US Army Corps
of Engineers®
New York District

NEW YORK AND NEW JERSEY HARBOR DEEPENING CHANNEL IMPROVEMENTS

NAVIGATION STUDY

DRAFT INTEGRATED FEASIBILITY REPORT & ENVIRONMENTAL ASSESSMENT

APPENDIX C:

Economic Analysis

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1. Introduction

The role of the U.S Army Corps of Engineers (USACE) with respect to navigation is to reduce navigation hazards and enable reliable and efficient waterborne transportation systems for the movement of commerce, national security needs, and recreation. The Planning Guidance Notebook (ER 1105-2-100) was referenced in performing this economic analysis. National Economic Development (NED) benefits are contributions to National Economic Development that increase the value of the national output of goods and services. NED benefits are the primary basis for Federal investment in water resource projects and are measured in average annual equivalent (AAEQ) terms.

1.1. Study Purpose and Scope

The purpose of this study is to evaluate Federal interest in alternative plans (including the No-Action Plan) for reducing transportation costs and addressing navigation safety issues for New York and New Jersey (NYNJ) Harbor and assess the effects of the alternatives on the natural system and human environment, including economic development. The economic analysis focuses on the overall efficiency of the system and comparison of transportation costs.

The current Federally authorized channel depth of NYNJ Harbor is -50 feet mean lower low water (MLLW). Potential navigation improvements include deepening and widening of navigation channels. The purpose of these improvements is to increase the efficiency of vessel operations within NYNJ, especially containership operations. This study identifies and evaluates alternatives that will:

- Accommodate current and anticipated future growth in both containerized cargo volume and containership size and call frequency; and
- Improve the efficiency of operations for containerships calling the Port of New York and New Jersey

The period of analysis is 50 years. The planning horizon starts in year 2039 and ends in year 2088. The analysis uses the vessel operating cost from the Economic Guidance Memorandum (EGM), 20-04, Deep Draft Vessel Operating Costs Fiscal Year 2019 Price Levels and the Federal discount rate from EGM, 21-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year (FY) 2020 of 2.5 percent[1]. The benefits in the economic analysis are derived from transportation cost savings.

1.2. Data Sources and Uses

Data was collected from multiple sources to characterize the existing conditions for the analysis. Where possible, analysis confirms data across multiple sources; however, vessel operating data is subject to error, gaps, and limitations. The following data sources were used:

[1] Initial alternatives analysis (Section 5.4. uses FY20 Federal Discount Rate and October 2019 price level. The recommended plan is updated to the FY21 discount rate and October 2020 price level.

- Waterborne Commerce Statistics Center
- National Navigation Operation & Management Performance Evaluation & Assessment System (NNOMPEAS)
- Port Authority of New York and New Jersey
- Sandy Hook Pilots Association

For the purposes of economic analysis, the NYNJ Harbor system was represented in the HarborSym model. HarborSym is a planning-level simulation model designed to assist in the economic analyses of coastal harbors. It was developed as a data-driven, Monte Carlo simulation model which allows users to evaluate the difference between study alternatives. The model calculates vessel interactions within the harbor with user provided input data such as the port layout, vessel calls, and transit rules. Using this model, analysts can calculate the cost of any changes in overall transportation costs that result from proposed modifications to the channel's physical dimensions. Full methodology and model behavior are presented in **Section 5.1.** of this appendix.

2. Existing Condition

The existing conditions are defined in this report as the project conditions that exist as of 2018 plus any changes that are expected to occur prior to the base year, 2039. The year 2018 is the most recent year for which complete data was obtained for containerized cargo volumes and fleet composition. Empirical data from 2009 to 2018 was used in the development of the commodity and fleet forecast to capture economic highs and lows in the baseline for analysis.

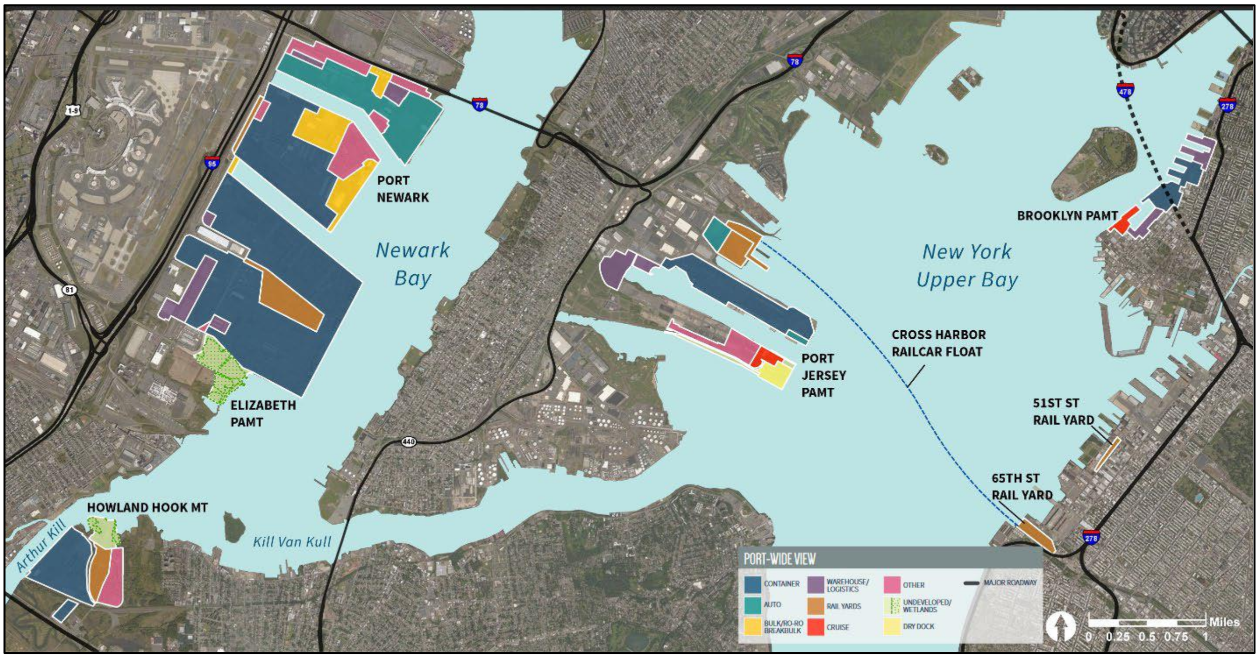
2.1. Economic Study Area

The Port of NYNJ is the largest East Coast container port and third largest US container port by TEU volume (USACE, 2019). The Port is comprised of both public and private terminals located in New York and New Jersey and is capable of handling containers, roll on-roll off (ro-ro) automobiles, liquid and dry bulk, breakbulk, and specialized project cargo. The port serves approximately 80 million consumers in the New York/New Jersey metropolitan area and markets in the Midwest, New England and Eastern Canada.

Of the approximately 51 marine terminals located in the study area, 22 facilities (43 percent) handle dry cargo and 29 (57 percent) facilities primarily handle liquid bulk cargo. Significant liquid bulk terminals include Bayway Terminal, International Matex Tank Terminals (IMTT) Bayonne, Buckeye Terminals, NuStar-Linden Terminal, and Shell Terminals.

