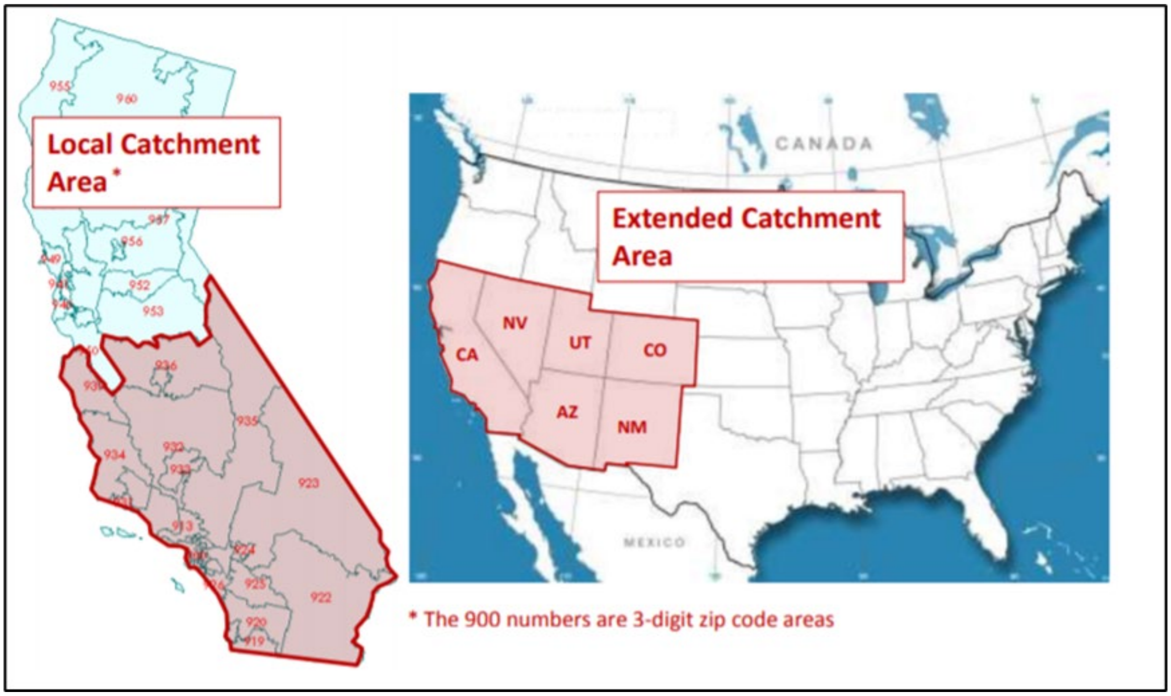

Figure 2-11. Local and Extended Catchment Areas for San Pedro Bay Ports

"Because a majority of the services that call the POLB also call at the Port of Oakland, the local catchment encompasses only the areas in California that are closer in over-the-road mileage to the POLB. Areas that extend beyond this are included in the extended catchment area. Northern California is included in the extended catchment area due to importers stopping at the POLB to discharge containers with goods for consumption across California, emphasizing those that are trans-loaded because most of the population of California is located in Southern California. The other five states included in the extended catchment area are land-locked, with a majority of goods that are trans-loaded being handled through the POLB or the Port of Los Angeles."

Oakland's domestic hinterlands for imports and exports overlap with the catchment areas of the San Pedro Bay ports. While some import hinterlands that overlap the extended catchment area only represent marginal amounts of tonnage or containers, production hinterlands for agricultural exports that overlap are potentially much more significant. In areas that overlap between multiple ports, many characteristics of services may explain why containers are handled at some ports and not others, other than total transportation costs. Examples of service differences that may account for market shares include: regional warehouse and DCs; differences in rail intermodal among ports, including first port of call (imports) and last port of call (exports); interactions with load centering systems capabilities, including markets served and railway clearances; and promised delivery dates for various goods. Last port of call effects for exports and delivery date rigidities may overshadow any rate fluctuations caused by project alternatives and keep the overall hinterland equilibriums relatively stable in this analysis.

2.3. Container Services

2.3.1. Existing Container Terminals and Capabilities

The majority of Port of Oakland's container traffic is handled at OICT. Annual throughput capacity at all active terminals is over 2 million TEUs and is expected to increase with the completion of landside infrastructure improvement and expansion projects at all terminals and are described in Section 3.1.1.

2.3.2. Carriers and Trade Lanes

According to the Port, in summer 2020, there were 61 different container services at Oakland. Figure 13 below details services that were considered for the economic evaluation, including the terminal, carrier(s), service name, vessel rotation, and ship sizes at that time. The Port of Oakland is typically a second port of call for several of the Asian – West Coast U.S. routes, usually after stops in San Pedro Bay (Los Angeles or Long Beach). Most services call from Asia via trans-Pacific routes. Major lines include COSCO, CMA CGM, OOCL, Hyundai, Maersk, and APL. However, in 2020 and 2021, the Port has added multiple services that call directly from Asia to Oakland as its first U.S. West Coast stop.

Ocean Carrier Services - Port of Oakland

Transpacific Services

THE Alliance	Hapag-Lloyd, ONE, Yang Ming, Hyundai			
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **ONE** Hapag-Lloyd Hyundai *CMA CGM(I)* *COSCO(I)* *OOCL(I)* *Evergreen(I)*	FP1 *FUJI* *JPSW* *JPX* *PS1*	TRAPAC	9,000	Singapore(I)–Kobe–Nagoya–Tokyo–San Pedro Bay–**Oakland**–Tokyo–Shimizu(I)–Kobe–Nagoya–Tokyo
2 **ONE** Hapag–Lloyd Yang Ming Hyundai(I)	FP2	OICT	14,000	Jeddah(I)–Singapore–Laem Chabang–Vung Tau/Cai Mep–Hong Kong–Yantian–San Pedro Bay–**Oakland**–Yokohama–Hong Kong–Laem Chabang–Vung Tau/Cai Mep–Singapore
3 **ONE** Hapag–Lloyd Yang Ming Hyundai	PS3	TRAPAC	8,500	Nhava Sheva–Pipavav–Colombo–Port Klang–Singapore–Vung Tau/Cai Mep–Haiphong–San Pedro Bay–**Oakland**–Busan–Shanghai–Ningbo–Shekou–Singapore–Port Kelang–
4 **Yang Ming** ONE Hapag-Lloyd Hyundai	PS4	TRAPAC	6,500	Xiamen–Yantian–Kaohsiung–Keelung–San Pedro Bay–**Oakland**–Keelung–Kaohsiung–
5 **ONE** Hapag-Lloyd Yang Ming Hyundai	PS6	TRAPAC	9,000	Qingdao–Ningbo–Busan–San Pedro Bay–**Oakland**–Kobe–
6 **ONE** Hapag-Lloyd Yang Ming Hyundai	PS8	TRAPAC	8,600	Shanghai–Kwangyang–Busan–San Pedro Bay–**Oakland**–Busan–Kwangyang–Incheon

Ocean Alliance	CMA-CGM, APL, COSCO Shipping, Evergreen, OOCL			
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **COSCO Shipping** CMA CGM APL Evergreen(I) OOCL	SEA Yangtse CC4 SEA VCS	OICT	10,000	Nhava Sheva(I)–Karachi(I)–Colombo(I)–Laem Chabang–Haiphong–Shanghai–Ningbo–San Pedro Bay–**Oakland**–Lianyungang(I)–Shanghai–Ningbo–Shekou(I)–Nansha(I)–Singapore(I)–Port Klang(I)–
2 **Evergreen** APL COSCO Shipping CMA CGM	CPS CC5 AAC3 Hangzhou Bay Bridge (HBB)	NUTTER	9,000	Qingdao–Shanghai–Ningbo–San Pedro Bay–**Oakland**–Tokyo–
3 **Evergreen** CMA CGM COSCO Shipping APL(I)	TPA Jade Express AAS4 SC8	NUTTER	7,000	Port Klang(I)–Cai Mep(I)–Hong Kong–Kaohsiung–Taipei–San Pedro Bay–**Oakland**–Tacoma–Kaohsiung–Ningbo–Shanghai–Shekou–
4 **Evergreen** COSCO Shipping OOCL CMA CGM	HTW AAS3 PCS2 Guangdong Express (GEX)	NUTTER	8,500	Taipei–Xiamen–Hong Kong–Yantian–San Pedro Bay–**Oakland**–
5 **CMA CGM** APL COSCO Shipping Evergreen OOCL	Columbus JAX PE1 SEA2 PE1 SEAP - PSW	OICT	10,000	(USEC)–Port Klang–Singapore–Laem Chabang–Cai Mep/Vung Tau–Yantian–San Pedro Bay–**Oakland**–Yantian–Cai Mep/Vung Tau–Singapore–Port Klang–Colombo–(USEC)

Bolded Carrier(s) *operates all or the majority of vessels within the service*
(Italicized Carrier) denotes non-alliance carrier with slot allocation on the service
(I) denotes ocean carrier does not market corresponding port on rotation
Vessel Size is Nominal Capacity, in TEUs

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Transpacific Services, continued

2M	Maersk, MSC			
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **Maersk**	TP8	OICT	11,000 - 11,300	Qingdao–Shanghai–Ningbo–Busan–San Pedro Bay–**Oakland**–
MSC	ORIENT			
Hamburg Sud	*UPAS 1*			
2 **Maersk**	TP2	OICT	11,075 - 13,800	Singapore–Laem Chabang–Nansha–Yantian–Shanghai–San Pedro Bay–**Oakland**–Busan–Ningbo–Shanghai–Yantian–Tanjung Pelepas–
MSC	JAGUAR			
Hamburg Sud	*UPAS 2*			

Non-alliance				
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **APL**	EX1	OICT	5110	Qingdao–Shanghai–Busan–San Pedro Bay–**Oakland**–Yokohama–Naha–Busan–

Bolded Carrier(s) *operates all or the majority of vessels within the service*
(Italicized Carrier) denotes non-alliance carrier with slot allocation on the service
(‡) denotes ocean carrier does not market corresponding port on rotation
Vessel Size is Nominal Capacity, in TEUs

North Europe & Mediterranean Services

THE Alliance	Hapag-Lloyd, ONE, Yang Ming, Hyundai			
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **ONE** Hapag–Lloyd Yang Ming	AL5 WB	OICT	4,000 - 4,900	Southampton–Le Havre–Rotterdam–Hamburg–Antwerp–Savannah(‡)–Cartagena(‡)–Balboa(‡)–San Pedro Bay–**Oakland**–Seattle(‡)–Vancouver(‡).
CMA CGM (‡)	*California Bridge*			
2 **ONE** Hapag–Lloyd Yang Ming	AL5 EB	OICT	4,000 - 4,900	Seattle(‡)-Vancouver(‡)–**Oakland**–San Pedro Bay–Balboa(‡)–Cartagena(‡)–Caucedo(‡)–Savannah(‡)–Southhampton–Le Havre–Rotterdam–Hamburg–Antwerp.
CMA CGM (‡)	*California Bridge*			

Non-alliance				
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **MSC**	California Express	OICT	8,800 - 9,400	Gioia Tauro–Civitavecchia–La Spezia–Fos–Valencia–Sines–Cristobal–Rodman–Manzanillo MX–San Pedro Bay–**Oakland**–Vancouver–Seattle–**Oakland**–San Pedro Bay–Ensenada–Manzanillo MX–Rodman–Cristobal–Barcelona–
2 **Hapag-Lloyd**	MPS	OICT	4,610 - 4,890	Livorno–Genoa–Fos–Barcelona–Valencia–Cartagena–Puerto Quetzal(‡‡)– Manzanillo MX(‡‡)–San Pedro Bay–**Oakland**–Seattle–Vancouver–**Oakland**–San Pedro Bay–Manzanillo MX(‡‡)–Manzanillo PA–Cartagena–Caucedo(‡‡)(‡)–Tangier–Valencia–
Hamburg Sud (‡)	MCPS			
ZIM(‡‡)	MPS			

Bolded Carrier(s) *operates all or the majority of vessels within the service*
(Italicized Carrier) denotes non-alliance carrier with slot allocation on the service
(‡) or (‡‡) - ocean carrier does not market corresponding port on rotation
Vessel Size is Nominal Capacity, in TEUs

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Latin America Services

THE Alliance	Hapag-Lloyd, ONE, Yang Ming, Hyundai			
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **ONE** Hapag-Lloyd Yang Ming	AL5 WB	OICT	4,000 - 4,900	Southampton–Le Havre–Rotterdam–Hamburg–Antwerp–Savannah–Cartagena–Balboa–San Pedro Bay–**Oakland**–Seattle–Vancouver.
2 **ONE** Hapag-Lloyd Yang Ming	AL5 EB	OICT	4,000 - 4,900	Seattle-Vancouver–**Oakland**–San Pedro Bay–Balboa–Cartagena–Caucedo–Savannah–Southhampton–Le Havre–Rotterdam–Hamburg–Antwerp.

Non-alliance				
OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **MSC**	California Express	OICT	8,800 - 9,400	Gioia Tauro–Civitavecchia–La Spezia–Fos–Valencia–Sines–Cristobal–Rodman–Manzanillo MX–San Pedro Bay–**Oakland**–Vancouver–Seattle–**Oakland**–San Pedro Bay–Ensenada–Manzanillo MX–Rodman–Cristobal–Barcelona–
2 **Hapag-Lloyd** Hamburg Sud (‡) ZIM (‡‡)	MPS MCPS MPS	OICT	4,610 - 4,890	Livorno–Genoa–Fos–Barcelona–Valencia–Cartagena–Puerto Quetzal (‡‡)–Manzanillo MX (‡‡)–San Pedro Bay–**Oakland**–Seattle–Vancouver–**Oakland**–San Pedro Bay–Manzanillo MX (‡‡)–Manzanillo PA–Cartagena–Caucedo (‡‡) (‡)–Tangier–Valencia–
3 **Hamburg Sud** SeaLand CMA CGM (‡)	WAMS WCCA2 AZTECA1	OICT	1,840	Guayaquil (‡)–Puerto Bolivar (‡)–Balboa–Puerto Caldera–Puerto Quetzal–Port Hueneme (‡)–**Oakland**–San Pedro Bay–Manzanillo MX–Lazaro Cardenas–Puerto Quetzal–Balboa–

Bolded Carrier(s) *operates all or the majority of vessels within the service*
(Italicized Carrier) denotes non-alliance carrier with slot allocation on the service
(‡) or (‡‡) - ocean carrier does not market corresponding port on rotation
Vessel Size is Nominal Capacity, in TEUs

Oceania Services

OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **ANL** (3 vessels) **Hamburg Sud** (3 vessels) **Hapag-Lloyd** (1 vessel) MSC (‡)	PSW1 PANZ WSN OCEANIA LOOP 1	OICT	3,534 - 5,044	Auckland–Sydney–Melbourne–Adelaide (‡‡)–Tauranga–Papeete (‡‡) (‡)–**Oakland**–Seattle (‡‡)–Vancouver (‡‡)–San Pedro Bay–Auckland–
2 **Hamburg Sud** **Polynesia Line**	SSEA POLYNESIA	OICT	550 - 1,100	Papeete–Apia–Pago Pago– San Pedro Bay– **Oakland**–

(‡‡) denotes fortnightly service
(‡) denotes ocean carrier does not market corresponding port of rotation
Weekly feeder service to* ***Suva *via Auckland***

Hawaii Services

OCEAN CARRIER	**SERVICE NAME**	**TERMINAL**	**VESSEL SIZE**	**ROTATION**
1 **Matson**	Hawaii (1)	Matson		Honolulu–**Oakland**–Los Angeles(*)–
2 **Matson**	Hawaii (2)	Matson		Honolulu–Seattle–**Oakland**–
3 **Pasha**	CHX	OICT		Honolulu–**Oakland**–San Pedro Bay–

Bolded Carrier(s) *operates all or the majority of vessels within the service*
(Italicized Carrier) denotes non-alliance carrier with slot allocation on the service
(‡) denotes ocean carrier does not market corresponding port on rotation
(*) denotes port called fortnightly
Vessel Size is Nominal Capacity, in TEUs

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Figure 2-12. Ocean Carrier Services - Port of Oakland, Source: portofoakland.com, July 2020.

2.3.3. TEU Weight by Container

TEU weight data was obtained by USACE and confirmed with the Port to determine weight per TEU. Data was obtained at a country and region level for calendar years 2014 through 2018 and were grouped into world regions and four route groups: Northeast Asia to West Coast United States (NEA-WCUS), Southeast Asia and India Sub-continent to West Coast United States (SEA-WCUS), Europe to United States (EU-WCUS), and Oceania to West Coast United States (Oceania-WCUS). This methodology is further described in Section 3.3.2. Table 2-6 presents loaded TEU weights, including the box weight of approximately 2 metric tons per box, for each world region. Table 2-7 presents loaded TEU weights by route group. Oakland's export commodities (mostly agricultural products including fruits, nuts, and wine) typically weigh substantially more than imports, and is reflected in the weight/TEU observations to its major trading partners of Asia and Europe.

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

World Region	Import – Average Weight per Loaded TEU (MT)	Export – Average Weight per Loaded TEU (MT)	Imports and Exports – Average Weight per Loaded TEU (MT)
Africa	11.6	11.6	11.6
Asia	6.6	10.0	8.3
Europe	9.4	11.5	10.7
Latin America & Caribbean	11.2	12.0	11.3
Middle East/Indian Subcontinent	12.5	10.8	11.0
Oceania	14.2	10.7	12.3

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

Route Group	Import - Average Weight per Loaded TEU (MT)	Export - Average Weight per Loaded TEU (MT)	Imports and Exports - Average Weight per Loaded TEU (MT)
Route 1: Northeast Asia	6.6	10.0	8.3
Route 2: Southeast Asia, Indian Sub-continent, and Middle East	9.5	10.4	9.9
Route 3: Europe, Africa, North America, Latin and South America	10.3	11.6	10.8
Route 4: Oceania	14.2	10.7	12.3
Overall Average Weight per Loaded TEU	7.9	10.3	9.1

2.4. Existing Fleet

Data for the container fleet was obtained from IHS Maritime's Sea-web database. From 2014 to 2019 a variety of different container ships called on the Port of Oakland. These ships are classified for this study as Sub-Panamax (SPX), Panamax (PX), Post-Panamax Generation 1 (PPX1), Post-Panamax Generation II (PPX2), Post-Panamax Generation III (PPX3), and Post-Panamax Generation IV (PPX4) depending on their capacity. The vessels are distinguished based on physical and operational characteristics, including lengths overall (LOA), design draft, beam, speed, and TEU capacity. It is common practice to separate the containership fleet in TEU bands or classes to analyze supply within the industry. However, due to the evolution of vessel design over time, these TEU bands do not correspond to a breakdown of the fleet by dimensions such as beam or draft. Accordingly, breakdowns in terms of beam and draft straddle different classes. To minimize the overlap, the beam band or range was used to distinguish container vessels into six vessel classes as shown in Table 2-8.

The authorized Federal project at Oakland is 50’ deep (MLLW), 900’ wide in the Entrance and Outer Harbor Channels, and 800’ wide in the Inner Harbor Channel. The original design vessel (circa 1998) for the Oakland Harbor Deepening Study was a 1,139-foot-long containership with a 6,500 TEU capacity. Today, vessels with nearly triple the capacity of the original design vessel call at the Port. Table 2-8 displays the fleet and associated dimensions of container ships that call at the Port of Oakland. The table displays the fleet in order of size, smallest to largest.

Sub-Panamax (SPX) and Panamax (PX), generally 4,800 TEUs and below, refer to those vessels that fit through the Panama Canal locks prior to its redesign. Post-Panamax Generation I and II, generally 9,900 TEUs and below, refer to those vessels that were too large to fit through the original Panama Canal. Post-Panamax Generation III, generally 15,000 TEUs and below, refers to the “New Panamax” vessels that were designed to fit through the expanded Panama Canal locks, which opened in 2016. Finally, Post-Panamax Generation IV refers to those vessels that are too large to fit through the expanded Panama Canal (i.e., the “new” Post-Panamax vessels), with capacities above 15,000 TEUs. All vessel classes listed in Table 2-8 regularly call at the Port, except for the Post-Panamax Generation IV.