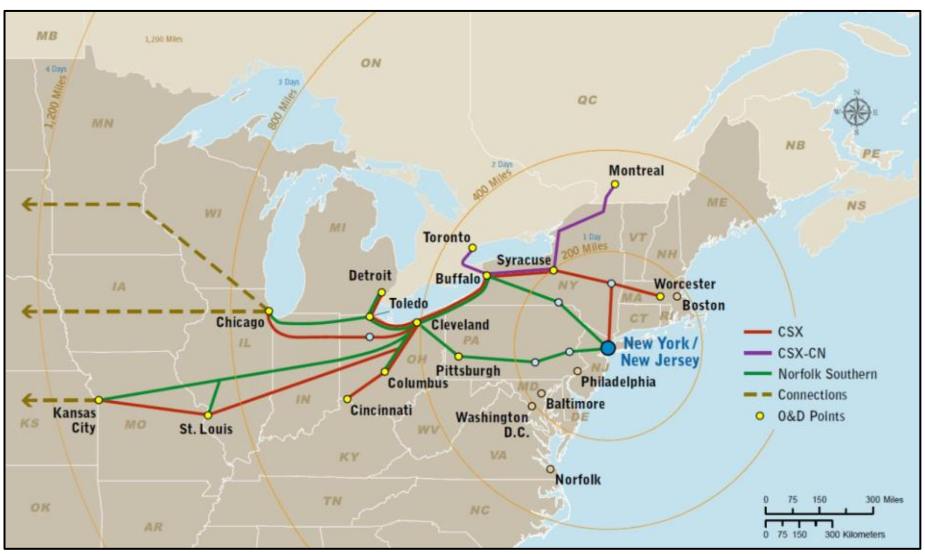
Most dry cargo\handled at NYNJ is containerized. Major container terminals included in this study are Elizabeth-Port Authority Marine Terminal (EPAMT), Port Jersey-Port Authority Marine Terminal (PJPAMT), and Port Newark. Navigation improvement to Howland Hook were considered for removed from evaluation based on lack of potential benefit. **Figure 1** identifies all container facilities in the study area.

Figure 1: NYNJ Harbor Layout



Port of NYNJ terminals are accessible via rail or truck. The rail system includes ExpressRail which connects to Regional Rails, which has dedicated facilities and additional support track and rail yards for each of the port's major container terminals. The NYNJ region is served by three Class 1 railroads: Canadian-Pacific, CSX Intermodal and Norfolk Southern. The trucking and roadway network have capacity to reach 100 million consumers within a day. The port is located within 700 miles of major cities and population centers in the Northeast. **Figure 2** depicts the rail network between Port of NYNJ and major inland population centers

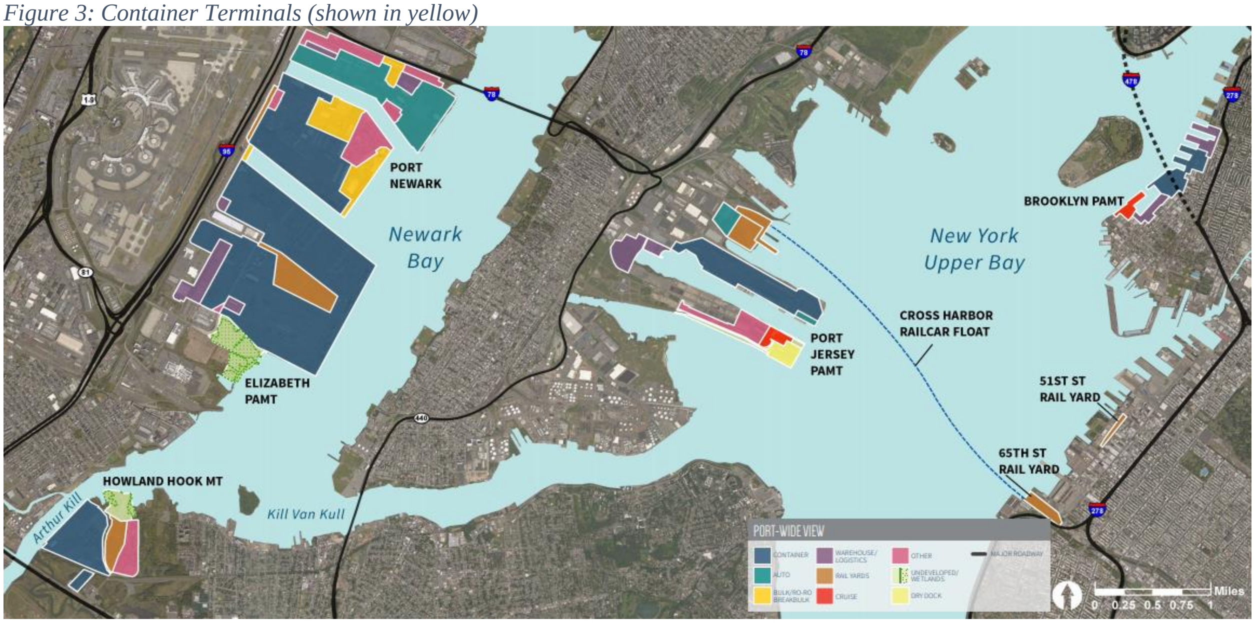
Figure 2: NYNJ Harbor Rail Network (Port Authority of NYNJ, 2020)



2.1.1. Port Facilities

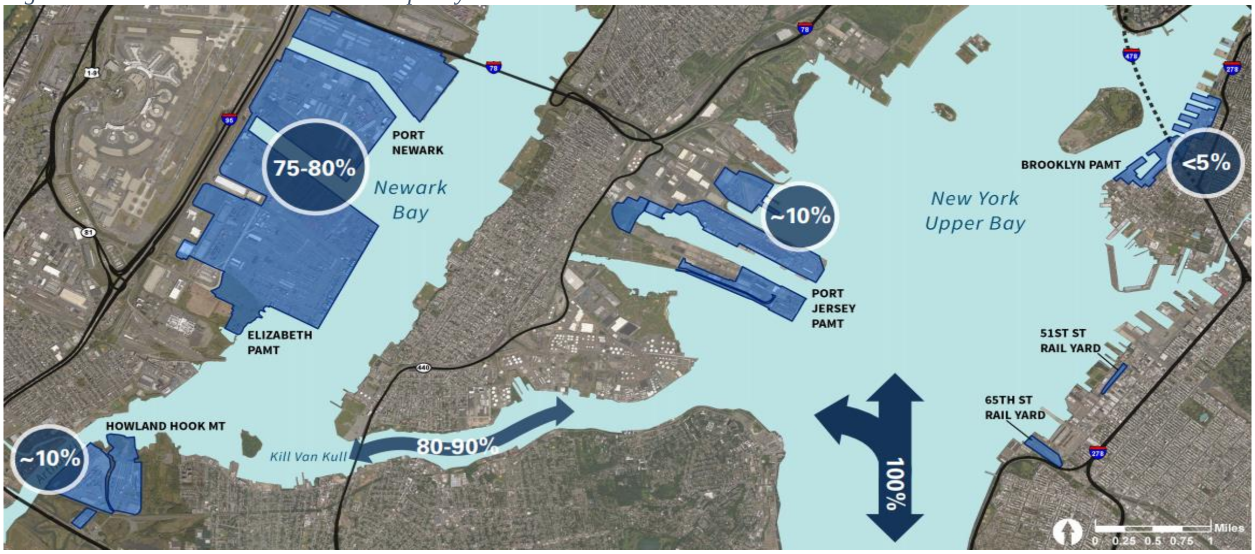
This study evaluates improvements for vessels calling six container terminals within NYNJ Harbor: Red Hook Container Terminal, Global Container Terminal Bayonne, Global Container Terminal New York/Howland Hook, APM Terminal, Maher Terminal and Port Newark Container Terminal. Container facilities are leased by the Port Authority to individual terminal operators. The terminals are the first port of call for approximately 72 percent of vessels calling the East Coast. The terminals serve 23 ocean carriers including all the major global alliances as well as 11 independent carriers. **Figure 3** is a map of NYNJ Harbor with container terminals highlighted blue.