Table 2-8. Container Vessel Fleet Subdivisions and Dimensions

Vessel Fleet Subdivision (Containerships)		From	To
Sub Panamax	Beam	0	98
	Draft	8.2	38.1
	LOA	222	813.3
	TEUs	Up to	2,800
Panamax	Beam	98	106
	Draft	30.8	44.8
	LOA	572	970
	TEUs	2,801	4,800
Post-Panamax Generation I (Post-Panamax)	Beam	106	138
	Draft	35.4	47.6
	LOA	661	1045
	TEUs	4,801	6,800
Post-Panamax Generation II (Super Post-Panamax)	Beam	138	144
	Draft	39.4	49.2
	LOA	911	1,205
	TEUs	6,801	9,900
Post-Panamax Generation III (New Panamax, or Ultra Post-Panamax)	Beam	144	168
	Draft	Up to	51.2
	LOA	Up to	1220
	TEUs	9,901	15,000
Post-Panamax Generation IV (New Post-Panamax)	Beam	168	200
	Draft	Up to	52.5
	LOA	1,295	1,315
	TEUs	15,000	23,000

Table 2-9 shows vessel calls at the Port of Oakland from 2014-2019, broken down by vessel class, based on data collected by the Port. Over this period, the use of Panamax vessels at the Port of Oakland is trending downward while the use of larger vessels is trending upward. The majority of vessel calls have shifted from PPX Generation I in 2014 to PPX Generation II by 2019. This shift can be attributed to smaller vessels (i.e., Panamax) being replaced with larger vessels that carry more tonnage on a single voyage, as evidenced by the increase in cargo tonnage and TEUs, and decrease in vessel calls, since 2014. This trend to reduce voyages is an effort to realize economies of scale in the container shipping market. While no PPX Generation IV vessels called from 2017-2019, there were four calls in 2020, five calls in 2021, and three in 2022.

Table 2-9. Container Vessel Fleet Port Calls by Class, 2014-2020 (Sources: USACE, 2023; Port of Oakland, 2020)

	Sub-Panamax	Panamax	PPX1	PPX2	PPX3	PPX4	Total
2014	109	485	518	273	174	0	1,558
2015	76	277	424	268	208	0	1,252
2016	112	316	508	378	247	3	1,563
2017	99	232	492	416	205	0	1,442
2018	96	163	498	398	231	0	1,386
2019	175	140	352	371	210	0	1,248
2020	75	104	255	406	217	4	1,061

Figure 2-14 shows the annual number of container vessels added to the world fleet from 1980 to 2021 by vessel classification, based on information obtained S&P Global SeaWeb. Finally, Figure 2-15 shows the progression of containerships calling the Port of Oakland from 1955 to present day. It should be noted that the 18,000 nominal TEU capacity ship CMA CGM Benjamin Franklin called the Port of Oakland on February 29, 2016 as part of a trial deployment of these ultra-large containerships to U.S. West Coast ports from Asia. Since then, many of these large capacity ships called on Oakland for spot charters in 2020.

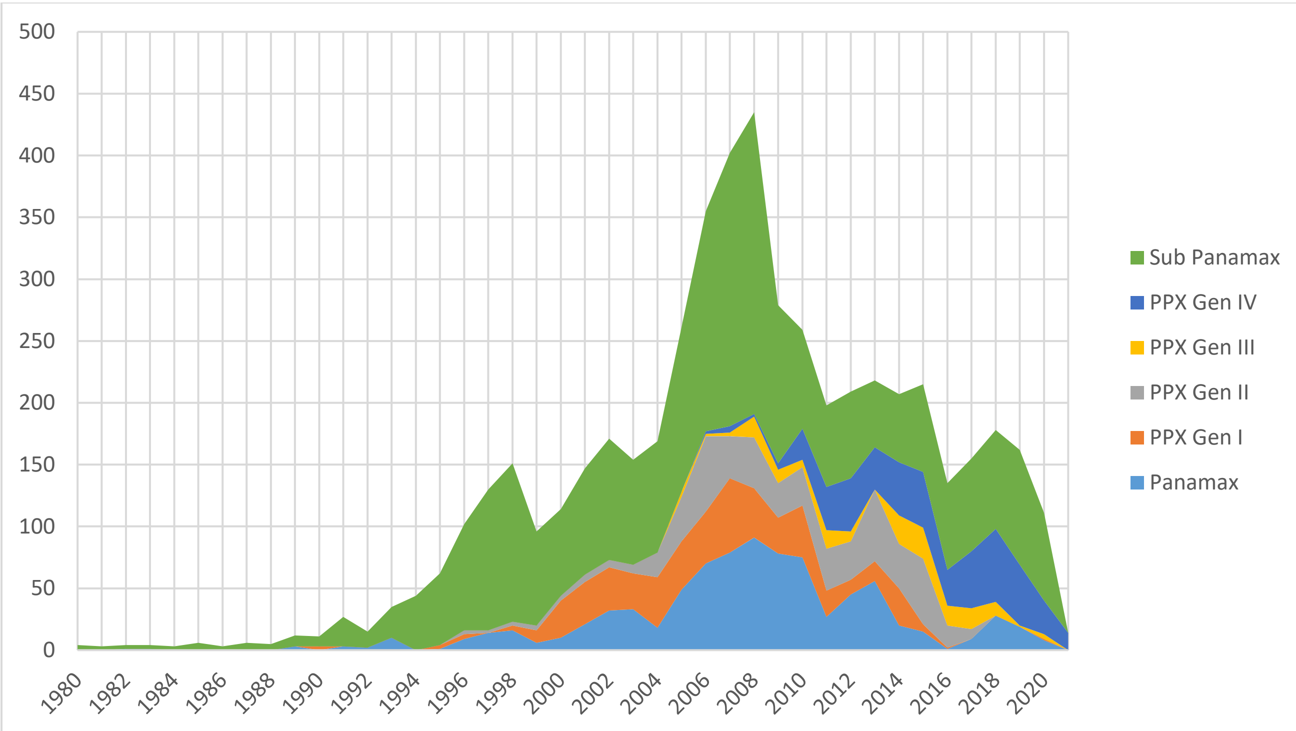


Figure 2-13. Total Number of New Container Vessels added to the World Fleet, by class, 1980-2021

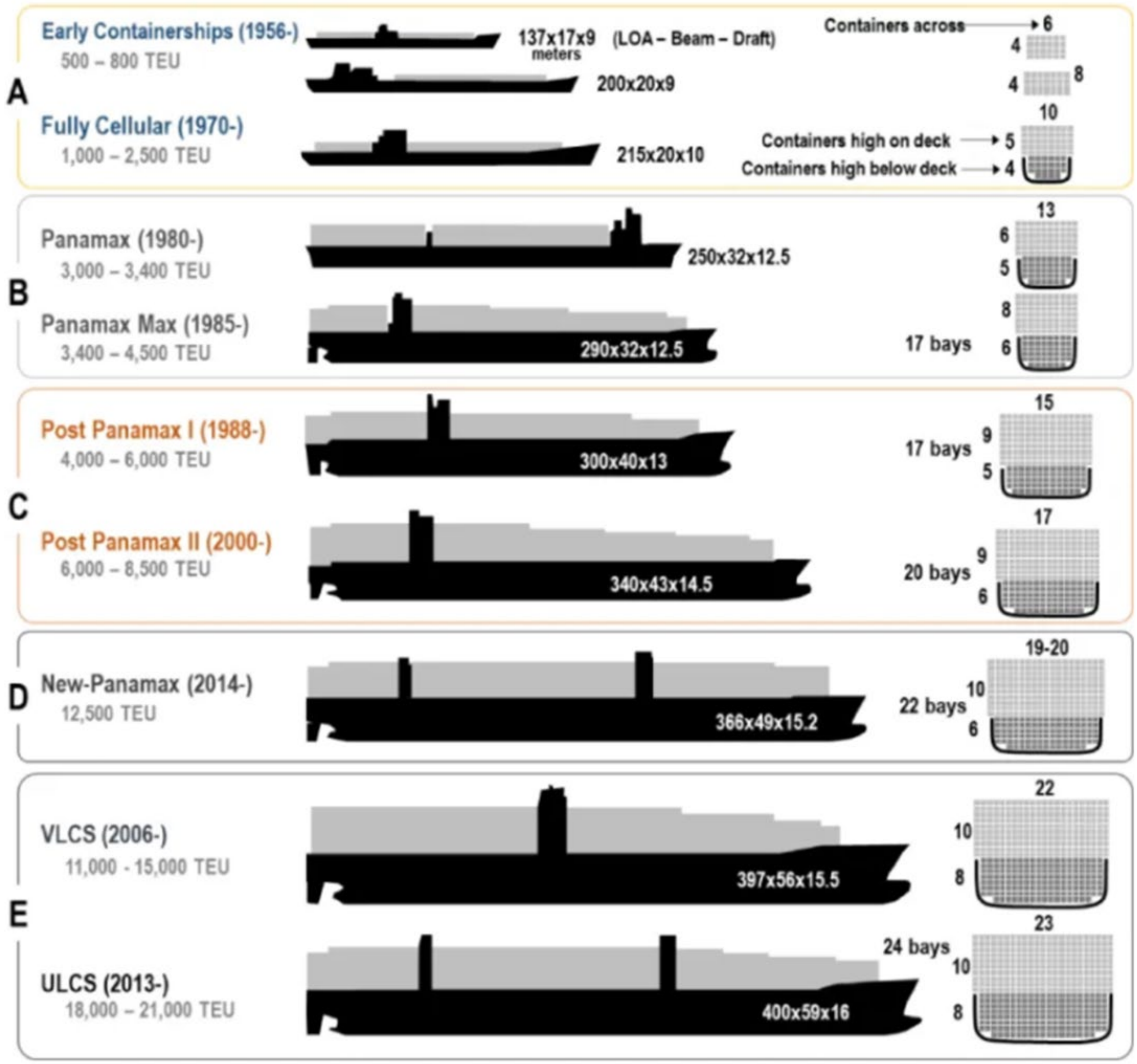


Figure 2-14. Containership Growth at Port of Oakland, 2000-Present

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

Oakland Pilots records show that the average containership size in the Port of Oakland has grown by 20 percent through the previous 5 years, from 2014 through 2019, according to USACE's Waterborne Commerce Statistics Center data. As shown in Table 2-10 below, the average ship for Oakland Harbor in 2014 was about 66,663 gross tons, and in 2019 the average ship had increased to 83,544 gross tons. This represents a 3.5 percent compound annual growth rate. This rate of growth in the typical ship, if sustained, would indicate the average ship gross tonnage for base year 2030 to be 90,000—typically classified as a Generation II Post-Panamax containership.

Table 2-10. Average Ship Gross Tonnage by Year, 2014-2019 (Source: USACE 2021)

Year	Average Gross Tonnage
2014	66,663
2015	71,621
2016	72,404
2017	74,822
2018	78,310
2019	83,544

Oakland is already handling a significant number of Post-Panamax ships. From 2014 through 2018, about 80 percent of all calls were Post-Panamax calls. Of all containership calls in this same period, 1,656 inbound or outbound transits were longer than current PPX Generation II LOA (1,115 ft.), which represents 12 percent of all containership transits over that period. Table 2-11 and Figure 2-17 display percent cargo by vessel class for years 2014 to 2019. Total cargo movements on PPX Generation II or larger containerships grew from 38 percent in 2014 to 46 percent in 2019.

Table 2-11. Percent Cargo by Vessel Class, 2014-2019 (Source: USACE, 2022)

	2014	2015	2016	2017	2018	2019
Sub Panamax	6%	5%	5%	6%	5%	4%
Panamax	9%	10%	10%	8%	7%	6%
PPX Generation I	46%	43%	37%	41%	42%	44%
PPX Generation II	21%	28%	32%	28%	28%	26%
PPX Generation III	17%	14%	16%	17%	17%	18%
PPX Generation IV	0%	0%	0.3%	0%	0%	2%

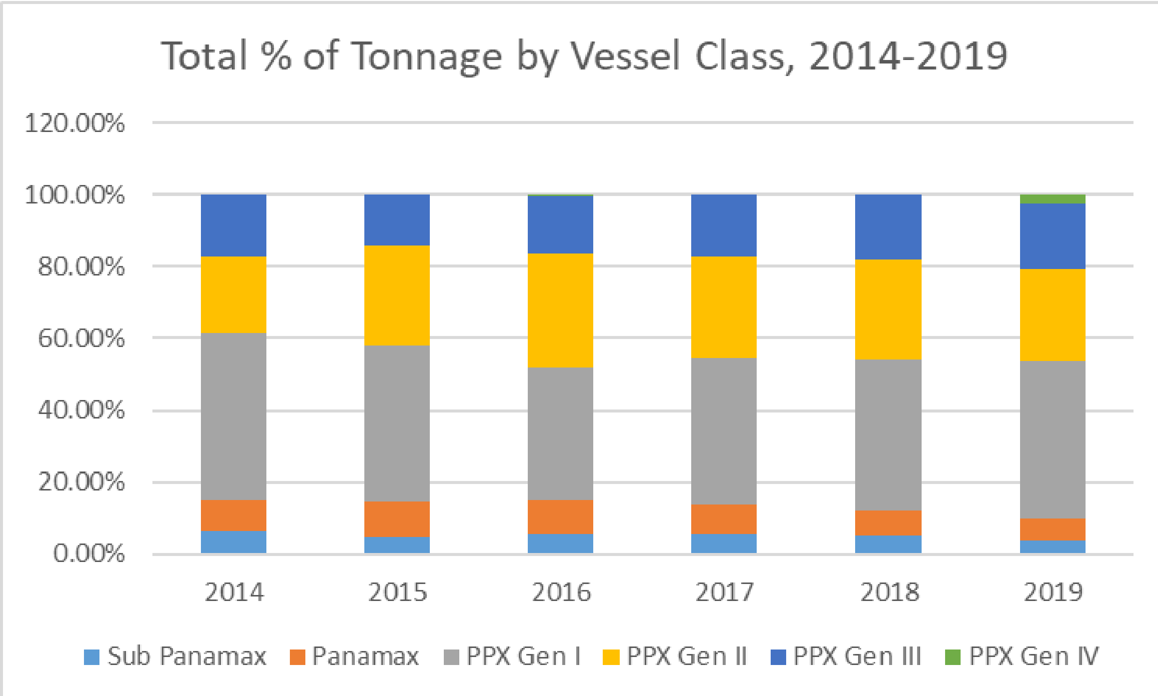


Figure 2-15. Total % of Tonnage by Vessel Class, 2014-2019 (Source: USACE, 2022)

Vessels currently calling at the Port of Oakland include 1,210-foot-long vessels in both the Inner and Outer Harbors, including 14,354 TEU capacity Evergreen vessels and 13,892 TEU capacity APL vessels. In Spring 2016, the 18,000 TEU CMA CGM Benjamin Franklin called both Inner and Outer Harbors. As previously mentioned, in 2020, four 19,000 TEU vessels called, with lengths of over 1,300 ft. Annual vessel calls averaged around 1,200 for the Inner Harbor and 400 for the Outer Harbor from 2015 to 2018, as shown in Figure 2-17. Non-containerized cargo and bulk vessels also called at the Inner Harbor and included Ro/Ro cargo and scrap metal exports.

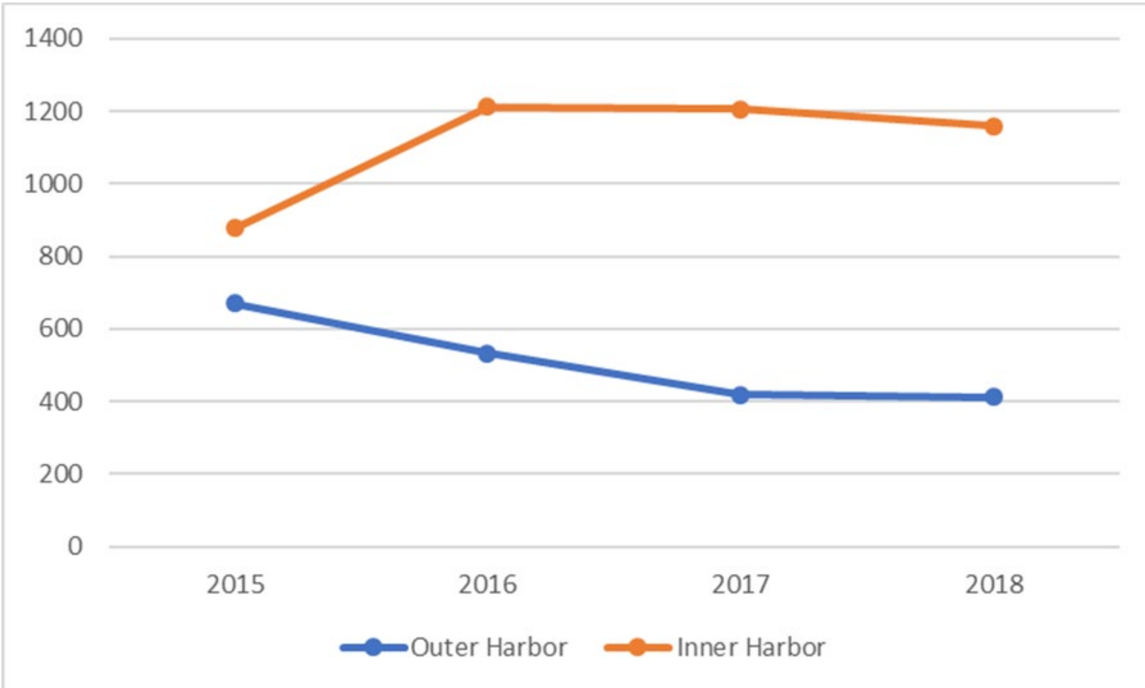


Figure 2-16. Vessel Calls by Channel, 2015-2018 (Source: Port of Oakland, 2020)

2.5. Shipping Operations

2.5.1. Pilot Restrictions on Large Container Vessels

Vessel transit guidelines are documented for the San Francisco Bar Pilots. Below are general guidelines for containership operations at the port. Ships calling at the Port of Oakland are subject to the San Francisco Bar Pilot (Pilots) guidelines.

Though the PPX Generation IV vessel class is expected to call with increased frequency on the U.S. west coast, it cannot call at the Port of Oakland without extensive restrictions, particularly in the Inner Harbor, due to the size of the turning basins. PPX Generation IV vessels typically range from 1,295-1,315' in length; therefore, they require additional tugs, pilots, and specific schedules to operate safely. Additionally, large tides and strong resulting currents can cause navigation issues for larger vessels transiting to and from Oakland's harbors.

In late 2015 and 2016, an 18,000 TEU container vessel, the CMA CGM Benjamin Franklin, called at the Port, in anticipation of PPX Generation IV vessels being deployed on Asia-West Coast routes. This PPX Generation IV vessel has a LOA of 1,310', a breadth of 178', and a design draft of 52.5'. It was able to call at the Port's Outer and Inner harbor, but required the following limitations:

- Outer Harbor:
  - Daylight transits only
  - Move only during slack water
  - Have an additional pilot onboard

    - Did not use turning basin to dock (berthed adjacent to the turning basin, blocking it for other traffic); swung through the basin from the dock to depart
- Inner Harbor
    - Daylight transits only
    - Move only during slack water
    - Have an additional pilot onboard
    - Did not use turning basin to dock (drove straight to berth, bow-in)
    - Backed out of berth with multiple tugs and turned outside the Inner Harbor Channel
    - No other movements into Outer or Inner Harbors during transits; resulting in 2-3-hour delays in scheduled arrivals and departures

These limitations have been adopted as standard practice for the pilots when handling PPX Generation IV vessels at the Port since 2016, including the four calls that occurred in 2020, and several more in 2021. Based on discussions with the Port, it is assumed that these PPX Generation IV vessels will call less frequently in the Inner Harbor when compared to the FWP alternative. Further, it is assumed that PPX Generation IV vessels will not call in the Outer Harbor due to their inability to use the turning basin and the impact on port operations.