Figure 3: Container Terminals (shown in yellow)



Estimated annual throughput capacity at all container terminals in NYNJ is approximately 9 million TEUs. Current containerized cargo capacity is between 75 to 80 percent of capacity at EPAMT, approximately 10 percent of cargo at Howland Hook and PJPAMT, and less than 5 percent at Brooklyn PAMT. Figure 4 shows the current container terminal capacity distribution.

Figure 4: Current Container Terminal Capacity Distribution



2.1.1.1. Red Hook Container Terminal

The Red Hook Container Terminal is located on the east side of the Anchorage channel in Brooklyn, New York. The terminal handles containers, breakbulk and ro-ro vessels. It sits on approximately 65 acres with berths at -42 feet Mean Low Water (MLW). The terminal has five cranes with an outreach of up to 150 feet. The ship berth has an alongside length of 2,080 feet. The Red Hook Terminal connects to Express Rail Elizabeth via barge service. The scope of this study is limited to the currently constructed -50 feet MLLW channel. Since the channel segment leading to Red Hook Container Terminal in New York was not included in the -50 feet MLLW deepening project, it was screened from further consideration for this study.

Figure 5 and **Figure 6** display the inbound and outbound sailing drafts, respectively, for vessels calling the Red Hook Container Terminal. **Table 1** displays the historical inbound and outbound tonnage.

Figure 5: Inbound Sailing Drafts, Red Hook Container Terminal

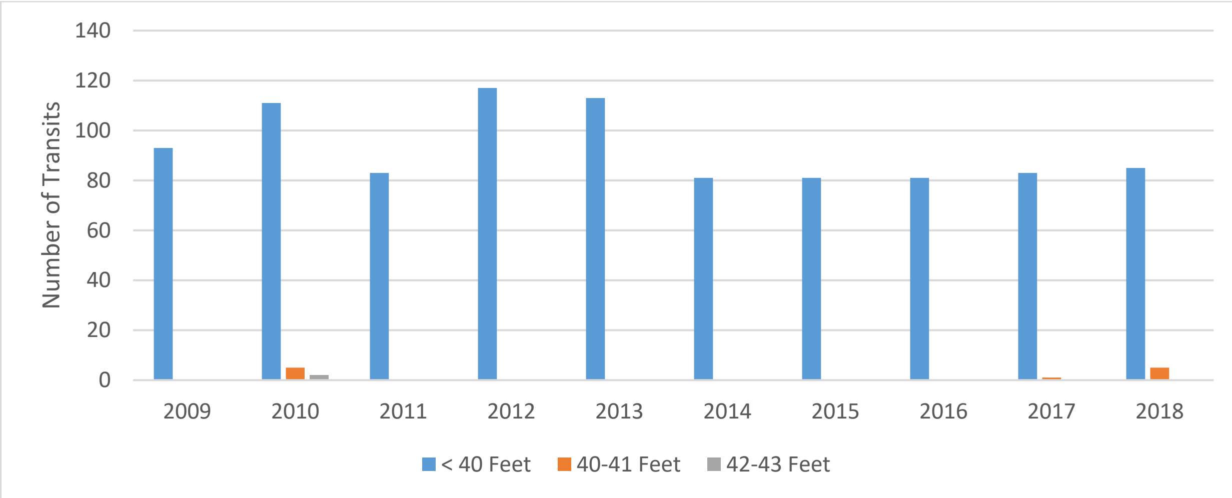


Figure 6: Outbound Sailing Drafts, Red Hook Container Terminal

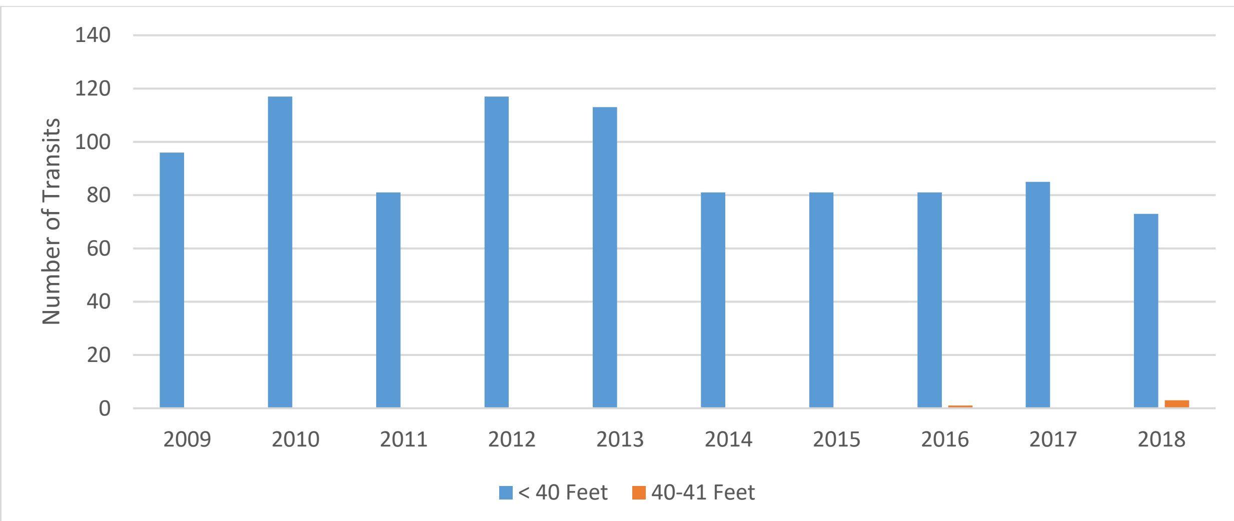


Table 1: Historical Containerized Tonnage, Red Hook Container Terminal (1,000 Metric Tons)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Imports	188	581	217	206	239	368	430	400	451	594
Exports	215	336	197	292	238	187	250	297	345	271

2.1.1.2. Global Container Terminal (GCT), Bayonne

GCT Bayonne sits on 169 acres with 2,700 feet in berth length. There are eight container cranes, two super post-Panamax with an outreach of 203 feet, two post-Panamax cranes with an outreach of 185 feet and two post-Panamax cranes with an outreach of 180 feet. The depth at berth is -50 feet MLW.

GCT is the closest container terminal to the NYNJ Harbor entrance. Rail service is provided by both the CSX and the Norfolk Southern Railroads. The terminal has direct access to the New Jersey Turnpike and is minutes away from bridges connecting to New York, Long Island, and the Northeast. The facility currently has three calling services: Hapag-Lloyd, Ocean Network Express, and Yang Ming. The facility has an annual throughput capacity of approximately 600,000 container lifts.

Figure 7 and **Figure 8** display inbound and outbound sailing drafts for vessels calling the GCT Bayonne Terminal. **Table 2** presents historical inbound and outbound tonnage.