2.6. Design Vessel

"For deep-draft projects, the design ship or ships are selected based on economic studies of the types and sizes of the ship fleet expected to use the proposed navigation channel over the project life. For project improvement studies, a thorough review and analysis of ships presently using the project should be included as a part of the study. Projections of ship fleet data, usually needed, account for expected ship construction trends" (USACE 1984, 1995, 1999).

For the Port of Oakland, the economics and coastal hydraulics team recommended consideration of a Generation IV Post-Panamax containerized carrier for evaluation based on timing for inception and frequency of service over the period of analysis. Historically, new vessels are first deployed on the Trans-Mediterranean lines, followed by the Pacific including the West Coast three to seven years later, followed by the Atlantic including the East Coast three to five years later, and finally calling the Gulf Coast a few years after the East Coast deployments. The specifications for the recommended design vessel are as follows:

Post-Panamax Generation IV

- 193 ft. in beam (extreme breadth (XB))
- 1,310 ft. length over all (LOA)
- Approximately 52.5 ft. maximum summer load line draught (MXSLLD)
- Nominal TEU intake of approximately 18,000 to 19,000 TEUs

It should be noted that the future fleet of containerships which may call Oakland may exceed the dimensions of the design vessel. As of January 2021, 19,000 nominal TEU capacity containerships have called Oakland on multiple occasions.

The selection of vessel specifications for fleet service forecasts and waterway engineering evaluations sometimes poses unique concerns given requirements to evaluate design and improvements for waterway systems over time. Generally, waterway improvements should be designed to be optimized across the entire fleet forecast regime or structure. Typically, it may include service by several sizes and types of vessels (i.e., bulk carriers, containerships, tankers, etc.). Where vessel designs are relatively mature (tankers and dry bulk carriers), the task is comparatively straightforward. However, where consideration is to include fully cellular containership services, associated hull designs are still evolving. On a world fleet basis, containership designs continue to change with respect to size and cargo carrying capacity and have not reached an absolute limiting threshold for rated carrying capacity as measured by weight (deadweight tonnage) or nominal intake for standard-unit slot capacity (i.e., nominal TEUs). Figure 2-18 below shows the current state of the world containership fleet by vessel classes for this study.

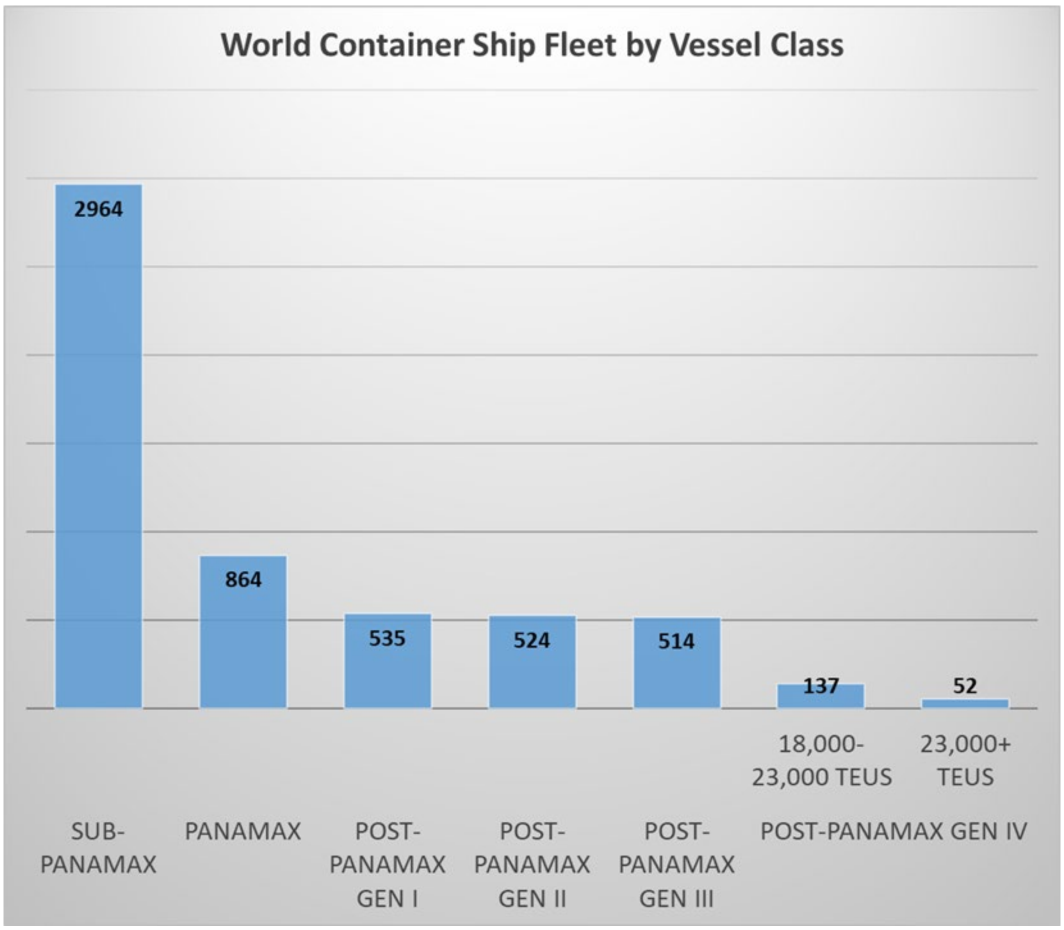


Figure 2-17. World Container Ship Fleet by Vessel Class; Source: Maritime IHS Sea-web as of November 2020; includes vessels On Order/Projected/Under Construction, which accounts for 38% of 23,000-TEU vessels

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

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

In addition to new or evolving Panamax specification, fleet service for harbors on the west of the United States such as Oakland have the potential to be serviced by the new Post-Panamax class(es) of ships, especially where concerns for depth and limitation on air draft are of little concern. The primary issue for these carriers is a matter of timing or when they will initiate service, frequency of service, and applicable load factor specifications applicable to the trades involved. These vessels fall within the classification of what could be called Generation IV (and above) Post-Panamax (with the definition of Post-Panamax based on the original or lock specifications of the Canal) or new Post-Panamax based on the new locks that were completed in 2016. The Generation IV Post-Panamax class of containership have beams exceeding 168 ft. through 185 to nearly 190 ft. and accordingly this class of ship represent hulls that are considered to clearly exceed the margins for accommodation of the new lock system of the Panama Canal and as previously described fall into the realm of what may be considered to the "new" Post-Panamax standard once the new lock system is commissioned into service.

Studies for Oakland Harbor involve the assessment and projection of fleet service to multiple terminals located in separate reaches of the harbor. These include containerized cargo handling facilities located along the Inner and Outer Harbors of Oakland. Neither the Golden Gate nor the Bay Bridge impose air draft limitations for these containerized cargo handling facilities within the harbor. Both Harbors are designed to allow only one-way traffic.

An analysis of the projected needs for Oakland Harbor has determined that both harbors will likely support the largest containerships that will serve the harbor via Pacific crossing routes from Asia. The Inner and Outer Harbors will need to be designed to support Post-Panamax Generation I-III range vessels currently serving the U.S. West Coast over the next several years with the potential to eventually support Generation IV or analogous vessels subject to timing and frequency. Oakland Harbor currently sees frequent calls from Generation II and Generation III containerships. The authorized width of the two waterways is 800 ft. and this falls within the recommended width to accommodate these existing vessel calls and those of larger containerships (Generations III and IV) in the future.

USACE has also conducted studies in the ports of Seattle, Tacoma, and Long Beach over the last five years, and any assumptions regarding the future fleet at Oakland must take previous assumptions of those studies into account. As many of the container liner services call on those ports, as well as Oakland on a given route, the future fleets for all these studies should be similar and consistent. The design vessels for those studies, based on the future fleet projections are as follows:

<u>Seattle Harbor Study</u>

Post-Panamax Generation III
1,200 to 1,220 ft. length over all (LOA)
168 ft. beam
51.2 ft. draft
Nominal TEU intake of 12,800 to nearly 14,000 TEUs

Post-Panamax Generation IV
1,300 to 1,315 ft. length over all (LOA)
185 to 190 ft. in beam
51.4 to 52.6 ft. draft
Nominal TEU intake of approximately 14,200 to 15,800 TEUs

<u>Tacoma Harbor Study</u>

1,295 to 1,315 ft. length overall (LOA)
175 to 194 ft. in beam
47.6 to 52.5 ft. draft
Nominal TEU intake of approximately 15,500 to 19,200 TEUs

<u>Long Beach Harbor Study</u>

1,300 ft. LOA
193 ft. in beam

52 ft. in draft
Nominal TEU intake of approximately 18,000 to 19,000 TEUs

Review of the world fleet indicates that as of December 2020, there were about 514 Generation III ships (i.e., approximately 152 to nearly 168 ft. in breadth) in service, under construction, or on order with TEU intake averaging nearly 12,400 nominal TEUs. Of the 514, about 68 percent were identified as the smaller sub-grouping (between 152 to nearly 160 ft. in XB) of Generation III ships. There are about 140 in service, under construction, or on order to be delivered in five years or less with corresponding nominal TEU intake capacities averaging nearly 11,800 TEUS. The upper 50 percent of this sub-group (as measured by TEU capacity) averaged about 13,060 nominal TEUs, 1,200 ft. LOA, nearly 1,150 ft. lower boundary point (LBP), 158 ft. XB, and 51.1 ft. in MXSLLD. For ships in the upper bound of the Generation III class range (with breadths of 160 to nearly 168 ft.), review of statistics indicates the larger sub-group of Generation III averaged about 13,740 TEUs, 1,200 ft. LOA, 1,047 ft. LBP, 168 ft. XB, and 51.3 ft. in reported MXSLLD. The corresponding upper 50 percent of the sub-group averages approximately 14,000 nominal TEUs, 1,200 ft. LOA, 168 ft. in XB, and 51.7 ft. in reported MXSLLD.
A review of new builds for containerized carriers as supported by the statistics reveal that for containerized carriers, the fixed dimensions of length, breadth, and draught largely converge toward the physical limits of the new locks presently under construction for expansion of the Panama Canal. Further, general evaluation indicates that more recent builds tend to have a greater proportion of nominal TEU capacity per rated deadweight tons (DWT) with efforts to more fully support repositioning or prepositioning of empty containers and where possible, better utilize DWT capacity given lashing and line of sight requirements, and typical cargo weights in containerized trade. The upper bound of 50 percent was assessed for sub-groupings as described and past experience has indicated physical dimensions and characteristics in the upper half of a sub-grouping for containerized carriers seem to provide a reasonable estimation for the general trends in characteristics for DWT and nominal TEU capacity for the foreseeable future[13]. To develop parameters for specifications of the future fleet representative of interim to long-term building trends for studies related to Oakland Harbor, the upper 50 percent of fleet groupings or sub- groupings operating and on order as of mid-2012 was selected as the basis for compilation of aggregate statistics representative of the trend toward increased TEUs relative to DWT. Additionally, general review of information for pending or publicized designs indicates the approach as generally described is reasonable for fleet forecast of physical parameters for hull design[14].

One issue for review of statistics is the specification for MXSLLD. The reported measures of length and breadth currently and historically available are often comparatively accurate across the reporting history of the world fleet database(s). However, the MXSLLD and requisite capacity based on related displacement is sometimes (initially) overstated because of confusion with initial reporting of draft for new builds of either MXSLLD or scantling draft without clarification as to which measure is actually reported or publicized followed by subsequent correction in the fleet characteristics database(s). The publicly stated capacity of the new locks under construction for expansion of the Panama Canal by physical dimension(s) is for a vessel not to exceed the following limits: 160 ft. in XB, 50 ft. in immersed draft TFW, approximately

[13] Maritime Strategies International (MSI) U.S. West Coast Deployment study for container fleets, 2015
[14] IHS Maritime SeaWeb online ship register data, collected January 2021

equal to 49.0 to 48.6 Summer Load Line (SLL) immersion (depending on hull shape and characteristics of displacement), 1,200 ft. for LOA, and 190 ft. for air draft above the immersed waterline. Research and review of MXSLLD indicates that with increasing breadths very few designs are being developed with MXSLLDs exceeding 50.0 to nearly 51.0 ft.. While traditionally it was not uncommon to see Panamax ships with MXSLLDs exceeding canal draught allowances by a notable margin (i.e., typically a world fleet average of 42.0 to 43.0 ft. versus the less than 40-foot immersed draft in the saline condition), the threshold of 50.0 to nearly 51.0 ft. appears to largely be driven by practical needs as a whole for port and berth depths as well as hydrologic considerations of the canal. With time, it is possible that the trend for increasing port depths will continue beyond limitations of the improved canal but will likely occur several years after canal improvements similar to the way Panamax carriers changed over time after the original locks were constructed and utilized. Accordingly, review of MXSLLD measurements for Generation II and lesser size carriers (which have been in existence and service comparatively longer than most Generation III hulls) indicate draft measurements are accurately or reasonably reported. However, some degree of adjustment may need to be applied to sub-groupings of Generation III carriers (i.e., hulls between approximately 150 and 158 ft. in XB) with adjustment to 50.0 ft. MXSLLD and relative capacity based on holding other dimensions and corresponding block coefficient(s) constant for estimation of change in associated displacement and DWT capacity as may be applicable to economic evaluations.

3. Future Conditions

3.1. Terminal Expansions

As mentioned in Section 2.1.1, the Port of Oakland's four active container terminals are:

- TraPac Terminal
- Ben E. Nutter Terminal
- Oakland International Container Terminal (OICT)
- Matson Terminal

There are efforts underway to expand two of these terminals, as detailed below. These expansion estimates helped inform the landside throughput capacity estimates for how much container cargo the port would be able to handle in the future.

The Ben E. Nutter Terminal is located on a peninsula and qualifies as a berth expansion area. The unused area at Berths 33–34, between the Ben E. Nutter and TraPac terminals, totals 23 acres. This is the only possible expansion space for the Nutter terminal, and as Figure 3-21 shows, the study team has treated it as part of a full build-out for that facility. The area at Berth 34 is not usable as a vessel berth due to the presence of BART's Transbay Tube about 20' below water level.

OICT is effectively fully built out at 290 acres, sharing its eastern boundary with the Matson terminal.

The TraPac terminal been completed partial rehabilitation and expanded to 123 acres. It is adjacent to the vacant 150-acre Outer Harbor Terminal (OHT, former Ports America) site. Because TraPac has recently been expanded and because of discussions around further expansion into the OHT site, this analysis assumes TraPac will expand at least an additional 50 acres in the without-project condition. Based on the Port's September 2019 release of a Notice of Preparation of a Draft Supplemental Environmental Impact Report to develop a dry bulk terminal on 20 acres of land at Berths 20-21, that land may not be available for near-term container terminal use, leaving 130 usable acres. The Port intends to use the Berth 20-21 land for dry bulk over the next 15 years, with potential reversion to container use thereafter.

Table 3-1 provides a summary of the Port’s acreage in terminals and off-dock staging. As the discussion below indicates, there is a distinction between:

- Sites and acreage currently used as operating marine terminals.
- Other sites and acres that could potentially be incorporated in marine terminals but may be idle or in ancillary uses at present, such as Berths 20-21, Berths 22-25, the Roundhouse parcel, and the Howard Terminal.
- Sites suitable for ancillary use but which cannot be incorporated in marine terminals, such as the 30 acres being used for off-dock staging by Shipper's Transport Express (STE).

The existing terminal acres and the acres and sites that could be functionally incorporated into marine terminals as "Potential Terminal Acres".

Table 3-1. Port of Oakland Marine Terminals and Acreages

Site	Acres	2019 Acres in Use	Potential Terminal Acres	Build-out Acres	Post-Electrification Acres
Ben Nutter	75	75	0	**95**	**93**
Berths 33-34	20	-	20		
OICT 55-56	120	120	0	**290**	**288**
OICT 57-59	170	170	0		
TraPac	123	123	0	**123**	**121**
Matson	75	75	0	**101**	**99**
Roundhouse	26	-	26		
Berths 20-21**	20	-	150	**150**	**148**
Berths 22-24	130	-			
Howard*	50	-	50	**40**	**38**
Subtotal	**809**	**563**	**246**	**799**	**787**
Off-Dock Staging***	30	30	0	0	0
Total	**839**	**593**	**246**	**799**	**787**

* Assumes 10 acres will be used for Inner Harbor Turning Basin
** 20 acres may become dry bulk terminal for 15 years (in negotiation)
**Not usable as long-term terminal space

The Matson terminal presently occupies 80 acres. The adjacent Roundhouse site of 39 acres could be used to extend Matson’s terminal to a total of 95 acres, although it does not provide additional berth length.

The Howard Terminal, presently used for ancillary support functions, covers 50 acres. There are no significant expansion options for Howard, and the Inner Harbor Turning Basin could reduce the available land to 40 acres.

Current CARB emission goals generally target zero emissions or near-zero emissions at marine terminals by 2030. With current and foreseeable technologies, achieving these goals requires electrification. Existing electrification technologies place two additional requirements on terminal land:

- Space for a battery exchange and servicing building. At LBCT in Long Beach, this function consumes about 1 acre.
- Additional electric service, potentially including a local substation. The study team has allowed an additional acre for this function.

The post-electrical acres in Table 3-1 therefore reduce the available size of each terminal by 2 acres. Since automation effectively requires electrification, the capacity estimates below reduce the working acres of each terminal according to Table 3-1 as automation is added.

The Port also has about 126 acres of undeveloped off-dock space, part of the former Oakland Army Base. All existing planning documents anticipate this land being used for ancillary support uses, rail infrastructure, or commercial development like the CenterPoint and CoolPort projects. This analysis therefore excludes this site from the terminal capacity estimates.

It should be noted that whether the Berth 33–34 site becomes part of the Nutter terminal or the TraPac terminal does not make a difference in the planning-level capacity estimates. Nor does it matter whether OHT becomes a separate terminal or part of TraPac. The only relevant size distinction is that automation strategies favor larger terminal sizes. While that factor may influence the sequence in which terminals are automated under some scenarios, the long-term potential capacity is a function of the total acres available.

3.2. Future Assumptions

3.2.1. Future Without Project Condition

ER 1105-2-100 states: "The without project condition is the most likely condition expected to exist over the planning period in the absence of a plan, including any known change in law or public policy. It provides the basis for estimating benefits for alternative with project conditions. Assumptions specific to the study should be stated and supported," (USACE, 2000).

3.2.1.1. Assumptions

For this Oakland study, all non-structural measures that are currently in place are assumed to remain in place over the period of analysis. For instance, all additional harbor pilot and assist tug operations will continue in the manner they currently occur to mitigate large container vessel turning operations with the given turning basin dimensions.

There are currently plans to improve the harbor being undertaken by the Port of Oakland that should be included in the future conditions. The transition of a portion of the Oakland Army Base into the new Seaport Logistics Complex is scheduled for completion by the end of 2020.

Key terminal upgrades including crane raisings, crane upgrades, and wharf upgrades are underway now. Other plans to improve truck flows in and out of the port are also scheduled to be complete by 2022. These changes will increase the port's container throughput capacity over the study period of analysis.

The period of analysis is 50 years, beginning with the base year of 2030, the project effective date, to 2079. The FY 2024 Federal discount rate of 2.75 percent is used to discount benefits and costs. The report uses methodology from ER 1105-2-100, transportation cost savings accruing to deep draft vessels.