Figure 7: Inbound Sailing Drafts, GCT Bayonne

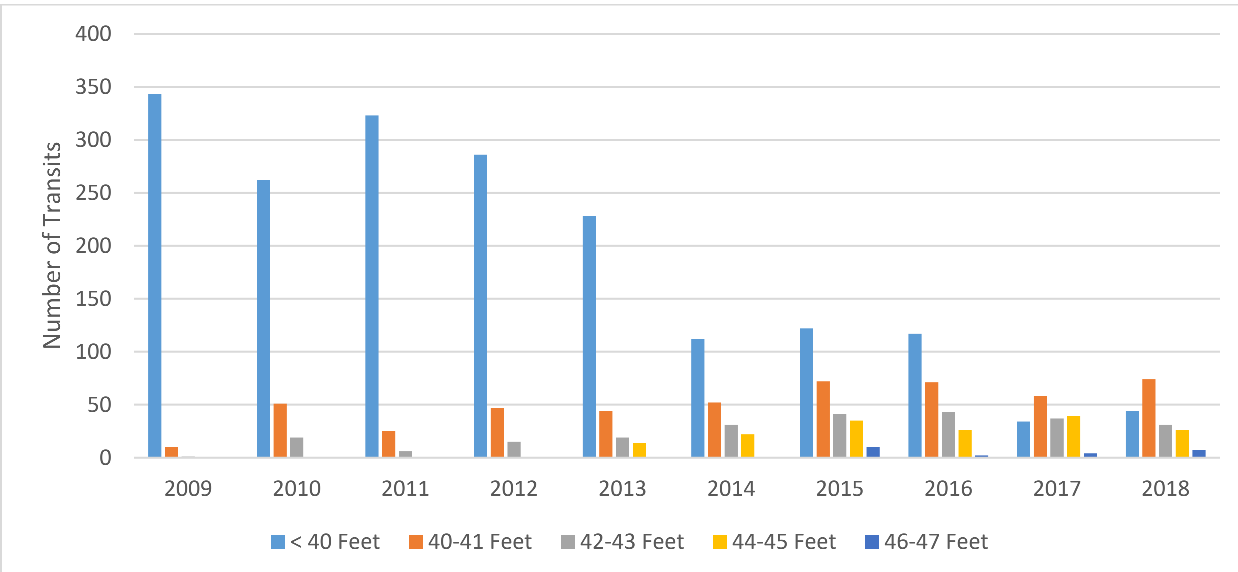


Figure 8: Outbound Sailing Drafts, GCT Bayonne

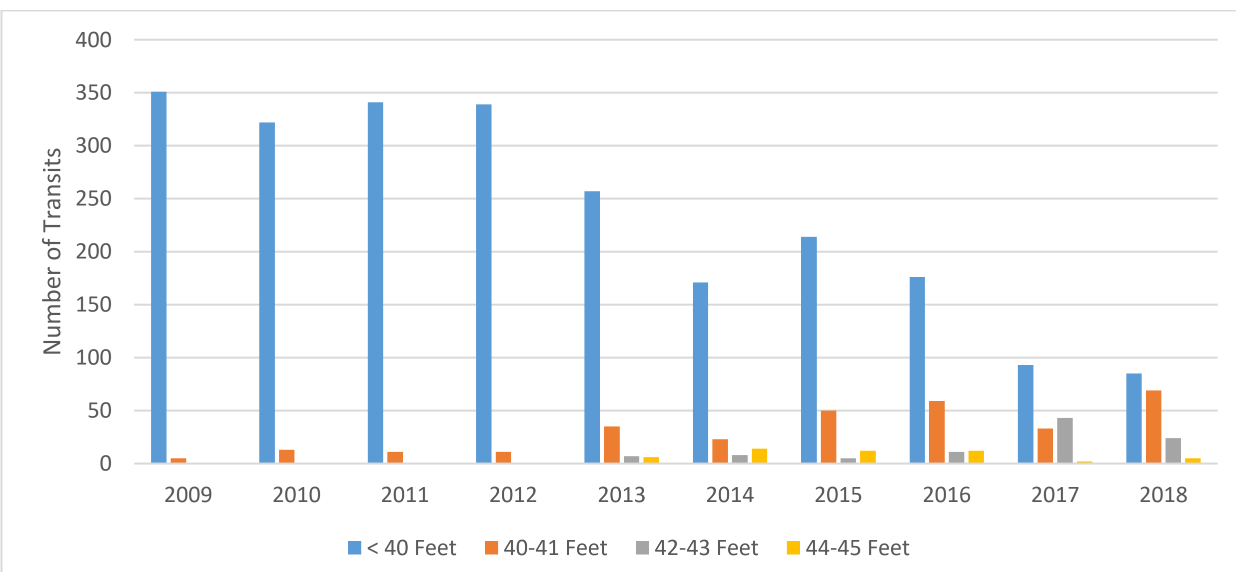


Table 2: Historical Containerized Tonnage, GCT Bayonne (1,000 Metric Tons)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018

Imports	2,087	2,333	2,732	2,921	2,990	3,670	5,105	4,299	3,720	3,203
Exports	967	1,145	1,384	1,165	1,238	1,494	1,558	1,425	1,526	1,254

2.1.1.3. Global Container Terminal (GCT), New York

The Global Container Terminal (GCT) New York is a 187-acre facility located at Howland Hook Marine Terminal, near the Goethals Bridge in Staten Island, New York. It has six ship-to-shore post-Panamax cranes, with an outreach of up to 135 feet. It has a berthing length of 3,012 feet. This terminal is uniquely equipped with an expanded on-dock rail transfer service operated by ExpressRail Staten Island (ESI), which has 5 tracks totaling 6,000 linear feet. GCT New York has access to I-278, Route 440, I-95, I-78, Route 1, and Route 9 and is minutes away from bridges connecting to the tri-state area and the Northeast. The terminal has 7 ocean carrier services: ACL, Hapag Lloyd, Sealand, Grimaldi, Yang Ming, Hamburg Sud, and Ocean Network Express. This terminal was screened from further analysis due to a lack in potential benefit.

Figure 9 and **Figure 10** display inbound and outbound sailing drafts for vessels calling the GCT Bayonne terminal. **Table 3** displays the historical inbound and outbound tonnage.