Total container cargo throughput is expected to increase in the future. Past TEU volumes have grown at an average rate of 2.1%, and that rate of growth is expected to persist throughout the forecast period, which ends in 2050. This will roughly double the TEU volumes handled by the Port of Oakland by the end of the forecast period. The commodity growth was limited to twenty years after the base year of the project, consistent with USACE practice for long-term commodity forecasts, and due to the uncertainty surrounding such long-term forecasts. However, benefit levels remain constant through the remaining period of analysis as well.

The port will see an increase in vessel traffic to accommodate this increase in volume. In 2019, the Port saw 1,248 vessel calls, a decrease of 10% from 2018. While smaller vessels are being replaced by larger ones to carry more cargo on a single voyage, the overall number of vessels will have to increase to match increasing TEU volumes over time. Also, the depth of the channels at Oakland are not expected to change over the study period, so loading practices and load factors are assumed to be unchanged from the existing condition. The Oakland Harbor Navigation Improvement (-50 foot) Project had a design vessel with a 48-foot draft, 1,139-foot length, and 140-foot beam. Vessels significantly larger than that study's design vessel, such as the Post-Panamax Generation III, currently carry about 20% of Oakland's TEU cargo and make up about 16% of the total vessel calls to the port. The largest vessels in the current container fleet, Post-Panamax Generation IV vessels, have called infrequently at the Port historically. However, both types of vessels will call more often over the forecast period to help accommodate future TEU volume increases, while helping suppliers and shippers take advantage of economies of scale. Generation IV vessels already in the world fleet are assigned to services from Asia to either the Middle East or Northern Europe because of its long voyage duration. The largest container vessels typically start their service on those routes and cascade into the trans-Pacific routes later. It is reasonable to assume that upwards of 40% of Oakland's TEU volume would be shifted to these larger classes of vessels by the end of the forecast period.

If Generation IV vessels cascade to Asia-Northern Europe to Pacific services, then they will likely call at San Pedro Bay, then Oakland next. To see the same vessel utilization rates as those currently on the Asia-Europe routes, there needs to be double the TEU volumes in the Pacific, while maintaining their current service frequencies. So, a gradual approach to cascading seems more likely, when shifting to larger vessels. Once the volumes have nearly doubled, by the end of the forecast period, utilization rates and frequencies of Generation IV vessel movements in the Pacific may more closely resemble those currently found on Asia to Northern Europe or Middle East services. Frequency is important at Oakland, given its reliance on agricultural exports, so they may keep weekly services to maintain speed to market.

The existing vessel fleet experiences operational inefficiencies due to the turning basins' dimensions. These inefficiencies are projected to continue and increase in the future as a larger share of the cargo is shifted to the larger vessel fleet, and these vessels call on Oakland more often. Because of these inefficiencies and delays, the total number of Generation IV vessels to call on Oakland will be lower than it would have been if the turning basins had been widened. Economies of scale will be easier to realize if the turning basins are widened, and longer, higher capacity vessels can call more efficiently. The largest vessels in the fleet will continue to be delayed due to restrictions and produce delays for the rest of the fleet that must accommodate them. Based on inputs from the Port's operators and Harbor Pilots, each Generation IV vessel creates delays of around 3-4 hours per transit—which could create additional delays if Generation III vessels are tide and current restricted already.

These assumptions and projections are made within the context of a "multiport analysis," i.e., a systematic determination of alternative routing possibilities, regional port analyses, and intermodal networks given the absence of a project. These considerations are explained in more detail in Section 6, Multiport Analysis.

3.3. Commodity Forecast

3.3.1. Cargo Volume Inventory

An essential step when evaluating navigation improvements is to analyze the types and volumes of cargo moving through the port. Trends in cargo history can offer insights into a port's long-term trade forecasts and thus the estimated cargo volume upon which future vessel calls are based. Under future without and future with project conditions, the same volume of cargo is assumed to move through Oakland Harbor. However, a modification project will allow shippers to better take advantage of larger vessels. This efficiency translates to savings and is the main driver of National Economic Development (NED). For the Port of Oakland, containerized cargo was inventoried and forecasted to provide estimates of future container volumes that could be seen at the Port. This data was provided by the Port of Oakland in a seaport forecast prepared in 2020 by an external consulting firm.[15]

3.3.2. Trade Forecast

The long-term trade forecast for the Oakland Harbor study combined empirical and forecast data obtained from the Port of Oakland. This forecast was produced in May 2020 by the Tioga Group and Hackett Associates, for the San Francisco Bay Conservation and Development Commission (BCDC). This report was produced to assist the commission in the development of the Bay Area's seaport land, subject to the projected land use required for future TEU volumes at the port and given certain throughout capacity measurements. BCDC proposed three different scenarios of future growth in containerized cargo from 2020-2050: slow, moderate, and strong. The moderate growth forecast was deemed most reasonable in their report, given the prevailing assumptions, and will be highlighted in this report as well. Enclosure 1 to this appendix contains the full BCDC report and the details of the other two forecast scenarios.

The international TEU forecasts for imports and exports are driven by projections of economic growth developed by Moody's and Caltrans, including sub-components of national-level Gross Domestic Product, industrial output, and Gross Metro Product[16] . The Moderate Growth scenario

[15] Bay Area Seaport Forecast, The Tioga Group and Hackett Associates, Prepared for the SF BCDC, May 22, 2020
[16] *ibid*

assumes that:

- Trade disputes are resolved, and most trade flows return to their recent growth patterns;
- Exporters affected by trade disputes either regain those former markets or find new markets;
- Long-term exports rebound as foreign markets recover economically;
- Refrigerated container trade grows due to the development of the recently completed CoolPort facility at the Port of Oakland; and
- Imports of automobile parts increase as Tesla increases production.

Figure 3-1 shows the elements of the Moderate Growth container cargo forecast. The Slow Growth and Strong Growth scenarios have alternative assumptions documented in the BCDC report. The empty TEU forecast is built upon the loaded TEU forecast and the relationship between empty containers and loaded container movements. For example, international outbound empty container volumes tend to move with international inbound loaded volumes. These relationships were assumed to persist over the forecast period. Domestic container volumes between the Port of Oakland and Hawaii are more opaque, and likely are driven primarily by market share shifts rather than economic growth. The overall compound annual growth rate is 2.2%, with imports at 2.9%, exports at 1.8%, and domestic at 0.7%. Domestic cargo accounts for only a minor portion of total containerized cargo[17]. Figure 3-2 displays the three forecast scenarios.

[17] Bay Area Seaport Forecast, The Tioga Group and Hackett Associates, Prepared for the SF BCDC, May 22, 2020, pp.12-13.

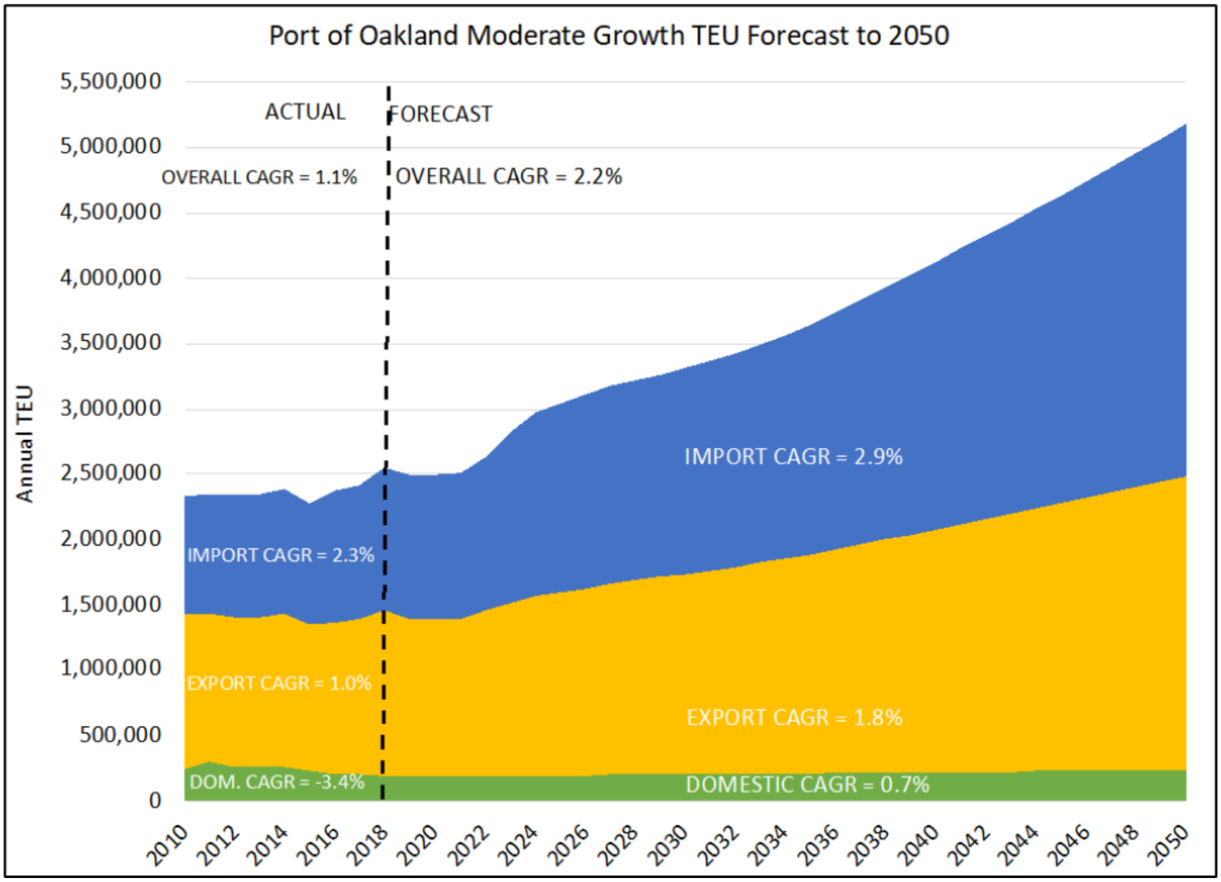


Figure 3-1. Bay Area Moderate Growth Containerized Cargo Forecast, 2010-2050

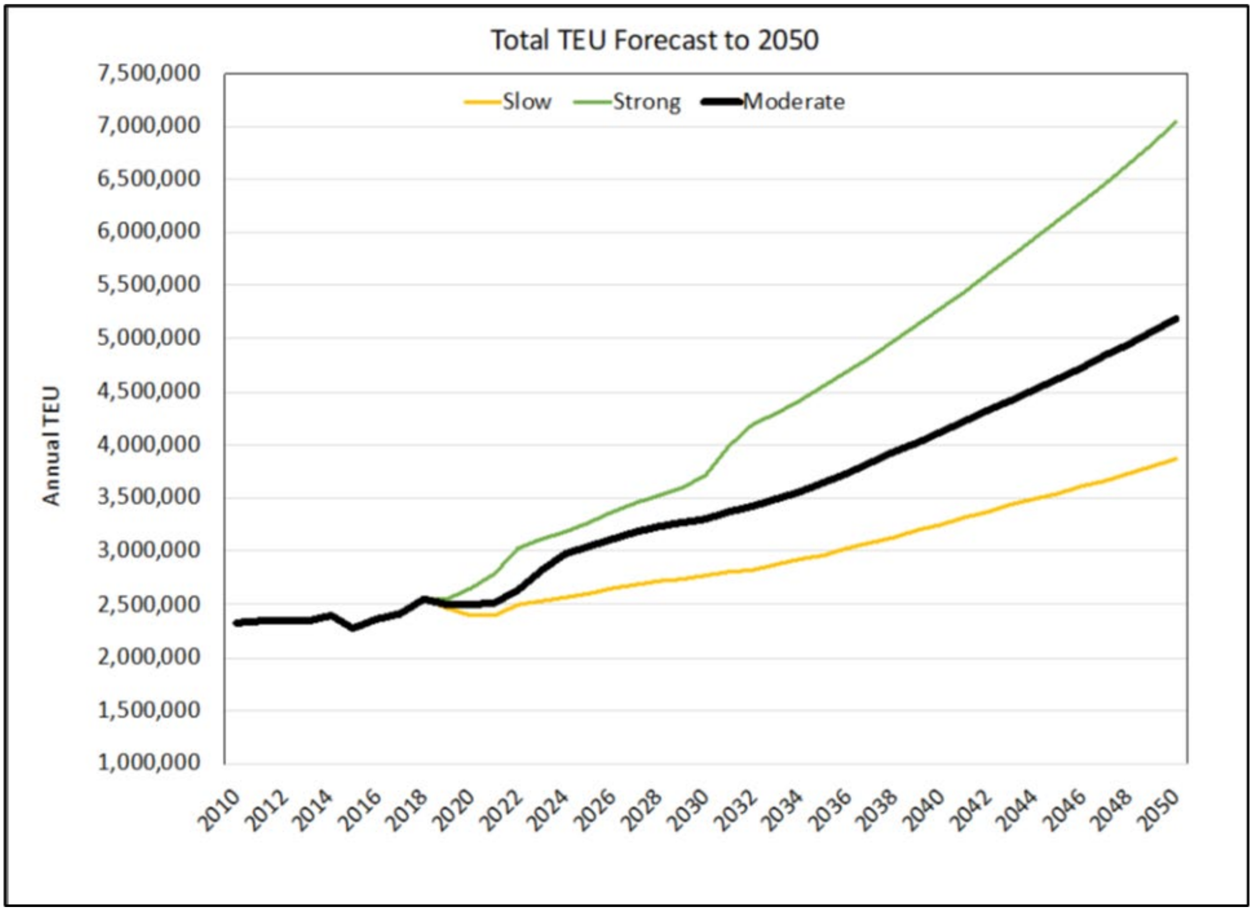


Figure 3-2. Total TEU Forecast to 2050

This containerized cargo forecast was then compared to the estimated future terminal capacity of the Port, given various land use options that may increase container handling capacity over the forecast period. Under the Moderate Growth forecast scenario, the Port of Oakland would be at or near its projected capacity by 2050. BCDC used a standard productivity benchmark of TEUs per acre to estimate the current capacity, sustainable capacity (80% of its maximum), and maximum capacity of the container terminals over the forecast period. The Port of Oakland container terminals currently average about 4,279 annual TEU per acre. The BCDC report estimated maximum current capacity at 6,061 annual TEU per acre based on current OICT performance, and long-term sustainable capacity at 7,112 annual TEU per acre based on achieving high terminal productivity in line with industry benchmarks. The forecast thus allows for a 66% productivity increase over the present average throughput. Container terminals can be expected to expand horizontally where possible, and then invest in productivity improvements to accommodate further cargo growth[18].

The Port currently plans to use about 20 acres at Berths 20-21 for dry bulk cargo for the next 15 years. If that land is not returned to container cargo use, the Port would be at about 95% of

[18] *Ibid*.

capacity by 2050 under Moderate Growth assumptions. If Howard Terminal were unavailable for container cargo handling but Berths 20-21 were available, the Port would be at about 98% of capacity in 2050. If both Howard and Berths 20-21 were unavailable for container cargo use, the port would be slightly over capacity by 2050[19].

The total number of TEUs, included loaded and empty containers, by import and export are shown in Table 3-2. The Moderate Growth 2018-2050 CAGR at 2.2% is slightly higher than the past average of about 2.1% due to expected long-term increase in Northern California manufacturing and distribution, and to the introduction of first call vessels to serve that increase. Figure 3-2 previously showed the components of the Moderate Growth scenario. Each of the three components (imports, exports, and domestic TEUs) allow for somewhat faster growth than the 2010-2018 record, but the slower growth of the export and domestic sectors keeps the overall rate below expected import growth[20].

Table 3-2. Oakland Total TEU Forecast by Decade to 2050

Moderate	International				Domestic				Total
	Loaded Imports	Empty Imports	Loaded Exports	Empty Exports	Loaded Inbound	Empty Inbound	Loaded Outbound	Empty Outbound	
2010	771,343	131,614	817,822	359,979	31,314	78,264	137,757	2,364	2,330,457
2018	946,524	139,719	807,975	462,690	19,028	79,249	89,829	1,338	2,546,351
2020	972,705	137,128	804,645	393,867	19,250	76,289	91,249	1,294	2,496,427
2030	1,407,818	164,421	964,799	570,054	20,423	82,615	98,737	1,358	3,310,226
2040	1,855,070	188,866	1,108,241	751,155	21,703	89,523	106,912	1,428	4,122,899
2050	2,493,437	210,692	1,236,308	1,009,642	23,101	97,064	115,839	1,505	5,187,588
2018-2050 CAGR	**3.1%**	**1.3%**	**1.3%**	**2.5%**	**0.6%**	**0.6%**	**0.8%**	**0.4%**	**2.2%**

This Total TEU forecast was then broken down by the Route Groups specified in Section 2.3.3. Since the routes vary greatly in overall distances, the TEU forecast must be allocated amongst each Route Group to properly weight potential transportation cost savings benefits. The share of the TEU forecast allocated to each Route Group was based on historical shares of TEU data collected from 2011-2018 and is shown in Table 3-3 below.

[19] *Ibid.*
[20] *Ibid.*

Table 3-3. TEU Forecast by Route Group 2020-2050

TEU	BCDC Total Imports		2,308,344	3,107,092	3,903,333	4,950,079
		Route Group	**2020**	**2030**	**2040**	**2050**
		Route 1: Northeast Asia	1,494,902	2,012,177	2,527,829	3,205,710
Imports		Route 2: Southeast Asia	160,881	216,549	272,044	344,997
		Route 3: Europe, Africa, and Latin America	586,954	790,056	992,520	1,258,681
		Route 4: Oceania	65,608	88,310	110,940	140,691
		Total	2,308,344	3,107,092	3,903,333	4,950,079
	BCDC Total Exports		188,082	203,133	219,566	237,509
		Route Group	**2020**	**2030**	**2040**	**2050**
		Route 1: Northeast Asia	146,623	158,356	171,167	185,154
Exports		Route 2: Southeast Asia	4,282	4,625	4,999	5,407
		Route 3: Europe, Africa, and Latin America	33,035	35,679	38,565	41,717
		Route 4: Oceania	4,142	4,474	4,836	5,231
		Total	188,082	203,133	219,566	237,509
	BCDC Total TEUs		2,496,427	3,310,226	4,122,899	5,187,588
	Totals	Route 1: Northeast Asia	1,641,524	2,170,533	2,698,996	3,390,865
		Route 2: Southeast Asia	165,162	221,174	277,042	350,404
		Route 3: Europe, Africa, and Latin America	619,989	825,734	1,031,085	1,300,398
		Route 4: Oceania	69,750	92,783	115,776	145,922
		Grand Total (TEU)	2,496,426	3,310,225	4,122,899	5,187,588

The TEU forecast was then converted to metric tons to allocate cargo to its respective route and dock in the HarborSym model. This also allowed the study team to properly model modifications to the Inner and Outer Harbors independently. The forecast by dock and route is shown in Table 3-4 below.

Table 3-4. Forecasted tonnage to Oakland buy Dock and Route, 2030-2050

	Route	2030	2040	2050
	Trapac			
Imports	NEA-WCUS	1,829,356	2,298,157	2,914,448
	SEA-WCUS	196,874	247,326	313,651
	EU-NA-LA-WCUS	718,273	902,342	1,144,320
	OCEANIA-WCUS	80,286	100,861	127,908
	Ben E Nutter			
	NEA-WCUS	1,614,138	2,027,786	2,571,571
	SEA-WCUS	173,713	218,229	276,751
	EU-NA-LA-WCUS	633,770	796,184	1,009,694
	OCEANIA-WCUS	70,841	88,995	112,860
	OICT			
	NEA-WCUS	7,317,424	9,192,628	11,657,790
	SEA-WCUS	787,497	989,306	1,254,605
	EU-NA-LA-WCUS	2,873,092	3,609,367	4,577,281
	OCEANIA-WCUS	321,144	403,443	511,633
	Trapac			
Exports	NEA-WCUS	165,881	179,300	193,953
	SEA-WCUS	4,844	5,236	5,664
	EU-NA-LA-WCUS	37,374	40,398	43,699
	OCEANIA-WCUS	4,686	5,065	5,479
	Ben E Nutter			
	NEA-WCUS	146,365	158,206	171,135
	SEA-WCUS	4,274	4,620	4,998
	EU-NA-LA-WCUS	32,977	35,645	38,558
	OCEANIA-WCUS	4,135	4,469	4,835
	OICT			
	NEA-WCUS	663,523	717,200	775,810
	SEA-WCUS	19,377	20,945	22,657
	EU-NA-LA-WCUS	149,497	161,591	174,796
	OCEANIA-WCUS	18,745	20,261	21,917

3.4. Vessel Fleet Forecast

3.4.1. World Fleet

In addition to a commodity forecast, a forecast of the future fleet is required when evaluating navigation projects. To develop projections of the future fleet calling at Oakland, the study team developed a world fleet forecast of containerships, a methodology to forecast total capacity calling at Oakland Harbor based on previous USACE studies at other West Coast ports and future throughput capacity at the port, and a breakdown of that capacity calling into containership size and TEU classes.

The methodology was then linked to the commodity forecast data for U.S. West Coast and Oakland. The commodity forecasts were unconstrained forecasts and consequently the fleet forecast model is similarly unconstrained in respect to inter-port competition on the U.S. West Coast. This means that forecasted commodity totals were not adjusted based on effects from nearby ports. So, volumes were not increased or decreased based on movements to substitute ports in the region, e.g., San Pedro Bay ports. More details on this approach can be found in Section 6, Multiport Analysis. Further, the study team did not consider land-based infrastructure as a limiting factor in its projections of the World Fleet. Table 3-5 shows the fleet subdivision using common vessel labeling terminology and vessel specifications for design draft, beam, and length overall (LOA).

Table 3-5. Fleet Subdivisions on Draft, Beam, LOA (in ft.), and Nominal TEU Capacity

Vessel Fleet Subdivision (Containerships)		From	To
Sub Panamax	Beam		98
	Draft	8.2	38.1
	LOA	222	813.3
	TEUs		2,800
Panamax	Beam	98	106
	Draft	30.8	44.8
	LOA	572	970
	TEUs	2,801	4,800
Post-Panamax Generation I (Post-Panamax)	Beam	106	138
	Draft	35.4	47.6
	LOA	661	1045
	TEUs	4,801	6,800
Post-Panamax Generation II (Super Post-Panamax)	Beam	138	144
	Draft	39.4	49.2
	LOA	911	1,205
	TEUs	6,801	9,900
Post-Panamax Generation III (New Panamax, or Ultra Post-Panamax)	Beam	144	168
	Draft		51.2
	LOA	Up to	1220
	TEUs	9,901	15,000
Post-Panamax Generation IV (New Post-Panamax)	Beam	168	200
	Draft		52.5
	LOA	1,295	1,315
	TEUs	15,000	23,000

By combining information from the commodity forecast with forecasted fleet capacity and Oakland's average share of cargo on a containerized vessel, the study team was able to allocate several post- Panamax, Panamax, and sub-Panamax vessels calls to Oakland's fleet. The number of transits, particularly those made by larger vessels, is a key variable in calculating the transportation costs. The study team'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.

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

As new larger vessels become a greater percentage of the world fleet and are deployed to

Oakland, they replace smaller vessels which are redeployed to shorter routes, which may utilize the smaller vessels more efficiently.

There is a strong relationship between the economic condition of a port and its total nominal vessel capacity. As an economy grows, exports from the port often increase (from the increased output) or demand for imports increase (from increased consumer purchasing power). Vessels respond accordingly to satisfy this increased level of trade. As the tonnage in Oakland 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 Oakland was determined, the future containers were allocated to various vessel classes (post-Panamax, Panamax, and sub-Panamax). The allocation to vessel classes was based on the examination of historical utilization of all container vessels, current trends in vessel design and orders, and the worldwide redeployment of vessels affected by the expansion of the Panama Canal.

3.4.1.1. World Fleet End of Period 2020

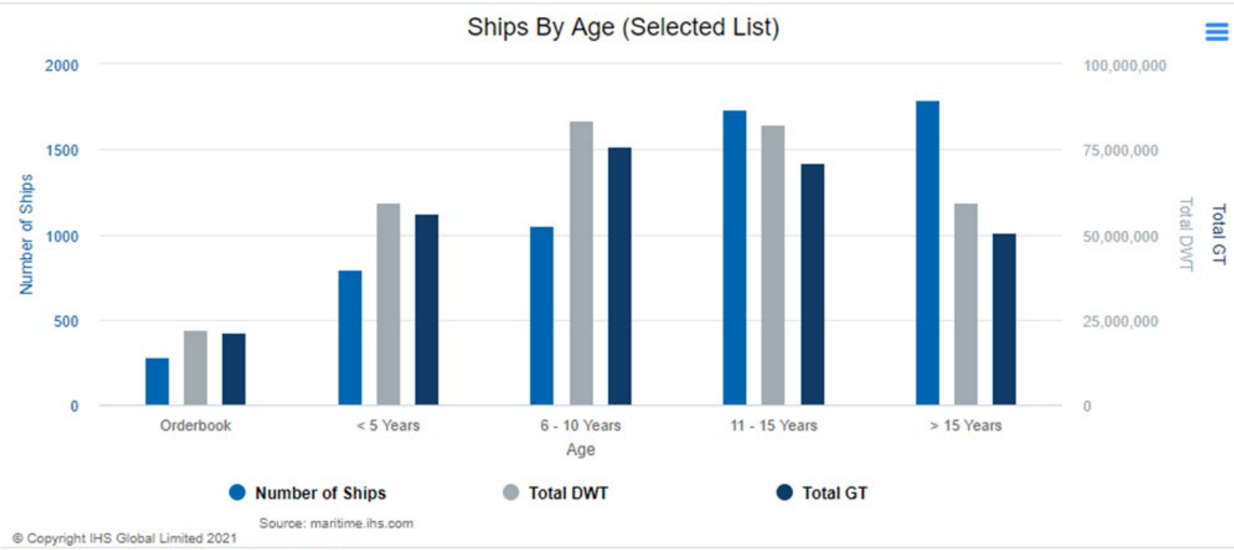
A projection of the World Fleet provides the necessary background for evaluating the future fleet forecast for Oakland. The starting point for this projection was a share of the world fleet by vessel class as extracted from the Lloyd's Register (LR)-Fairplay database for the years 2013, 2014, 2017, and 202015. As shown in Table 3-6, larger vessels are quickly becoming a higher percentage of the world fleet. In 2013, container vessels larger than 12,000 TEUs made up just under 3 percent of the world fleet while vessels greater than 7,600 TEUs totaled around 10.5 percent. As of 2020, 12,000 TEU vessels have increased to about 8.8 percent of the world fleet and vessels greater than 7,600 TEUs now make up about 21 percent.

Table 3-6. Snapshot World Fleet by TEU Band - 2013, 2014, 2017, and 2020

TEU Band	2013	2014	2017	2020
0.1 - 1.3 k TEU	1,600	1,557	1,553	990
1.3 - 2.9 k TEU	1,352	1,333	1,476	2,162
2.9 - 3.9 k TEU	303	295	271	190
3.9 - 5.2 k TEU	762	750	656	713
5.2 - 7.6 k TEU	519	536	468	454
7.6 - 12 k TEU	379	438	670	664
12 k TEU +	151	193	422	502
TOTAL	**5,066**	**5,102**	**5,516**	**5,675**

3.4.1.2. The "Order Book"

The "order book" is shorthand for the vessels that have been contracted to be built by ship builders around the world. Vessel deliveries are primarily the function of new building contracting. These contracts can take several forms. There are firm contracts for vessels that are under construction. There are also option contracts that secure the capacity of the shipyard but do not require the buyer to exercise the option to construct the vessel. Some contracts have financing that is committed; others do not. There are several other nuances and the challenge is to translate the number of vessels and types of contracts into future vessels coming online at a specific time. Forecasts must be made for future contracts, vessel scrapping, and vessel deliveries. 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. In Figure 3-3 below, the world fleet of containerships, according to the IHS SeaWeb database in 2021, is broken down by age; including those in the "order book."



Ships By Age (Selected List)

Age	Number of Ships	Total DWT	Total GT
Orderbook	280	22007758	21118005
< 5 Years	795	59418526	56415788
6 - 10 Years	1053	83495387	76084068
11 - 15 Years	1731	82412577	71230355
> 15 Years	1789	59357191	50538274

Figure 3-318. World Containership Fleet by Age; Source: IHS SeaWeb Database, maritime.ihs.com; Accessed 14 January 2021

The breakdown of newbuild containerships contained in the "order book" is shown in Figure 3-4 below. Post-Panamax Generation II ships were not reflected at all in this total, and Generation III and IV vessels (15,000 TEU and up) made up 35 percent of newbuilds.

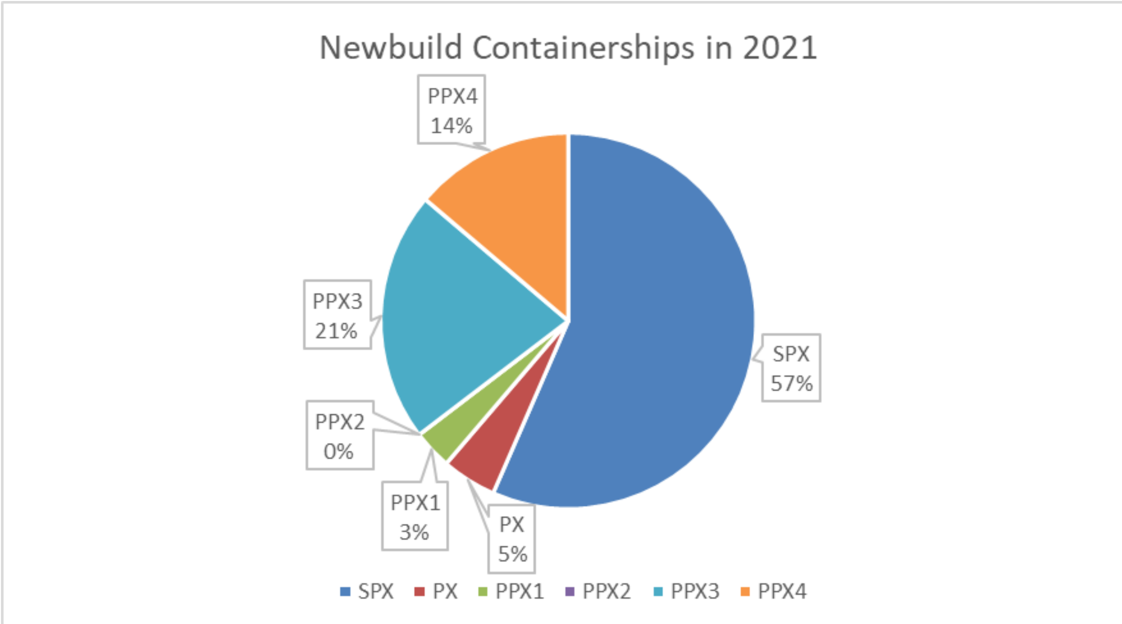
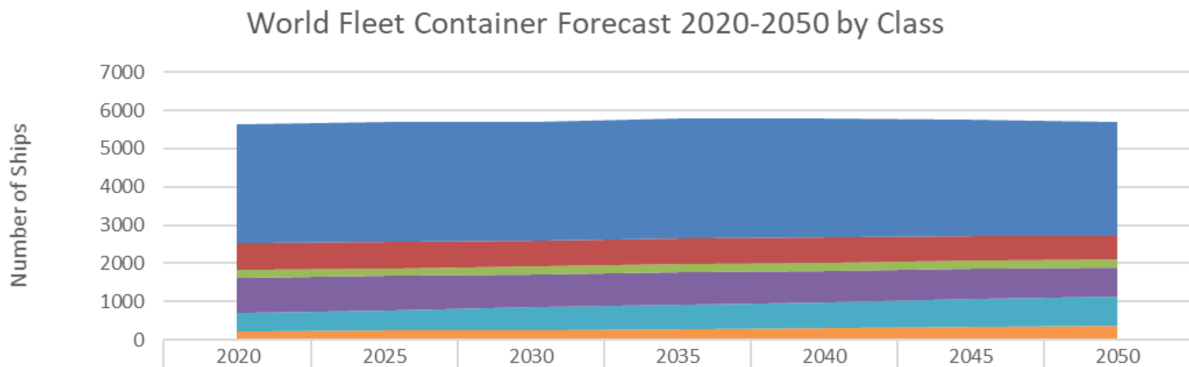


Figure 3-4. Newbuild containerships in the "order book" by study class; Source: IHS SeaWeb database, maritime.ihs.com; Accessed 14 January, 2021

3.4.1.3. World Fleet Forecast

With historical data for deliveries and scrapping collected, a forecast of the fleet from the 2020 fleet to the end of each forecast year was estimated. Figure 3-5 displays the world containership forecast by vessel class through 2050.



	2020	2025	2030	2035	2040	2045	2050
Sub Panamax	3112	3122	3111	3131	3102	3053	2978
Panamax	709	700	685	676	656	633	604
PPX Gen I	194	199	205	211	218	224	231
PPX Gen II	908	890	866	846	815	781	742
PPX Gen III	505	541	582	626	672	717	761
PPX Gen IV	207	231	258	288	318	348	378

PPX Gen IV PPX Gen III PPX Gen II PPX Gen I Panamax Sub Panamax

Figure 3-5. World Fleet Forecast by Class, 2020-2050

Figure 3-6 shows the net growth in selected Post-Panamax TEU bands from the 2020 fleet. The figure shows the additional vessels added to the fleet. These types of vessels are a key factor in the evaluation of port studies such as Oakland Harbor. The future fleet that serves Oakland will mirror the changes in the world fleet of containerships by class.

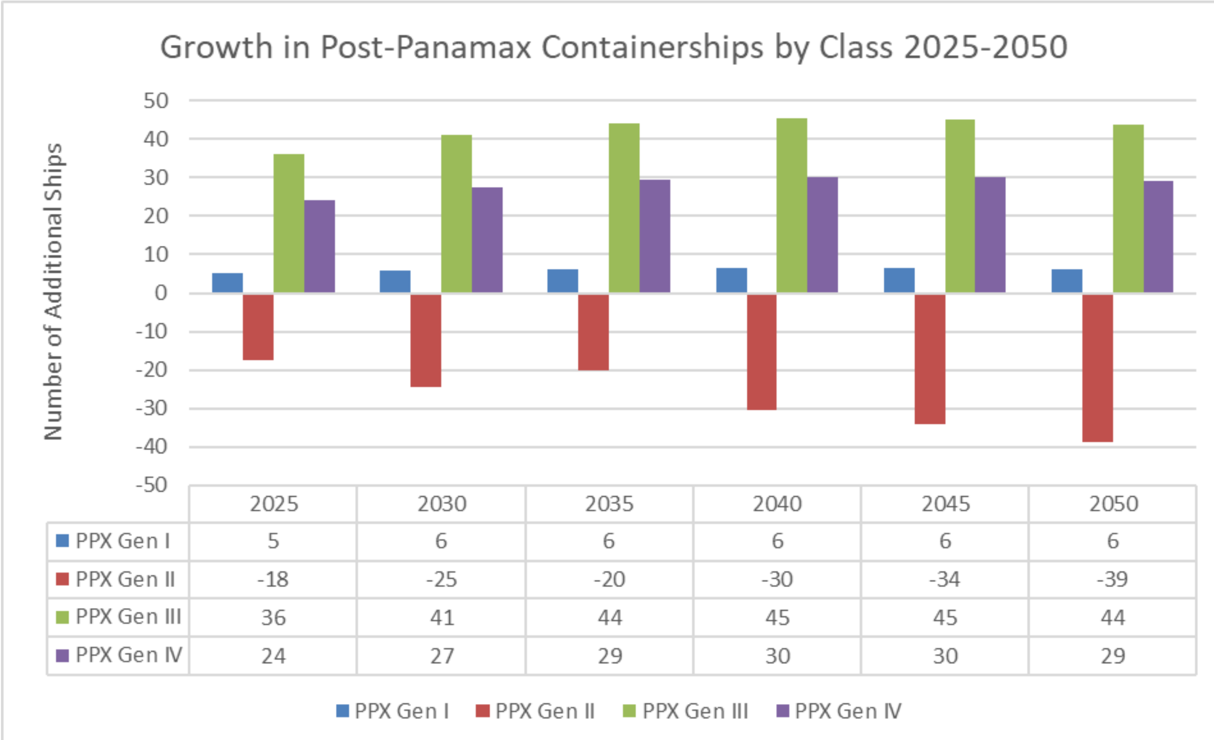


Figure 3-6. World Fleet Net Growth Forecast of Post-Panamax Containership Classes

3.4.2. Container Vessels Calling at the Port of Oakland

3.4.2.1. Port of Oakland Vessel Capacity

The study team used the historical fleet deployment and capacity as a baseline for forecasting the future fleet. Table 3-7 and Table 3-8 show the historical calls at Port of Oakland by Class and the percent share of the calls, respectively.

Table 3-7. Historical Vessel Calls at Port of Oakland by Class, 2014-2019

Vessel Class	2014	2015	2016	2017	2018	2019
SPX	109	76	112	99	96	175
Panamax	485	277	316	232	163	140
PPX Generation I	518	424	508	492	498	352
PPX Generation II	273	268	378	416	398	371
PPX Generation III	174	208	247	205	231	210
PPX Generation IV	0	0	3	0	0	0
Total	1,558	1,252	1,563	1,442	1,386	1,248

Table 3-8. Historical Cargo Share by Vessel Class

Vessel Class	2014	2015	2016	2017	2018
SPX	4%	2%	3%	4%	4%
Panamax	23%	17%	15%	11%	9%
PPX Generation I	32%	33%	28%	28%	30%
PPX Generation II	25%	28%	33%	36%	35%
PPX Generation III	17%	20%	20%	20%	22%
PPX Generation IV	0%	0%	0.3%	0%	0%

3.4.2.2. Forecasted Vessel Capacity Calling at the Port of Oakland

The Port of Oakland TEU forecast was used to estimate total annual nominal capacity calling at Oakland for the years 2025 to 2050. The forecast assumed that existing nominal capacities would persist at the beginning of the forecast period, and slowly shift to the larger Post-Panamax vessels during the mid- and late years of the period to allocate the appropriate TEU volumes. This shift would occur in line with the world fleet forecast as more or less vessels of a certain class become available, and cascade into trans-pacific routes. Once the study team determined the total annual nominal capacity over the period of analysis, the estimated capacity was allocated into each class since this demand is likely to be satisfied by a range of vessels.

3.4.2.3. Forecasted Share of Vessel Capacity

The forecasted capacity calling at Oakland was allocated to container vessel routes and classes according to the forecast of capacity share, as shown in Table 3-9. The forecasted capacity share at Oakland was estimated by considering changes to the available fleet and the forecasted tonnage for the port. Different routes did not shift their share of vessel capacity in the same way. Routes with smaller volumes of cargo shipped, such as the Oceania route, didn’t fully utilize the largest containership classes because they weren’t estimated to require the larger capacity ships to maintain their call frequency and meet the increased demand in volumes forecasted. By the same rationale, European routes didn’t utilize the largest classes of vessels in the same way as the Asian routes.