Figure 9: Inbound Sailing Drafts, GCT New York

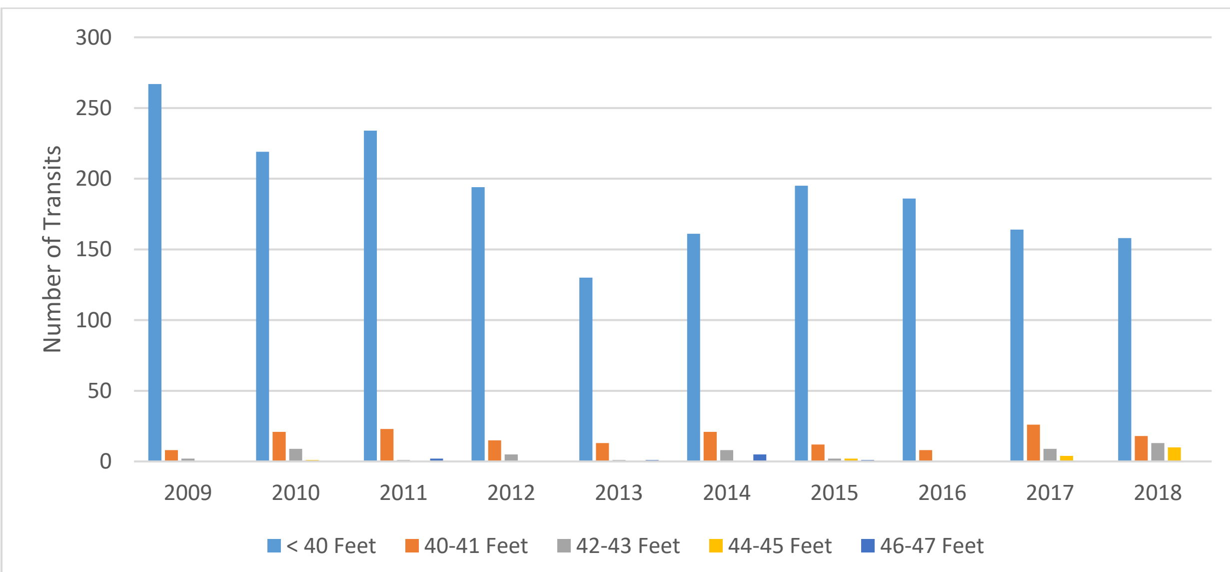


Figure 10: Outbound Sailing Drafts, GCT New York

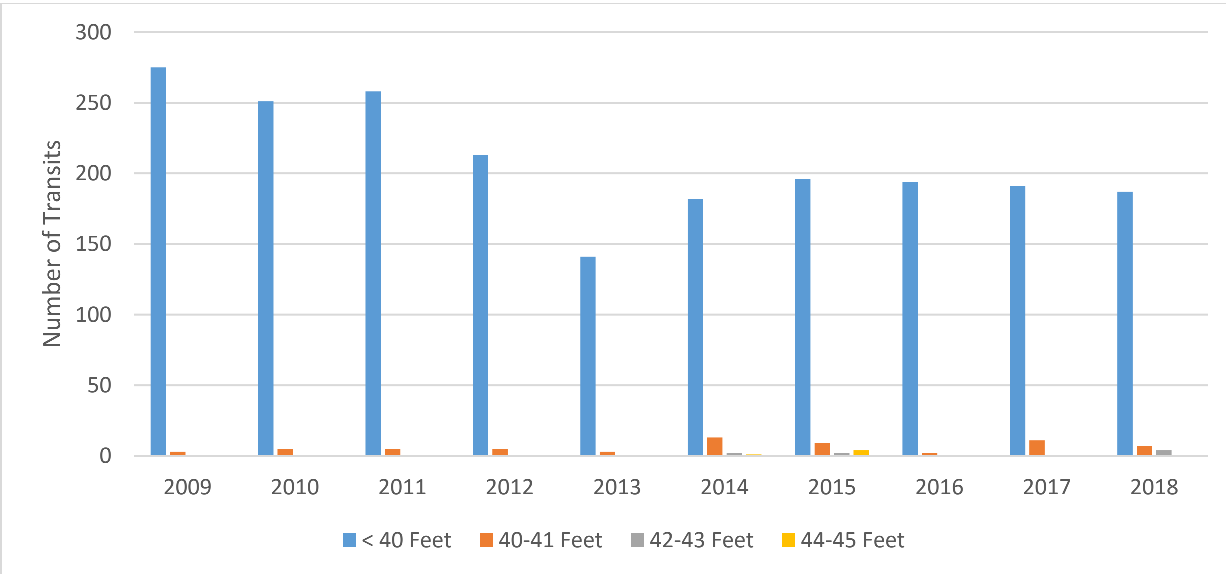


Table 3: Historical Containerized Tonnage, GCT New York (1,000 Metric Tons)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Imports	2,454	2,667	2,701	2,110	1,087	1,233	1,262	857	1,542	1,705
Exports	994	1,104	1,084	940	509	608	646	534	711	888

2.1.1.4. APM Terminals

The APM Terminal is a 350-acre facility located at the EPAMT in Elizabeth, New Jersey. The terminal is less than one mile from the New Jersey Turnpike, as well as Route 1 and Route 9, and less than two miles from I-78. It has 15 ship-to-shore Post-Panamax cranes; four Super Post-Panamax cranes with an outreach of 206 feet and 11 Post-Panamax cranes with an outreach of up to 140 feet. It has a berthing length of 6,001 feet and a throughput capacity of approximately 2.3 million TEUs. APM terminal is adjacent to the ExpressRail Elizabeth (EMT). Sixteen ocean carriers service the terminal: ACL, CMA-CGM, COSCO, Evergreen, Hamburg Sud, Hapag Lloyd, Hyundai, Maersk, MSC, Nile Dutch, NYK, OOCL, Safmarine, Sealand, Turkon, and Zim Line. Berth depths range from -45 to -50 feet MLW.

Figure 11 and **Figure 12** display inbound and outbound sailing drafts for vessels calling at APM Terminal. **Table 4** shows historical tonnage.