These capacity shares were a bit more conservative than growth projections contained in USACE’s feasibility study for the Port of Long Beach. For example, that study had overall shares of 41% for Generation IIIs and 40% for Generation IVs by 2040 in both the FWOP and FWP conditions. Long Beach (San Pedro Bay) and Oakland are on many of the same container liner routes, with Oakland typically being the second port of call in the U.S. This occurs for two main reasons: first, San Pedro Bay (Long Beach or Los Angeles) has access to a larger consumer market for imported goods and sees larger volumes than Oakland; second, Oakland is a significant export point of departure for agricultural and manufactured goods from the San Francisco Bay Area and Northern Super Region of California. Therefore, some, but not all, of the vessels that are forecasted to arrive in Long Beach in the future will most likely proceed to Oakland as well. As more Generation IIIs and IVs join trans-Pacific liner services, fewer Generation Is and IIs will be required to move their share of containerized cargo.

Table 3-9. FWOP Forecasted Shares of Container Vessel Capacity

Route	Class	2025	2030	2040	2050
NEA	**SPX**	0%	0%	0%	0%
NEA	**PX**	7%	7%	6%	2%
NEA	**PPX1**	27%	26%	23%	10%
NEA	**PPX2**	37%	31%	26%	18%
NEA	**PPX3**	28%	28%	29%	30%
NEA	**PPX4**	1%	8%	17%	40%
SEA	**SPX**	0%	0%	0.0%	0%
SEA	**PX**	2%	5%	4.5%	2%
SEA	**PPX1**	38%	32%	26.0%	10%
SEA	**PPX2**	47%	36%	28.0%	18%
SEA	**PPX3**	9%	19%	24.5%	30%
SEA	**PPX4**	0%	8%	17.0%	40%
EU	**SPX**	11%	8%	6%	6%
EU	**PX**	30%	14%	11%	7%
EU	**PPX1**	41%	33%	26%	18%
EU	**PPX2**	17%	21%	20%	17%
EU	**PPX3**	1%	16%	23%	27%
EU	**PPX4**	0%	8%	14%	27%
OCEANIA	**SPX**	26%	16%	10%	8%
OCEANIA	**PX**	69%	38%	21%	11%
OCEANIA	**PPX1**	5%	31%	46%	54%
OCEANIA	**PPX2**	0%	16%	23%	27%
OCEANIA	**PPX3**	0%	0%	0%	0%
OCEANIA	**PPX4**	0%	0%	0%	0%

3.4.2.4.

The PDT developed the FWOP fleet forecast using the previously mentioned projections as well as an analysis of Port of Oakland historical calls. Namely, the study team used the forecasted share of capacity by vessel class to distribute forecasted tonnage. The PDT then used historical average percent empty containers, arrival drafts, and box weights to determine the number of calling vessels. The FWOP forecast of containerized vessels through the year 2050 is depicted in Table 3-10. These values were input into HarborSym's Container Loading Tool (CLT), which built a year's worth of vessel traffic using these total call inputs. The CLT data and loading algorithm is discussed in Section 4.1.2.

Table 3-10. FWOP Forecast of Containerized Vessels through 2050

Route Group	Vessel Class	Without Project Year 2030	Without Project Year 2040	Without Project Year 2050
SEA	PX	6	4	3
SEA	PPX1	42	45	34
SEA	PPX2	96	104	103
SEA	PPX3	14	22	40
SEA	PPX4	2	7	19
EU	SPX	106	99	118
EU	PX	47	45	41
EU	PPX1	145	156	150
EU	PPX2	87	122	157
EU	PPX3	34	70	95
EU	PPX4	7	26	71
NEA	PX	151	158	69
NEA	PPX1	333	374	298
NEA	PPX2	374	416	423
NEA	PPX3	273	406	540
NEA	PPX4	15	36	167
OCEANIA	SPX	44	33	31
OCEANIA	PX	27	17	13
OCEANIA	PPX1	12	25	36
OCEANIA	PPX2	6	16	18
Total		**1,821**	**2,181**	**2,426**

3.5. Project Alternatives

An array of three alternatives underwent an initial round of qualitative screening. Alternatives were formulated to address the objectives through the combinations of screened management measures. The formulation strategy focused on the information provided by the harbor pilots who are responsible for maneuvering the container fleet into and out of Oakland Harbor.

3.5.1. Alternative A: No Action Alternative

The No Action Alternative is analyzed as the future without-project conditions for comparison with the action alternatives. Taking no action would mean continuing standard operations at Oakland Harbor with no improvements to the Federal navigation channel. All physical conditions at the time of this analysis are assumed to remain. The No Action Alternative assumes one-way traffic within the harbor and assumes O&M dredging would occur within the Federal navigation channel at authorized depths (-50 MLLW).

3.5.2. Alternative B: Expanding the Inner Harbor Turning Basin Only

Alternative B proposes to expand the Inner Harbor Turning Basin to allow the harbor pilots to remove transit restrictions for current and time of day for large container vessels currently calling on the Inner Harbor's OICT at Oakland. Widening this basin would directly reduce transit restrictions to 2 kinds of vessels but will also alleviate backups in smaller vessels who must accommodate the larger, high-priority vessels. This would also enable origin-to-destination economic benefits by allowing more of the fleet's largest container vessels to call than in the FWOP condition.

3.5.3. Alternative C: Expanding the Outer Turning Basin Only

Alternative C proposes to expand the Outer Harbor Turning Basin to allow the harbor pilots to remove transit restrictions for current and time of day for large container vessels currently calling on the Outer Harbor's Ben E. Nutter and TraPac terminals at Oakland. Widening this basin would directly reduce transit restrictions to 2 kinds of vessels but will also alleviate backups in smaller vessels who must accommodate the larger, high-priority vessels. This would also enable origin-to-destination economic benefits by allowing more of the fleet's largest container vessels to call than in the FWOP condition.

3.5.4. Alternative D: Expanding Both Turning Basins

Alternative D proposes to expand both the Inner Harbor and Outer Harbor Turning Basins.

3.5.5. Alternative D-2: Expanding Both Turning Basins, Maximizing Beneficial Reuse, and Electric Dredging

Alternative D-2 proposed to expand both the Inner and Outer Harbor Turning Basins as well. It also proposes to maximize the beneficial use of any dredged material destined for offshore disposal. This would lead to benefits to endangered species through habitat creation at existing beneficial use sites. More detail on this aspect of the plan can be found in the Environmental Analysis appendix. This plan would also include electric dredging plants at the Inner Harbor Turning Basin. This would improve air quality and reduce the noise associated with a traditional dredge. Discussion on the reduction of the health impacts associated with these activities can also be found in the Environmental appendix. Despite these differences in the impacts to environmental quality and other social effects, Alternative D-2 has the same NED effects as Alternative D that expands both turning basins. The NED benefits to transportation cost reduction are the same in both alternatives, and the NED costs are higher for Alternative E. The

Port of Oakland supports the use of electric dredging as a locally preferred element of the plan at full non-federal cost. Therefore, Alternative D-2 is being carried forward as the environmentally preferred plan recommended under NEPA.

3.6. Economic Evaluation Assumptions

Economic evaluation will focus on different combinations of measures for turning basins. Based on the outcomes of the variation screening and given the expected low costs of these alternatives, the engineering recommendations for width based on the design vessel parameters will be carried forward and an incremental evaluation of turning basin diameter is not planned at this time.

The authorized channel depths were considered in the setup of the economic evaluation which is presented in Section 4. The Federal channel and turning basins have been maintained to their -50 MLLW authorized depths and are not anticipated to change in the future conditions.

4. Transportation Cost Savings Benefit Analysis

The purpose of this analysis is to describe the benefits associated with the expanding the turning basins at the Port of Oakland. NED benefits were estimated by calculating the reduction in transportation cost using the HarborSym Modeling Suite of Tools (HMST) developed by IWR. The HMST reflects USACE guidelines on transportation cost savings analysis.

4.1. Methodology

Channel improvement modifications result in reduced transportation cost by allowing a more efficient future fleet mix. The HMST was designed to allow users to model these benefits. The ability of the Port of Oakland to handle large vessels efficiently is expected to encourage shippers to replace smaller, less efficient vessels with the larger, more efficient vessels on Oakland route services.

While lesser in magnitude when compared to replacing smaller vessels with larger vessels, additional transportation cost saving benefits result from the channel modifications aimed at reducing congestion within the harbor. HarborSym allows for detailed modeling of vessel movements and transit rules on the waterway.

To begin, HarborSym was setup with the basic required variables. To estimate OD cost saving benefits, the Container Loading Tool (CLT), a module within the HMST, was used to generate a vessel call list based on the commodity forecast at the Port of Oakland for a given year and the vessel fleet projected to call at Oakland under the different 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 turning basins to the expanded ones as was described in Section 3.6, Economic Evaluation Assumptions. 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. A HarborSym analysis revolves around the factors that characterize or affect a vessel movement within the harbor.

4.1.1.1. Model Behavior

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

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

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

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

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

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

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

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

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:

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

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 Oakland 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 Oakland Harbor study. The base year for the model was 2030. A model run was performed for the following years: 2030, 2040 and 2050. After 2050 the forecast number of TEUs was held constant until the end of the period of analysis. Each model run consisted of 50 iterations. Figure 4-1 illustrates the total vessel time in the system for the OD model runs. For the base condition OD model run in 2030, the average total vessel time in the system after 50 iterations was 32,364 hours, with a standard deviation of 229 hours. A test run was completed using 100 simulations to compare the standard deviation of the total vessel time in system to that of the 50-iteration run. The difference in the standard deviation was insignificant; thus, 50 iterations was determined to be sufficient.

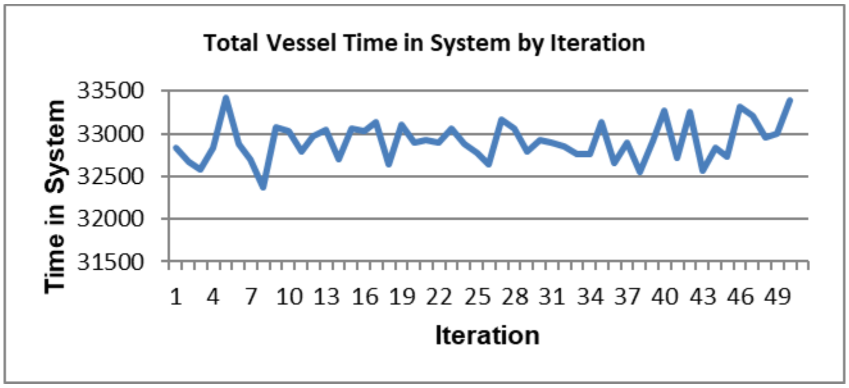


Figure 4-1. HarborSym Iterations - Hours

Physical and Descriptive Harbor Characteristics

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

Figure 4-2. Oakland Harbor HarborySym Node Network

General Information

General information used as inputs to the model include: specific vessel and commodity classes, route groups (Table 4-1), commodity transfer rates at each dock (Table 4-2), specifications of turning area usage at each dock, and specifications of anchorage use within the harbor. Distances between the route groups were developed by evaluating the trade routes calling on Oakland Harbor in 2019. Those routes were separated into four route groups based on their world region and itinerary. The route group distance included in the analysis for each trade lane is calculated from the most likely distance for each identified route.

Table 4-1. HarborSym Route Group and Most Likely Distances

		Distance to Prior Port	Distance to Next Port	Additional Sea Distance

Route Group	Description	(nautical miles)	(nautical miles)	(nautical miles)
EU-NA-LA-WCUS	Europe, North America, Latin America	396	857	9,451
NEA-WCUS	Northeast Asia	396	4,560	6,742
OCEANIA-WCUS	New Zealand, Australia, Pacific Island, Hawaii	7,372	857	9,000
SEA-WCUS	Southeast Asia	396	4,935	11,963

Table 4-2. HarborSym Commodity Transfer Rates for Containers

Dock Name	Loading (Units/hour)			Unloading (Units/hour)		
	Min	Most Likely	Max	Min	Most Likely	Max
Ben E Nutter	556	834	834	556	834	834
TraPac	392	834	834	392	834	834
OICT	237	1,148	1,148	237	1,148	1,148

Prior and next port depths were left at their default value in the HarborSym model. Because loading practices are assumed to remain the same in the FWPC as the FWOPC, prior and next port depths were not considered a limiting factor.

Vessel Speeds and Operations

The speed at which vessels operate in the harbor, by vessel class both loaded and light loaded, were determined for each channel segment by evaluating pilot logs and port records and verifying the data with the pilots. Hourly operating costs while in-port and at-sea were determined for both domestic and foreign flagged containerized vessels. Sailing speeds at-sea were also determined and are based on service speeds and operating expenses obtained from Institute for Water Resources (IWR) Vessel Operating Cost spreadsheets and Economic Guidance Memorandum (EGM) 20-04 (dated 23 June 2020), Deep-Draft Vessel Operating Costs FY 2019 Price Levels. Economical or slow-steam speeds at sea and associated costs were included in the evaluation. Vessel operating costs and speeds at sea are entered as a triangular distribution (minimum, most likely, maximum). Vessel speed and operations inputs are provided in Table 4-3 and Table 4-4 for each reach of the node network for containerized vessels. Vessel operating costs 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 Section 4 of the Freedom of Information Act.

Table 4-3. HarborSym Vessel Speed in Reach for Containerships (knots)

	Sub-Panamax – PPX3	PPX4

Reach	Light	Loaded	Light	Loaded
Entrance to Bay Bridge (Reach 1)	8.0	8.0	8.0	8.0
Bay Bridge to Bar Channel (Reach 2)	8.0	8.0	8.0	8.0
Bar Channel to Inner Harbor Entrance (Reach 3)	5.0	5.0	3.5	3.5
Inner Harbor Entrance to OICT (Reach 4)	4.0	4.0	3.5	3.5
OICT to Inner Harbor Turning Basin (Reach 5)	2.0	2.0	2.0	2.0
Bar Channel to Outer Harbor Turning Basin (Reach 9)	5.0	5.0	5.0	5.0
Outer Harbor Turning Basin to Ben E Nutter (Reach 10)	2.0	2.0	2.0	2.0
Outer Harbor Turning Basin to TraPac (Reach 11)	2.0	2.0	2.0	2.0

Table 4-4. Containerized Vessel Operations

Description	Sub-Panamax	Panamax	PPX1	PPX2	PPX3	PPX4
Vessel Speed at Sea, Min (knots)	16.9	18.0	19.0	18.2	18.4	17.5
Vessel Speed at Sea, Most Likely (knots)	19.5	20.7	21.9	21.0	21.1	20.2
Vessel Speed at Sea, Max (knots)	22.2	23.6	25.0	23.9	24.1	23.0

Reach Transit Rules

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

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

Vessel Calls

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

4.1.2. Containerized Vessel Call List

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

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 Oakland Harbor study.

4.1.2.1. CLT Loading Algorithm

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

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

1. Prior port limiting depth,
2. Design draft, and
3. Limiting depth at the dock + underkeel clearance + sinkage adjustment + tidal availability + sea level change.

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

Next, the CLT conducts a Loading Factor Analysis (LFA) given the physical characteristics of each generated vessel. LFA explores the relationships between a 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 calculated from the inputs and used by the LFA algorithm.

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

Total weight per loaded container = Average Laden Weight per Loaded TEU by Route (tons) +

Average Container (Box only) Weight per TEU (tons) +

(Average Container (Box only) Weight per TEU (tons) * (Percent Empty TEUs))

Shares of vessel capacity are then calculated as:

Cargo Share = Average Laden Weight per Loaded TEU by Route (tons) Total weight per loaded container in tons

Laden Container Share

= Average Container (Box only) Weight per TEU (tons) Total weight per loaded container in tons

Empty Container Share

= ((Average Container (Box only) Weight per TUE (tons))

* (Percent Empty TEUs)) Total weight per loaded container in tons)

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 (tons)

= Max Laden TEUs * Average Laden Weight per Loaded TEU by Route (tons)

Max weight for laden boxes (tons)

= Max Laden TEUs * Average Container (Box only) Weight per TEU (tons)

Max weight for empties (tons)

= Max Empty TEUs * Average Container (Box only) Weight per TEU (tons)

Total volume restricted tonnage (cubed out tonnage) (tons)

= Max weight for cargo + Max weight for laden boxes + Max weight for empties

The LFA proceeds as follows:

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

DWT Available for Vessel Draft = DWT Rating (tons) – [(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 tons = DWT Rating (tons) * 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 (tons) =

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 (tons) =

Available for Cargo adjusted for volume restriction if any in tons * Cargo Share in percent

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

Distribution of Space Available for Empty TEUs (tons) =
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 Laden Weight per Loaded TEU by Route (tons)

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

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

Vacant Slots = Nominal TEU Rating – Occupied TEU Slots

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

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

4.1.2.2. CLT Data Inputs for Oakland Harbor

There are several data required by the CLT. The commodity forecast and vessel fleet forecast are two inputs that have previously been discussed. Details on the commodity and fleet forecast can be found in Section 3.3 3.4, respectively.

Table 4-5 provides the vessel class inputs used in the load factor analysis (LFA)20, such as average lading weight per TEU (see Section 2.3.3), container weight, vacant slot allotment, variable ballast, etc. These inputs were developed using historical data provided by the Port (Import/Export fractions) and with the assistance of IWR (Lading Weight per Loaded TEU, Empty TEU and Vacant Slot allotment, Operations Allowance, and Variable Ballast).