Figure 11: Inbound Sailing Drafts, APM Terminal

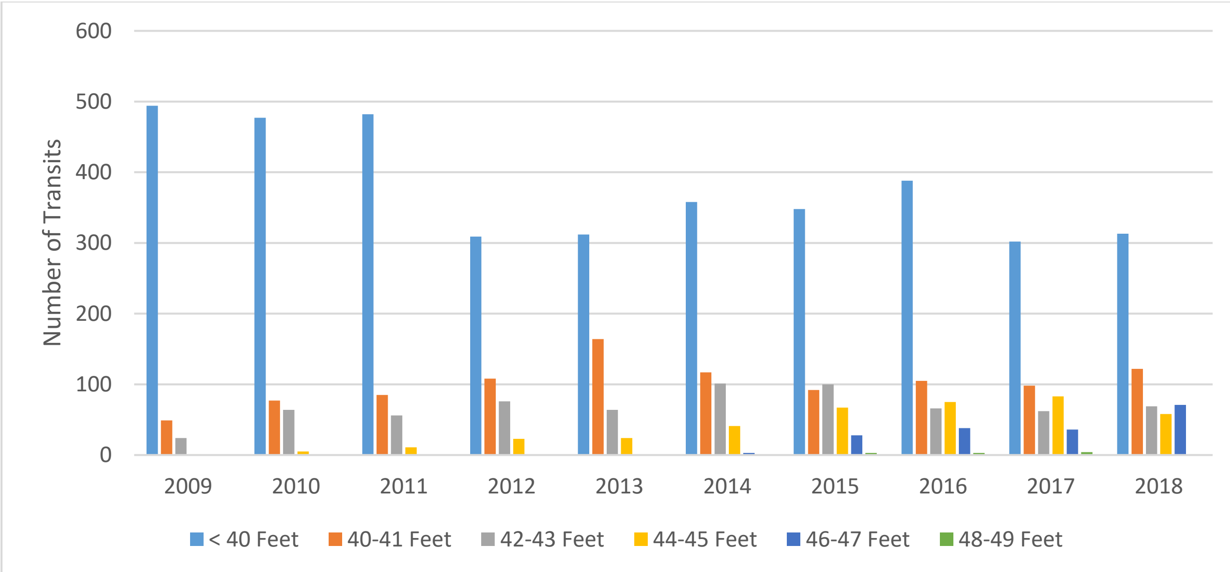


Figure 12: Outbound Sailing Drafts, APM Terminal

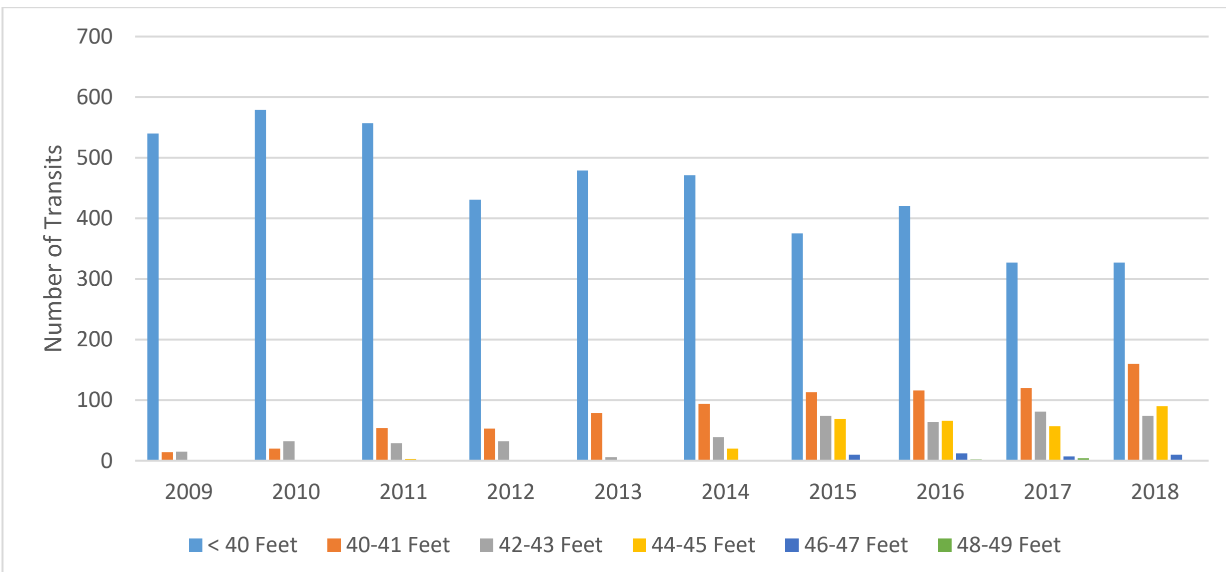


Table 4: Historical Containerized Tonnage, APM Terminal (1,000 Metric Tons)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Import	4,755	4,668	5,303	5,776	6,349	7,173	7,260	6,635	7,106	8,293
Export	3,016	2,806	3,464	3,525	3,554	3,535	3,737	3,895	3,483	4,371

2.1.1.5. Port Newark Container Terminal (PNCT)

The Port Newark Container Terminal (PNCT) is a 272-acre facility at the Port Newark in New Jersey. It has 13 Post-Panamax Class ship-to-shore cranes; seven accommodating the Super Post-Panamax vessels with an outreach of up to 225 feet and six accommodating the Post-Panamax vessels with an outreach of up to 200 feet. Moreover, PNCT has a total berthing area of 4,400 linear feet. PNCT currently serves 7 ocean carriers: Hamburg Sud, Hyundai, Maersk, MSC, Safmarine, Sealand, and ZIM. The depth at the berth ranges from -40 to -50 feet MLW.

At its current configuration, PNCT has a throughput capacity of approximately 1.3 million TEUs. Currently, the terminal moves 25% of its vessel container volume via rail. Additional improvements are planned for the terminal, including a new gate complex, increasing terminal capacity, and improving peak crane handling. Moreover, PNCT plans to expand the terminal by developing 50 additional acres, deepening the berthing area, and upgrading the container handling equipment, including additional super post-Panamax ship-to-shore cranes. It has a long-term lease agreement with the Port Authority of NYNJ, through the year 2050.

Figure 13 and **Figure 14** display the sailing drafts for vessels calling at PNCT. **Table 5** displays historical tonnage for PNCT.

Figure 13: Inbound Sailing Drafts, PNCT

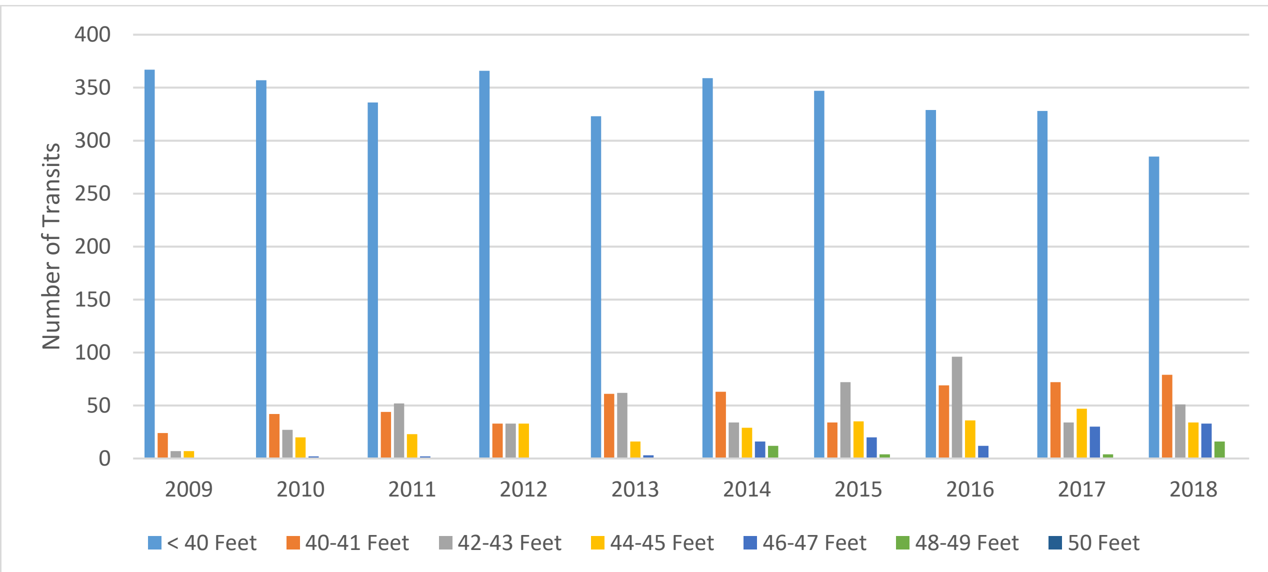


Figure 14: Outbound Sailing Drafts, PNCT

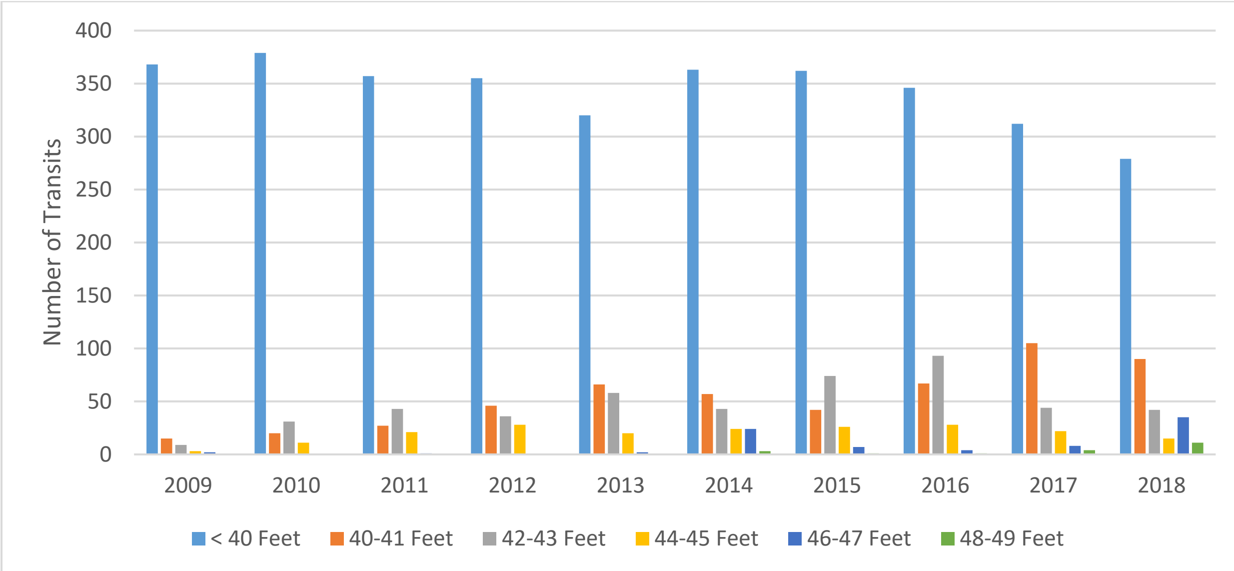


Table 5: Historical Containerized Tonnage, PNCT (1,000 Metric Tons)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Imports	2,806	3,910	4,514	4,858	4,704	4,893	5,053	4,801	6,127	6,187
Exports	2,047	2,592	2,957	3,209	3,047	2,670	2,178	2,539	2,545	2,627