Table 4-6 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 4-5. Vessel Class Inputs

Service	Vessel Class	Avg Lading Wt per Loaded TEU (MT)	Avg Tare Wt per TEU (MT)	Empty TEU %	Vacant Slot %	Operations Allowance (% of DWT)	Variable Ballast (% of DWT)	Import Fraction Most Likely	Export Fraction Most Likely

SEA	Sub-Panamax	9.9	2	22.0	6.0	6.7	11	7%	14%
SEA	Panamax	9.9	2	19.0	6.0	6.7	11	48%	14%
SEA	PPX1	9.9	2	25.0	6.0	6.7	11	28%	3%
SEA	PPX2	9.9	2	21.2	6.2	6.7	11	15%	1%
SEA	PPX3	9.9	2	21.2	6.2	6.7	11	23%	2%
SEA	PPX4	9.9	2	21.2	6.2	6.7	11	34%	11%
EU	Sub-Panamax	10.8	2	22.3	6.2	6.7	11	27%	3%
EU	Panamax	10.8	2	19.2	6.2	6.7	11	75%	6%
EU	PPX1	10.8	2	25.0	6.2	6.7	11	31%	4%
EU	PPX2	10.8	2	21.2	6.2	6.7	11	29%	1%
EU	PPX3	10.8	2	21.0	6.2	6.7	11	28%	13%
EU	PPX4	10.8	2	21.2	6.2	6.7	11	25%	14%
NEA	Sub-Panamax	8.3	2	22.0	6.2	6.7	11	1%	37%
NEA	Panamax	8.3	2	19.0	6.2	6.7	11	24%	7%
NEA	PPX1	8.3	2	24.9	6.2	6.7	11	29%	3%
NEA	PPX2	8.3	2	21.2	6.2	6.7	11	28%	3%
NEA	PPX3	8.3	2	21.2	6.2	6.7	11	25%	2%
NEA	PPX4	8.3	2	21.2	6.2	6.7	11	34%	14%
OCEANIA	Sub-Panamax	12.3	2	29.6	6.2	6.7	11	21%	2%
OCEANIA	Panamax	12.3	2	22.6	6.2	6.7	11	26%	2%
OCEANIA	PPX1	12.3	2	25	6.2	6.7	11	32%	5%
OCEANIA	PPX2	12.3	2	21	6.2	6.7	11	25%	9%

Table 4-6. Vessel Subclass Inputs

Vessel Class	LOA	Beam	Max Draft	Capacity (DWT)	Applied Draft	TEU Rating	TPI Factor	UKC	Sinkage	% of Class
SPX	499	79	28.9	14,924	28.00 to 29.99	1,090	68.8	2.7	0.8	10%
SPX	535	85	30.4	18,438	30.00 to 30.99	1,388	78.5	2.7	0.8	10%
SPX	571	87	31.3	20,643	31.00 to 31.99	1,447	87.1	2.7	0.8	5%
SPX	585	90	33.5	24,283	33.00 to 33.99	1,618	93.6	2.7	0.9	1%
SPX	596	92	34.6	24,812	34.00 to 34.99	1,778	96.3	2.7	0.9	10%
SPX	603	92	35.6	25,370	35.00 to 35.99	1,895	97.1	2.7	0.9	37%
SPX	657	98	36.2	31,139	36.00 to 36.99	2,268	113.8	2.7	1	2%
SPX	676	99	37.6	33,887	37.00 to 37.99	2,470	117.7	2.7	1	25%
Panamax	777	105	38.5	42,183	38.00 to 38.99	3,084	146	2.8	1	2%
Panamax	766	104	39.4	43,311	39.00 to 39.99	3,188	142.8	2.8	1	3%
Panamax	794	106	40.3	44,991	40.00 to 40.99	3,389	150.2	2.8	1.1	5%
Panamax	846	106	41.2	50,070	41.00 to 41.99	3,841	162.7	2.8	1.1	15%
Panamax	907	106	42.5	56,792	42.00 to 42.99	4,125	176.7	2.8	1.1	10%
Panamax	887	104	43.4	54,885	43.00 to 43.99	3,993	170.4	2.8	1.2	5%
Panamax	959	106	44.4	64,956	44.00 to 44.99	4,729	192.7	2.8	1.2	60%
PPX1	1,014	132	39.4	74,070	39.00 to 39.99	5,918	240.9	3	1	3%
PPX1	928	131	41.4	75,623	41.00 to 41.99	5,534	214.7	3	1.1	15%
PPX1	972	123	42.8	77,149	42.00 to 42.99	4,858	219	3	1.1	5%

PPX1	900	130	44.4	78,284	44.00 to 44.99	4,912	208	3	1.2	25%
PPX1	935	131	46	78,618	46.00 to 46.99	5,793	215.1	3	1.2	5%
PPX1	949	132	46	79,891	46.00 to 46.99	6,050	221.6	3	1.2	10%
PPX1	954	132	46.1	80,651	46.00 to 46.99	6,186	222.3	3	1.2	1%
PPX1	965	132	46.1	80,504	46.00 to 46.99	6,295	225.4	3	1.2	1%
PPX1	975	132	46.1	81,237	46.00 to 46.99	6,387	228.7	3	1.2	1%
PPX1	981	132	46.1	110,448	46.00 to 46.99	6,441	230.7	3	1.2	5%
PPX1	984	132	46.1	75,898	46.00 to 46.99	6,505	230.9	3	1.2	3%
PPX1	989	132	46.2	86,060	46.00 to 46.99	6,549	233.1	3	1.2	3%
PPX1	992	132	46.2	102,179	46.00 to 46.99	6,600	233.7	3	1.2	5%
PPX1	992	132	46.3	102,871	46.00 to 46.99	6,662	233.5	3	1.2	15%
PPX1	970	132	47.6	103,817	47.00 to 47.99	6,329	229.4	3	1.3	3%
PPX2	1,101	146	42.7	104,549	42.00 to 42.99	9,148	290.3	3	1.1	1%
PPX2	984	141	44.3	104,104	44.00 to 44.99	6,332	244.6	3	1.2	15%
PPX2	1,018	143	46.1	103,865	46.00 to 46.99	7,200	260.3	3.1	1.2	5%
PPX2	1,090	142	47.6	104,657	47.00 to 47.99	8,212	284.9	3	1.3	20%
PPX2	1,099	143	47.6	105,458	47.00 to 47.99	8,528	289.2	3	1.3	20%
PPX2	1,106	143	47.6	106,737	47.00 to 47.99	8,670	291.5	3	1.3	15%
PPX2	1,109	143	47.7	108,348	47.00 to 47.99	8,787	292	3	1.3	1%
PPX2	1,112	144	47.7	92,498	47.00 to 47.99	8,874	292.6	3	1.3	5%
PPX2	1,114	144	47.7	92,875	47.00 to 47.99	8,916	293.5	3	1.3	1%
PPX2	1,118	144	47.7	93,905	47.00 to 47.99	9,018	295.3	3	1.3	1%

PPX2	1,122	145	47.7	95,169	47.00 to 47.99	9,145	297.7	3	1.3	1%
PPX2	1,127	145	47.7	96,687	47.00 to 47.99	9,294	300.3	3	1.3	5%
PPX2	1,139	145	47.6	98,893	47.00 to 47.99	9,513	303.4	3	1.3	10%
PPX3	1,147	150	49.3	118,712	49.00 to 49.99	9,954	330.2	3	1.3	5%
PPX3	1,100	160	49.2	121,270	49.00 to 49.99	10,036	337.5	3	1.3	20%
PPX3	1,105	159	50.9	119,324	50.00 to 50.99	10,100	341.4	3	1.3	10%
PPX3	1,139	149	50.9	131,229	50.00 to 50.99	10,700	325.9	3	1.3	5%
PPX3	1,204	141	50.9	115,993	50.00 to 50.99	11,008	335.9	3	1.3	10%
PPX3	1,191	150	50.9	131,236	50.00 to 50.99	11,356	342.8	3	1.3	15%
PPX3	1,192	150	52.5	138,377	52.00 to 52.99	11,668	345.6	3	1.3	5%
PPX3	1,200	160	50.9	139,408	50.00 to 50.99	12,400	371.4	3	1.3	5%
PPX3	1,201	158	50.9	141,448	50.00 to 50.99	13,092	361.4	3	1.3	15%
PPX3	1,207	168	50.9	150,166	50.00 to 50.99	13,892	389.3	3	1.3	5%
PPX3	1,201	159	52.5	148,992	52.00 to 52.99	14,414	381.6	3	1.3	5%
PPX4	1,310	194	52.5	186,650	52.00 to 52.99	16,652	444	3	1.3	15%
PPX4	1,309	194	55.7	174,239	55.0 to 55.99	17,816	467	3	1.3	30%
PPX4	1,310	194	53.5	199,980	53.00 to 53.99	18,340	467	3	1.3	35%
PPX4	1,307	194	52.5	200,148	52.00 to 52.99	19,224	467	3	1.3	20%

4.1.2.3. Containerized Vessel Calls

Vessel calls by route group and vessel class are shown in Table 4-7. These are a result of the CLT loading algorithm, the containerized trade forecast for Oakland Harbor, the available vessel fleet by service, and the LFA data inputs.

Table 4-7. Vessel Calls by Class/Route Alternative

Route & Class	No Action	FWP OHTB	FWP IHTB	FWP Both TBs	No Action	FWP OHTB	FWP IHTB	FWP Both TBs	No Action	FWP OHTB	FWP IHTB	FWP Both TBs
	2030				2040				2050			
SEA PX	6	5	3	2	4	2	3	1	3	2	1	0
SEA PPX1	42	36	34	28	45	32	32	19	34	15	21	2
SEA PPX2	96	84	101	89	104	79	100	75	103	59	91	47
SEA PPX3	14	19	17	22	22	31	31	40	40	49	43	52
SEA PPX4	2	3	3	4	7	11	8	12	19	30	24	35
EU SPX	106	96	82	72	99	77	66	44	118	96	57	35
EU PX	47	35	50	38	45	29	41	25	41	20	37	16
EU PPX1	145	126	112	93	156	119	102	65	150	92	95	37
EU PPX2	87	90	91	94	122	105	113	96	157	115	148	106
EU PPX3	34	56	52	74	70	107	92	129	95	143	125	173
EU PPX4	7	13	12	18	26	50	50	74	71	121	105	155
NEA PX	151	137	119	105	158	133	106	81	69	47	22	0
NEA PPX1	333	288	234	189	374	289	209	124	298	143	174	19
NEA PPX2	374	347	381	354	416	350	397	331	423	284	364	225

NEA PPX3	273	317	348	392	406	471	491	556	540	583	612	655
NEA PPX4	15	25	20	30	36	70	71	105	167	267	212	312
OCEANIA SPX	44	40	38	34	33	30	25	22	31	26	22	17
OCEANIA PX	27	27	25	25	17	17	16	16	13	12	11	10
OCEANIA PPX1	12	13	12	13	25	23	25	23	36	35	35	34
OCEANIA PPX2	6	6	7	7	16	15	14	13	18	19	18	19
Total	**1,821**	**1,763**	**1,741**	**1,683**	**2,181**	**2,040**	**1,992**	**1,851**	**2,426**	**2,158**	**2,217**	**1,949**

4.2. Transportation Cost Savings Benefits by Alternative

Transportation cost benefits were summarized and annualized using HarborSym results from multiple simulations. The team collected the transportation costs from various model run output files and generated the transportation cost reduction for all project years, and then produced an Average Annual Equivalent (AAEQ).

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, 2040, and 2050. Since terminal capacity is not expected to be reached during the planning period of analysis, the transportation costs were held constant beyond 2050. The present value was estimated by interpolating between the modeled years. Transportation costs were annualized to determine AAEQ costs and savings by discounting the cost stream from year 2030 to 2079 at the current FY 2024 Federal Discount rate of 2.75 percent using the transportation cost and savings information shown in Table 4-8 through Table 4-10. Estimates were determined for each alternative.

Table 4-8. AAEQ Transportation Cost Savings Benefits by Alternative (in Thousands $)

Alternative/Depth	Total Benefits (NPV) ($1,000s)	AAEQ Benefits ($1,000s)
Alternative A (Without Project)	$0	$0
Alternative B (IHTB Only)	$789,061	$29,227
Alternative C (OHTB Only)	$563,545	$20,874
Alternative D (Combo)	$1,327,883	$49,186

4.3. Benefit-Cost Analysis

The benefit-cost analysis presented in this section is for each alternative evaluated. Parametric costs have been annualized using the current discount rate of 2.75 percent and are presented at the October 2023 price level. The costs include all economic costs such as financial costs (construction cost) for the Federal project; interest during construction; operations, maintenance, repair, rehabilitation, and replacement (OMRR&R) expenses associated with maintenance of those alternatives; and aids-to-navigation.

Alternative costs are presented in Table 4-9 below, including interest during construction (IDC), operations and maintenance cost assumptions. Estimated first costs include the cost to construct the alternative, including contingency, Real Estate costs, Cultural Resource Preservation costs, Preconstruction, Engineering and Design (PED) and Construction Management (CM) costs presented at current price levels (October 2023). Interest during construction is based on an assumed 31-month construction duration for each measure and alternative. Total economic costs represent implementation costs and includes project first costs, interest during construction, and aids-to-navigation.

Table 4-9. Alternative Costs (in $1,000s, Oct 2023 prices, 2.75% discount rate)

Alternative	Project First Costs	Construction Duration (months)	Interest During Construction	Assoc. Costs	Total Economic Costs	Annual OMRR&R	Average Annual Equivalent Cost
Alt B (IHTB Only)	$405,707	31	$14,260	-	$419,967	$1,105	$16,215
Alt C (OHTB Only)	$111,559	31	$3,921	-	$115,480	$1,105	$5,238
Alt D (Combo)	$522,591	31	$18,368	-	$540,959	$1,105	$20,577

The results of the origin-destination (OD) transportation cost saving benefit analysis are displayed in Table 4-10. As shown, Alternative D maximizes net NED benefits and is recommended for construction. At the time of this analysis in October 2023, no local service facility costs were anticipated for any alternatives. Construction costs of the proposed alternative are $522 million, with a total economic cost of approximately $540 million after interest during construction, and associated O&M costs of $1,105,000 every year.

Table 4-10. Benefit Cost Analysis (Oct 2023 prices, 2.75% discount rate)

Alternative	Total AAEQ Costs	Incremental AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	BCR
Alt B	$16,215,000		$29,228,000	$13,013,000	1.8
Alt C	$5,238,000	$(10,977,000)	$20,874,000	$15,636,000	4.0
Alt D	$20,577,000	$15,339,000	$49,186,000	$28,609,000	2.4

5. Sensitivity Analysis

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

5.1. Scenarios

5.1.1. Higher Container Forecast Growth Rates

For the first sensitivity scenario, effects were tested on the increase of commodity volumes over the forecast period. Since commodity volumes drive fleet sizes and vessel calls, the benefits could be very sensitive to volume increases. Volumes were assumed to match the Strong Growth Scenario from Section 3.3.2 due to macroeconomic forces and industry surges because of the COVID-19 pandemic, as shown in Figure 5-1 below.

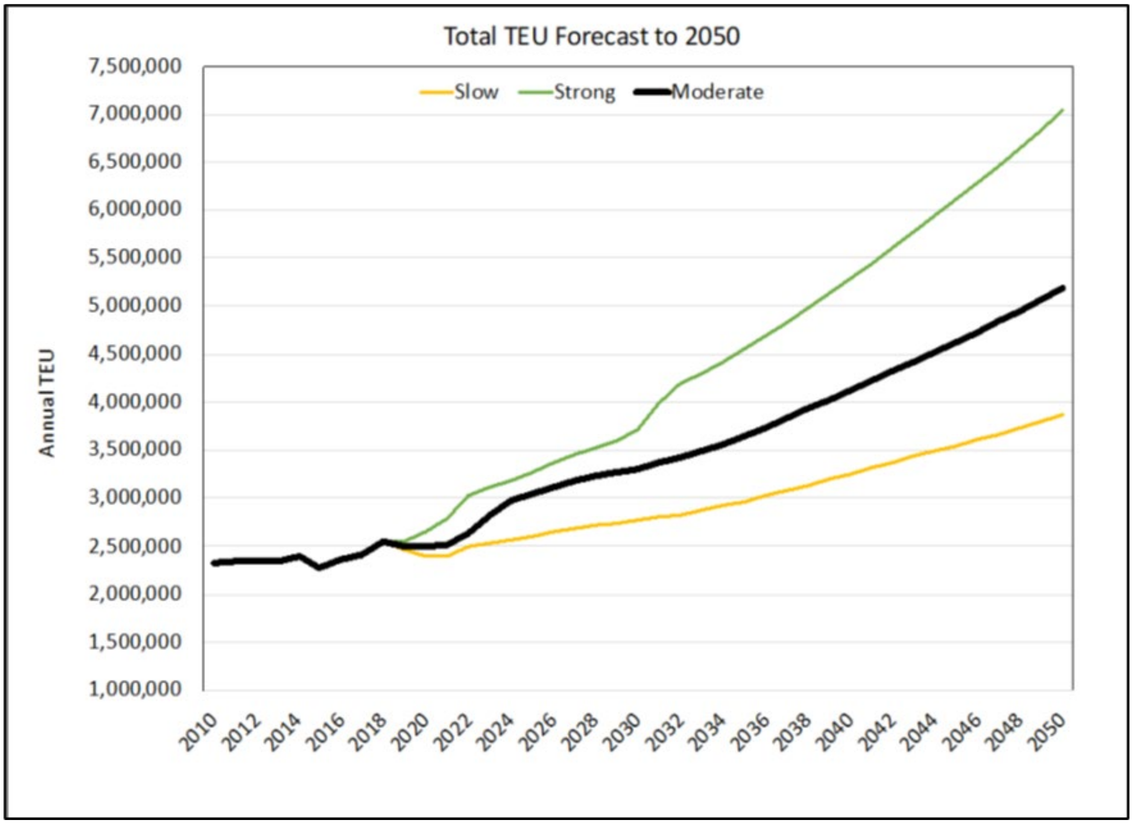


Figure 19. Total TEU Forecast to 2050

In this scenario, the fleet mix did not change. So, the same proportion of container vessels carried cargo to and from Oakland over the forecast period. There was no fleet shift to PPX4's carrying a larger share of the cargo, as there was in the FWOP and FWP conditions. This captures the effects of commodity volumes, fleet sizes, and cargo share on project benefits. The results of this scenario are shown in Table 5-1 below.

Table 5-1. Higher Growth Scenario Economic Analysis

Alternative	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	BCR
Alt D	$20,577,000	$56,522,000	***$35,945,000***	2.7

5.1.2. Lower Future Post-Panamax Generation IV Utilization Rates

For the second sensitivity scenario, effects of a change in the fleet mix were tested, instead of changing the commodity volumes. The largest class of container vessel in this study, Post-Panamax Generation IV, has high vessel operating costs, so the benefit results are very sensitive to the final number of those vessels included in the model. Commodity volumes were kept consistent with the Moderate Growth forecast scenario, but the share of cargo handled by PPX4 vessels to and from Oakland was decreased over the forecast period. This cargo was then handled by smaller vessels instead. This shift resulted in a different fleet mix of container vessels calling at Oakland. The adjusted vessel call numbers through Oakland are shown in Table 5-2 below, along with the original numbers in parentheses.

Table 5-2. Adjusted FWP Forecast of Container Vessel Calls

	2030	2040	2050
SEA PX	2 (2)	2 (1)	0(0)
SEA PPX1	27(28)	19 (19)	3(2)
SEA PPX2	86 (89)	76 (75)	43(47)
SEA PPX3	25 (22)	47 (40)	62(52)
SEA PPX4	3 (4)	10 (12)	32(35)
EU SPX	70 (72)	49 (44)	36(35)
EU PX	39 (38)	23 (25)	13(16)
EU PPX1	95 (93)	64 (65)	38(37)
EU PPX2	95 (94)	101 (96)	110(106)
EU PPX3	77 (74)	151(129)	202(173)
EU PPX4	15 (18)	54 (74)	125(155)
NEA PX	110(105)	82 (81)	0(0)
NEA PPX1	186(189)	124(124)	20(19)
NEA PPX2	348(354)	329(331)	224(225)
NEA PPX3	408(392)	644(556)	751(655)
NEA PPX4	27 (30)	78(105)	277(312)
OCEANIA SPX	34 (34)	22(22)	17(17)
OCEANIA PX	25 (25)	16(16)	10(10)
OCEANIA PPX1	13 (13)	23(23)	34(34)
OCEANIA PPX2	7 (7)	13(13)	19(19)
Total	**1,692 (1683)**	**1,927(1851)**	**2,016(1949)**

The results of this scenario are shown in Table 5-3 below.

Table 5-3 Low PPX4 Utilization Scenario Economic Analysis

	Total AAEQ	Total AAEQ	Total Net	BCR

Alternative	Costs	Benefits	Benefits	
Alt D	$20,577,000	$39,976,000	***$19,399,000***	1.9

5.1.3. Low Growth Scenario

The third scenario began with the same settings as the previous scenario with regards to the fleet mix. Commodity volumes then remained flat from 2020 through 2025. Then, in 2026, commodity volumes were adjusted significantly downward, and given a recovery period of slow growth over the remaining 25 years of the forecast period. This was repeated until the resulting fleet was small enough not to generate enough AAEQ benefits to cover the costs of the Recommended Plan.

Table 5-4 below compares forecasted vessel calls from the base scenario to the decreased calls in this scenario. Base scenario calls are in parentheses next to their adjusted counterparts.

Table 5-4. Vessel Calls by Vessel Class, Unity Scenario Compared to Base Scenario

	2030	2040	2050
SEA PX	2(2)	2(1)	2(0)
SEA PPX1	27(28)	27(19)	27(2)
SEA PPX2	86(89)	86(75)	86(47)
SEA PPX3	25(22)	25(40)	25(52)
SEA PPX4	3(4)	3(12)	3(35)
EU SPX	70(72)	70(44)	70(35)
EU PX	39(38)	39(25)	39(16)
EU PPX1	95(93)	95(65)	95(37)
EU PPX2	95(94)	95(96)	95(106)
EU PPX3	77(74)	77(129)	77(173)
EU PPX4	15(18)	15(74)	15(155)
NEA PX	110(105)	110(81)	110(0)
NEA PPX1	186(189)	186(124)	186(19)
NEA PPX2	348(354)	348(331)	348(225)
NEA PPX3	408(392)	408(556)	408(655)
NEA PPX4	27(30)	27(105)	27(312)
OCEANIA SPX	34(34)	34(22)	34(17)
OCEANIA PX	25(25)	25(16)	25(10)
OCEANIA PPX1	13(13)	13(23)	13(34)
OCEANIA PPX2	7(7)	7(13)	7(19)
Total	**1,692(1683)**	**1,692(1851)**	**1,692(1949)**

The results of this scenario are shown in Table 5-5 below.

Table 5-5. Unity Scenario Economic Analysis

Alternative	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	BCR
Alt D Unity Scenario	$20,577,000	$20,554,000	***-$23,000***	0.99

6. Multiport Analysis

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 wider elements to operate larger containerships more efficiently. 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 distribution centers 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 design 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 Oakland cargo share remaining the same in both the future without-project and future with-project conditions. To restate the multiport considerations in another way, justification of the recommendation for this study is not based on the assumption that cargo will shift to Oakland with expanded turning basins alone. The analysis assumes Oakland receives the same share of regional cargo volumes with or without the turning basin expansions.

The Port of Oakland handles nearly all containerized imports and exports for Northern California, as well as smaller volumes of intermodal cargo moving to and from inland points. For exports, Oakland's geographic position near California agricultural production gives it an advantage. Oakland is also often the last U.S. port of call before vessels return to Asia, providing a later and faster shipping option for exporters. As a result, Oakland is one of few U.S. West Coast ports where containerized exports often exceed imports.

Oakland competes for different trade flows in different ways. California ports compete for "discretionary" container traffic (i.e., commodities that can move by rail to other regions through any one of several ports). For example, Oakland competes for Asian imports to Midwestern consumer markets with the ports of Los Angeles, Long Beach, Vancouver, Prince Rupert, New York-New Jersey, Baltimore, and Virginia. However, this "discretionary" traffic has made up less than 10% of historic containerized volume at Oakland.

Another important issue is whether carriers would consider servicing local Bay Area customers via truck or rail from another U.S. port. Such a concern is prompted by carriers which offer services that "straddle" the Port with a sailing rotation that calls Southern California and the Pacific Northwest. It is reasonable to assume that Oakland will remain a major U.S. West Coast port of call for four primary reasons:

- The Port provides access to a significant local population, the second largest population center along the U.S. West Coast, and fourth largest in the U.S. It also serves a large local manufacturing base and agricultural areas in Central and Northern California.

- Most carriers in the transpacific trade designate the Port as the second or last port of call, after first calling at Los Angeles or Long Beach. This has limited the rival ports' ability to absorb additional cargo. Current congestion issues also limit their ability for additional cargo from Oakland.
- The lack of enough intermodal capacity to supply the local Oakland market from competing ports. Chassis shortages at Long Beach are current examples of this.
- The costs to supply this local population from an alternative port of call via trucks or rail are significantly higher than calling directly at the Port.

A 1997 Booz-Allen & Hamilton report examined the alternative cost of serving the local market via truck between Southern California and Oakland. The inland trucking costs to the Port would be approximately $450 per container over the cost of an Oakland dray, resulting in total inland transportation costs of $252,450. Compared to the additional two port cost of $26,231, avoiding Oakland would cost a carrier over $225,000 per voyage. Beyond the additional cost, it is questionable whether the ports on the West Coast and the existing inland infrastructure would have the capacity to handle significant diversions of the Port's cargo. In addition to needing shoreline facilities, other support such as landside transportation would be impacted.

There have been shifts amongst U.S. West Coast and even Canadian west coast ports, including Seattle, Tacoma, Portland, Prince Rupert (Canada), and Vancouver (Canada). Cargo has decreased at one of these ports, while increasing at others. However, there does not appear to be a significant shift to competing ports away from Oakland, since most of the cargo is used in the immediate area. For example, some domestic TEUs destined for Hawaii have shifted to Long Beach from Oakland in recent years, but these volumes are marginal (less than 5% of total TEUs). Today, an estimated 78-98% of imports and 70-90% of exports are for locations within 300 miles of Oakland. It is unlikely to be cost effective for significant diversions of that cargo away from Oakland to occur.

7. Costs

Feasibility-level cost estimates were developed for the Recommended Plan at the October 2023 price level. They reflect the expansion of both turning basins. A detailed "Basis of Cost Estimate" that outlines cost assumptions appears in Appendix E. Potential risk events were evaluated and incorporated into a risk model to determine appropriate contingency levels.

Table 7-1 summarizes the cost information for the Recommended plans which were used in the economic evaluation. Construction first costs were $538,831,000 for the Recommended Plan. Interest during construction was computed on the construction first cost using a 31-month construction duration and the current discount rate of 2.75%. The total economic cost is the sum of the construction first cost and interest during construction.

Table 7-1. NED Economic Costs (October 2023 prices)

Cost	***NED Plan***
Construction First Cost	$538,831,000
IDC (31 months @ 2.75%)	$18,939,000
Total Economic Cost	$557,770,000
AAEQ Cost	$20,660,000
AAEQ OMRR&R	$1,105,000
Total AAEQ Cost	$21,765,000

7.1. Net Benefits and Benefit-Cost

Table 7-2 provides a summary of the costs and benefits of the Recommended Plan. O&M dredging expenses have been estimated to occur every year at $1,105,000 at the October 2023 price level. AAEQ cost is estimated at $21,765,000, which includes an AAEQ cost for O&M of $1,105,000. AAEQ benefits include origin-to-destination transportation cost savings of approximately $49,186,000, resulting in total net benefits of $27,421,000 (AAEQ benefits minus AAEQ costs) and a 2.3 BCR. First costs for authorization are estimated at $538,831,000 (October 2023 price level).

Table 7-2. Average Annual Equivalent (AAEQ) Benefits and Costs of Oakland Harbor Plan

	Cost and Benefit Summary of the Recommended Plan (October 2023 price level)
Interest Rate (Fiscal Year 2023)	2.75%
Interest Rate, Monthly	0.07%
Construction Period, Months	31
Period of Analysis, Years	50
Construction First Costs	$538,831,000
Interest During Construction (First Costs only)	$18,939,000
Estimated Local Service Facilities	$0
Estimated Aids to Navigation	$0
Estimated Economic Costs (Oct 2023 price level)	***$557,770,000***
AAEQ Costs	
Amortized Cost	$20,660,000
OMRR&R	$1,105,000
Total AAEQ Costs	***$21,765,000***
AAEQ Benefits	
Origin-to-Destination Transportation Cost Savings[1]	$49,186,000
Total AAEQ Benefits	***$49,186,000***
AAEQ Net Benefits (AAEQ Benefits – AAEQ Costs)	**$27,421,000**
Benefit-to-Cost Ratio (computed at 2.75%)	**2.3**

1 Transportation costs and cost savings benefits are based on FY19 vessel operating costs updated from EGM 20-04.

8. Socioeconomic and Regional Analysis

The parameters used to describe the demographic and socioeconomic environment include recent trends in population, private sector employment, wage earnings by sectors for the State of California, the San Francisco Bay area, and two counties that comprise the Oakland-Hayward-Berkeley Metropolitan Division (MD). Other social characteristics such as race composition, age distribution, and poverty issues will be examined within the City of Oakland, Alameda and Contra Costa Counties, and the State of California, whose communities may be directly impacted by the expansion of the turning basins at the Port of Oakland.

8.1. Population

The City of Oakland is in Alameda County and is part of the San Francisco Bay Area, which has a total population of over 7 million people across nine counties (Table 8-1). Between 2000 and 2020, Alameda County's population increased by approximately 17 percent, which is about one percentage point below national population growth (18 percent). Population growth was slowest in Marin County from 2000 to 2020, followed by Sonoma and San Mateo counties. Population growth was fastest in Contra Costa County from 2000 to 2020, followed by Alameda, Santa Clara, and Solano counties. The population of the Bay Area grew faster than any other part of California between 2000 and 2020; in general, California has experienced its slowest rate of growth ever recorded in 2019, with many residents migrating to other states (Green, 2019).

Table 8-1. Population Trends, 2000-2020 Estimates

	Population			Percent Change		
Geographical Area	2000	2010	2020	2000 to 2010	2010 to 2020	2000 to 2020
Sonoma County	458,614	483,878	488,863	6%	1%	7%
Marin County	247,289	252,409	262,321	2%	4%	6%
San Francisco County	776,733	805,235	873,965	4%	9%	13%
San Mateo County	707,161	718,451	764,442	2%	6%	8%
Santa Clara County	1,682,585	1,781,642	1,936,259	6%	9%	15%
Alameda County	1,443,741	1,510,271	1,682,353	5%	11%	17%
Contra Costa County	948,816	1,049,025	1,165,927	11%	11%	23%
Solano County	394,542	413,344	453,491	5%	10%	15%
Napa County	124,279	136,484	138,019	10%	1%	11%
California	33,871,648	37,253,956	39,538,223	10%	6%	17%
United States	281,421,906	308,745,538	331,449,281	10%	7%	18%
Source: U.S. Census Bureau & Bay Area Census, Census of Population and Housing (2000-2020)						

8.1.1. Employment and Wages by Sector

In 2019, there were over 19 million people in the civilian labor force in California with an average weekly pay of $1,484 (Table 8-2). While the number of employed individuals dropped to just under 19 million in 2020, the average weekly pay increased to $1,656 for that period. In 2019 and 2020, over 2 million people were employed in federal, state, and local government. In 2019 and 2020, Service-providing industries accounted for more than 38 percent of total monthly employment, followed by Trade, Transportation, and Utilities (over 9 percent), and Professional and Business Services (over 8 percent). These NAICS sectors also account for the highest total annual payroll.

Table 8-2. Average Employment and Payroll Statistics, California, 2019-2020

NAICS Code	Industry Title	Average Monthly Employment		Total Annual Payroll ($1,000)		Average Weekly Pay	
		2019	2020	2019	2020	2019	2020
11, 21, 23, 31-33	Goods-producing	2,651,704	2,545,324	$212,703,777	222,659,827	$1,543	$1,682
11, 21	Natural Resources and Mining	2,651,704	425,665	$212,703,777	$18,105,341	$774	$818
23	Construction	885,668	855,879	$64,957,714	$65,680,182	$1,410	$1,476
31-33	Manufacturing	1,322,455	1,263,780	$129,893,887	$138,874,304	$1,889	$2,113
22, 42, 44-45, 48-49, 51, 52-56. 61-62. 71-72, 81, 92, 99	Service-Providing	12,475,874	11,421,391	$863,380,858	$890,889,889	$1,331	$1,500
42,44-45,48-49,22	Trade, Transportation, and Utilities	3,042,089	2,888,684	$167,035,136	$169,854,016	$1,056	$1,131
51	Information	550,084	527,549	$105,218,867	$114,948,558	$3,678	$4,190
52-53	Financial Activities	841,829	817,007	$94,922,426	$101,396,338	$2,168	$2,387
54-56	Professional and Business Services	2,723,437	2,600,604	$259,673,224	$276,928,630	$1,834	$2,048
61-62	Education and Health Services	2,734,574	2,651,781	$147,417,298	$152,922,267	$1,037	$1,109
71-72	Leisure and Hospitality	2,034,920	1,482,600	$65,887,810	$53,506,505	$623	$694
81	Other Services	547,972	452,175	$23,175,484	$21,288,573	$813	$905
99	Unclassified	970	990	$50,613	$45,001	$1,003	$874
All	Federal Government	248,244	260,077	$21,402,826	$22,719,175	$1,658	$1,680
All	State Government	476,217	474,292	$40,316,904	$42,584,913	$1,628	$1,727
All	Local Government	1,779,450	1,676,975	$120,218,377	$122,879,078	$1,299	$1,409
Source: California Employment Development Department, Quarterly Census of Employment and Wages (QCEW)							

8.1.2. Median Household and Poverty

Median Household incomes for selected counties that comprise the Oakland-Hayward-Berkeley Metropolitan Division (MD) are shown in Table 8-3 below. Alameda County's household median income is over 137 percent of the state median income, while the City of Oakland's income is 105 percent of the state median income.

Table 8-3. Median Household Income, 2019

Geography	Median Houshold Income (2019)	Percent of State Median Household Income
Contra Costa County	$106,555	136.20%
Alameda County	$107,589	137.70%
City of Oakland	$82,018	105%
California	$78,105	100%
United States	$86,011	N/A
Source: St. Louis FRED & Data USA: U.S. Census Bureau Small Area Income and Poverty Estimates (SAIPE)		

The unemployment rate in the Oakland-Hayward-Berkeley MD was 8.9 percent in 2020 and 6.5 percent in 2021, nearly 1.5 percentage points below the state average in both years and .8 percentage points above the national average (see Table 8-4).

Table 8-4. Unemployment Rate, 2019-2021

Geographical Area	Unemployment Rate (percent)		
	2019 average	2020 average	2021 average (JAN-SEPT)
Contra Costa	3.1	8.9	6.8
Alameda	3	8.8	6.5
Oakland-Hayward-Berkeley	3.1	8.9	6.5
California	4.2	10.2	8
United States	3.7	8.1	5.7
Source: US Bureau of Labor Statistics & St. Louis FRED (Current Population Survey)			

8.2. Social Characteristics and Trends

This section describes the social characteristics of the Oakland-Hayward-Berkeley MD, which is comprised of Alameda and Contra Costa counties. The social characteristics assessed in this section include race, age, education, and regional income and poverty data.

8.2.1. Racial Composition

Most persons living in the City of Oakland are White (35.5 percent), followed by Hispanic or Latino (27 percent), and Black/African American (23.8 percent). The City of Oakland has a much higher percentage of Black/African American persons than Alameda and Contra costa Counties, California, and the United States (see Table 8-5). In general, California has a higher percentage of Hispanic or Latino persons than the rest of the United States.

Table 8-5. Racial Composition

Racial Composition (Percent)					
Race	City of Oakland	Alameda County	Contra Costa County	California	United States
White	35.5	49.3	65.1	71.9	76.3
Black	23.8	11	9.5	6.5	13.4
American Indian	0.9	1.1	1	1.6	1.3
Asian	15.5	32.3	18.3	15.5	5.9
Pacific	0.6	0.9	0.6	0.5	0.2
Hispanic or Latino	27	22.3	26	39.4	18.5
Two or more races	6.9	5.4	5.4	4	2.8
White alone, not Hispanic or Latino	28.3	30.6	42.7	36.5	60.1
Source: U.S. Census Bureau, Population Estimates Program (PEP) & American Community Survey (ACS) 5-Year Estimates, 2015-2019					

8.2.2. Age Distribution

Most persons living in the City of Oakland are over 18 and under 65 years of age (see Table 8-6). The City of Oakland has a higher population of persons under five years of age than Alameda and Contra Costa Counties, California, and the United States, but a lower population of persons under 18 years of age or over 65.

Table 8-6. Age Characteristics

Age Characteristics (Percent)					
Age Group	City of Oakland	Alameda County	Contra Costa County	California	United States
Persons under 5 years	6.3	5.7	5.6	6	6
Persons under 18 years	19.9	20.3	22.4	22.5	22.3
Persons 65 years and over	13.1	14.3	16.3	14.8	16.5
Source: U.S. Census Bureau, Population Estimates Program (PEP) & American Community Survey (ACS) 5-Year Estimates, 2015-2019					

8.2.3. Education

Approximately 88.4 percent of persons age 25 years or older held a high school degree or higher between 2015-2019 in the City of Oakland (see Table 8-7). This figure is consistent with the national average but is higher than the same rate for California. Contra Costa County, Alameda County, and the City of Oakland have a higher percentage of persons with a bachelor's degree or higher than California (33.9 percent) and the United States (32.1 percent).

Table 8-7. Education Characteristics

Education Characteristics, Percent		
Region	High School Graduate or Higher	Bachelor's Degree or Higher
Contra Costa County	89.5	42.4
Alameda County	88.4	47.4
City of Oakland	82.6	44
California	83.3	33.9
United States	88	32.1
Source: U.S. Census Bureau, American Community Survey (ACS) 5-Year Estimates, 2015-2019		

8.2.4. Income and Poverty

In general, the City of Oakland has a slightly higher median income than the state of California, or the United States (see Table 8-8). Regardless, the poverty rate in the City of Oakland is much higher than in all other regions and the United States as a whole. This implies that a large portion of persons residing in the City of Oakland earn incomes far below the national standard for poverty.

Table 8-8. Income and Poverty

	City of Oakland	Alameda County	Contra Costa County	California	United States
Median Income	$36,171	$43,583	$42,181	$31,960	$31,133
Persons in poverty, percent	16.7	9.9	8.7	13.3	13.4
Source: U.S. Census Bureau, American Community Survey (ACS) 5-Year Estimates, 2015-2019					

8.3. Regional Economic Development (RED) Analysis

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

The USACE Online Regional Economic System (RECONS) is a system designed to provide estimates of regional, state, and national contributions of federal spending associated with Civil Works Projects. It also provides a means for estimating the forward linked benefits (stemming from effects) associated with non-federal expenditures sustained, enabled, or generated by USACE Recreation, Navigation, and Formally Utilized Sites Remedial Action Program (FUSRAP). Contributions are measured in terms of economic output, jobs, earnings, and/or value added. For this report, RECONS version 2.0 was used to estimate contributions.

USACE Institute for Water Resources, Louis Berger, and Michigan State University have developed a regional economic impact modeling tool, RECONS (Regional ECONomic System), that provides estimates of jobs and other economic measures such as labor income, value added, and sales that are supported by USACE programs, projects, and activities. This modeling tool automates calculations and generates estimates of jobs, labor income, value added, and sales using IMPLANs multipliers and ratios, customized impact areas for USACE project locations, and customized spending profiles for USACE projects, business lines, and work activities. RECONS allows the USACE to evaluate the regional economic impact and contribution associated with USACE expenditures, activities, and infrastructure.

The expenditures associated with Oakland Turning Basin Expansion Project are estimated to be $538,831,000, over the three-year construction period from 2027-2030. Of this total expenditure, $338,415,433 will be captured within the San Francisco Metropolitan Statistical Area (MSA). The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in Table 47 below. The regional economic effects are shown for the local, state, and national impact areas. In summary, the Civil Works expenditures $462,400,000 support a total of 5,108.3 full-time equivalent jobs, $348,121,798 in labor income, $263,177,704 in the gross regional product, and $589,081,430 in economic output in the local impact area. More broadly, these expenditures support 7,505.0 full-time equivalent jobs, $596,860,871 in labor income, $735,923,218 in the gross regional product, and $1,245,073,828 in economic output in the nation.

Table 8-9 RECONS Model Results by Area

Overall Summary

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$338,415,433	3,623.6	$319,388,928	$209,541,091
Secondary Impact		$250,665,997	1,484.7	$28,732,870	$53,636,613
Total Impact	$338,415,433	$589,081,430	5,108.3	$348,121,798	$263,177,704
State					
Direct Impact		$359,301,112	3,811.0	$319,888,320	$210,040,483
Secondary Impact		$356,992,375	1,775.1	$30,367,066	$75,729,386
Total Impact	$359,301,112	$716,293,486	5,586.2	$350,255,386	$285,769,870
US					
Direct Impact		$440,845,546	4,098.7	$346,949,259	$302,990,382
Secondary Impact		$804,228,282	3,406.4	$249,911,612	$432,932,837
Total Impact	$440,845,546	$1,245,073,828	7,505.0	$596,860,871	$735,923,218

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

9. References

References are cited throughout the appendix.

USACE (U.S. Army Corps of Engineers). Economic Guidance Memorandum (EGM) 17-04, Deep- Draft Vessel Operating Costs FY 2016 Price Level. 24 April 2017.

USACE. Economic Guidance Memorandum (EGM) 15-04, Deep-Draft Vessel Operating Costs FY 2013 Price Level. 28 September 2015.

USACE. Engineering Regulation (ER) 1105-2-100, Planning Guidance Notebook. October 2010, as amended.

USACE. IWR Report 10-R-4, National Economic Development Manual for Deep Draft Navigation.

April 2010.

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

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

U.S. Census Bureau. 2015-2019 American Community Survey (5-year estimates).

U.S. Census Bureau. 2010 Census.