2.1.1.6. Maher Container Terminal

The Maher Container Terminal is a 450-acre facility located at EPAMT in Elizabeth, New Jersey. It has 24 ship-to-shore Post-Panamax cranes; among them, eight are Super Post-Panamax cranes with an outreach of up to 225 feet and 16 are Post-Panamax cranes with an outreach of up to 200 feet. In addition, it has a total berthing length of 10,128 feet. The Maher Container Terminal is immediately adjacent to the Express Rail Elizabeth (EMT), which has 18 working tracks totaling 43,000 linear feet. The Maher Container Terminal services 14 ocean carriers, including: ACL, APL, Bermuda Container, CMA-CGM, COSCO, Evergreen, Hamburg Sud, Hapag Lloyd, K Line, MOL, OOCL, UASC, Yang Ming, and Zim Line. The depth at the berth is -50 ft MLW.

Figure 19 and **Figure 20** display sailing drafts for vessels calling at Maher Container Terminal. **Table 6** shows historical tonnage.

Figure 15: Inbound Sailing Drafts, Maher Container Terminal

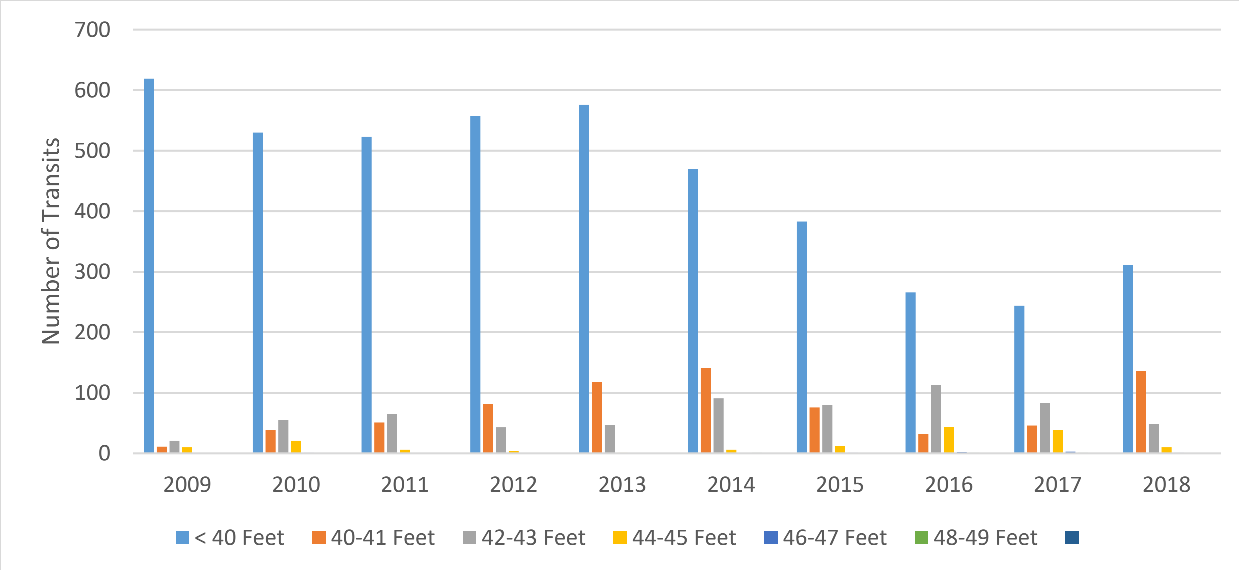


Figure 16: Outbound Sailing Drafts, Maher Container Terminal

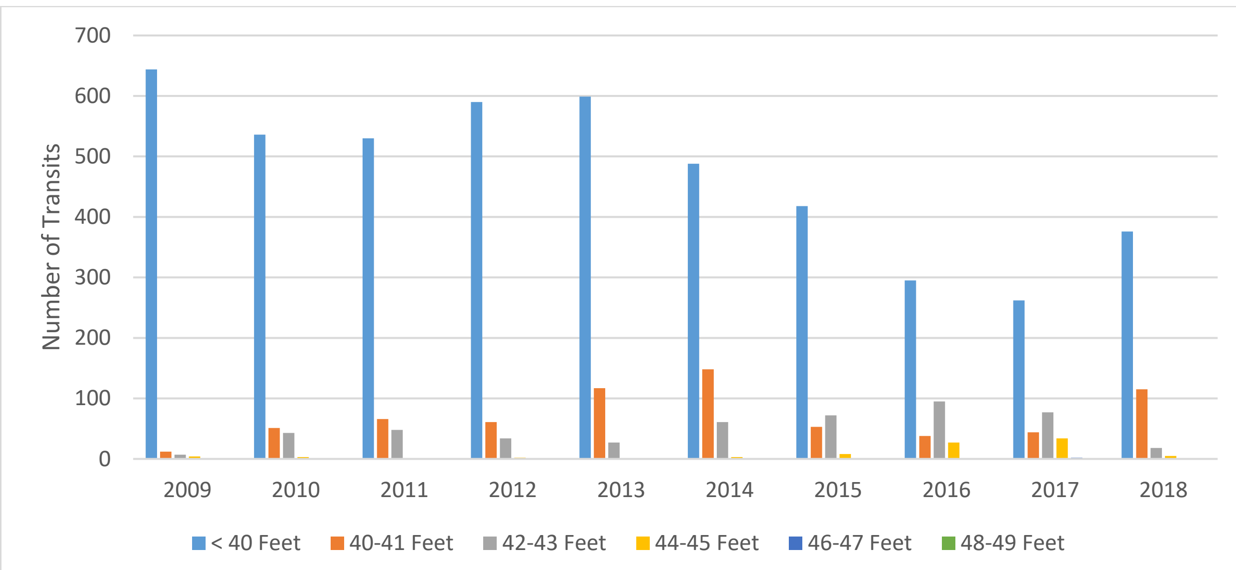


Table 6: Historical Containerized Tonnage, Maher Container Terminal (1,000 Metric Tons)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Imports	4,802	5,504	5,270	5,740	5,731	6,245	6,096	6,590	8,185	9,669
Exports	2,866	3,710	3,562	3,481	3,122	3,231	3,275	3,301	3,807	3,312

2.1.2. Hinterland

2.1.3. Distribution Centers

Approximately 1 billion square feet of warehousing and distribution space is located within 50 miles of the port. These facilities serve as a gateway for products headed to 13 million consumers in one hour, 27 million consumers in two hours, and 44.7 million within four hours.

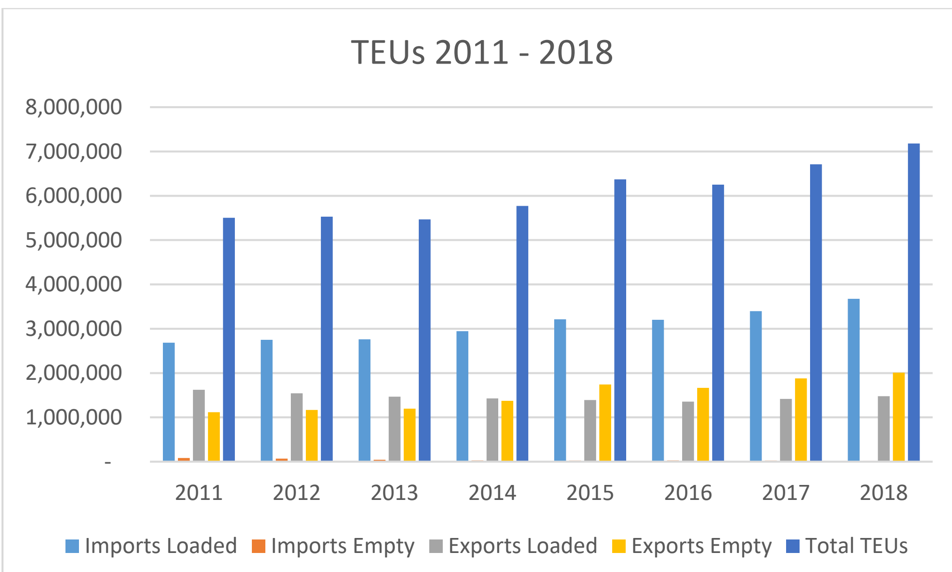
These facilities include:

- TRT International Ltd.
- Harbor Freight Transport
- Eastern Warehouse
- East Coast Warehouse & Distribution Corp.
- New York Container Terminal Inc.
- Red Hook Container Terminal; and
- Courier Systems

2.1.4. Cargo Profile

The Port of NYNJ handled approximately 7.2 million twenty-equivalent units (TEUs) in 2018 and ranks third in the United States in terms of total containerized volume exported and imported. The largest containerized import volumes are for furniture followed by machinery & appliances, plastic and beverages. The largest containerized export volumes are wood pulp followed by vehicle parts, plastic and wood. The lead trading partner is China followed by India for both imports and exports. Germany is third in terms of volume traded for imports and Spain for exports. **Figure 14** shows historical TEUs traded at the port.

Figure 17: NYNJ TEUs, 2011-2018

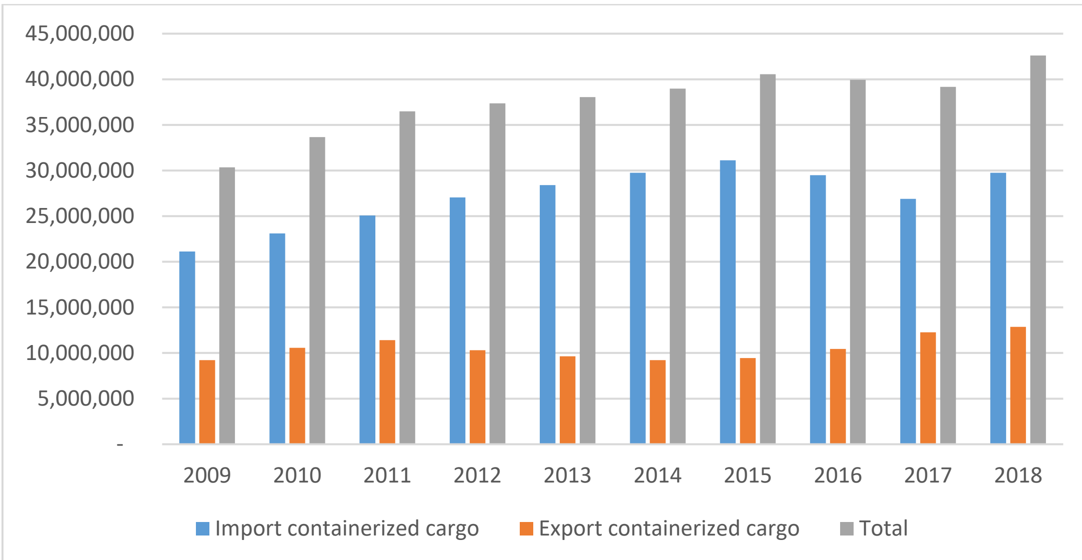


2.2. Historical Commerce

The Port of NYNJ captures 53.5 percent of the North Atlantic market share, 32.8 percent of the East Coast market share and 15.9 percent of the U.S. market share. The Port is a net importer based on metric tons. NYNJ is the first port of call for approximately 72% of all carrier services on the East Coast. The port is located in the heart of the New York metropolitan region and provides access to 27 million local consumers. In addition, the Port's rail connections allow shippers to reach another 98 million consumers in destinations as far away as the Ohio Valley, Midwest, and Canada.

Based on data for years 2009 to 2018, foreign shipments averaged approximately 37.7 million metric tons. Of this total, imports accounted for approximately 27 million metric tons, or 72 percent, while exports accounted for 10.5 million tons, or 28 percent. **Figure 18** shows historical containerized metric tonnage moving through NYNJ Harbor.

Figure 18: NYNJ Historical Containerized Tonnage, 2009-2018



Source: Port Authority Data

2.3. Fleet Composition

Data for the container fleet was obtained from Waterborne Commerce Statistics Center, the National Navigation Operation & Management Performance Evaluation Assessment System (NNOMPEAs) and the Port Authority of NYNJ to determine vessel characteristics of the fleet calling the port. The Port of NYNJ is a multi-use port and receives calls from bulkers, containerships, general cargo vessels, passenger vessels, RoRo vessels, and tankers. Non-containerized vessels transported approximately 50 percent of all cargo in 2018. **Table 7** provides total cargo distribution for all facilities within the study area by vessel type. Behind containerships, tankers carry the most cargo as a percent of total throughput at NYNJ.

Table 7: 2018 Port of NYNJ Vessel Calls by Type

Vessel Type	Percent of Throughput Tonnage Carried	2018 Total Vessel Calls Estimate*
Bulker	7%	275
Containership	50%	2,206
General Cargo	0%	67
Other	0%	33
Passenger	0%	123
RoRo	1%	560
Tanker	40%	1,128
Total	**100%**	**4,238**

*NNOMPEAS Estimate to determine vessel distribution. Actual calls may vary.

The focus of this economic evaluation is on benefits related to containerships. Containerships are classified as sub-Panamax, Panamax, post-Panamax Generation I (PPX Gen 1), port-Panamax Generation II (PPX Gen 2), post-Panamax Generation III (PPX Gen 3) and post-Panamax Generation IV (PPX Gen 4). The vessels are distinguished based on physical and operation characteristics, including lengths overall (LOA), design draft, beam, speed and TEU capacity. Containership classes overlap in all facets of dimensions, such as length, beam, depth, and TEU capacity. For purposes of this document, **Table 8** shows the breakdown of the containership class sizes. For the purposes of this analysis, beam width was the characteristic that separated the classes. The Port and industry tend to use the terms "very large container vessel (VLCV)" to describe vessels with TEU capacity between 11,000 and 15,000 TEU and "ultra large container vessel (ULCV)" to describe vessels with TEU capacity of 18,000 to 21,000 TEU. These industry classes roughly correspond with PPX3 and PPX4 vessel class, respectively.

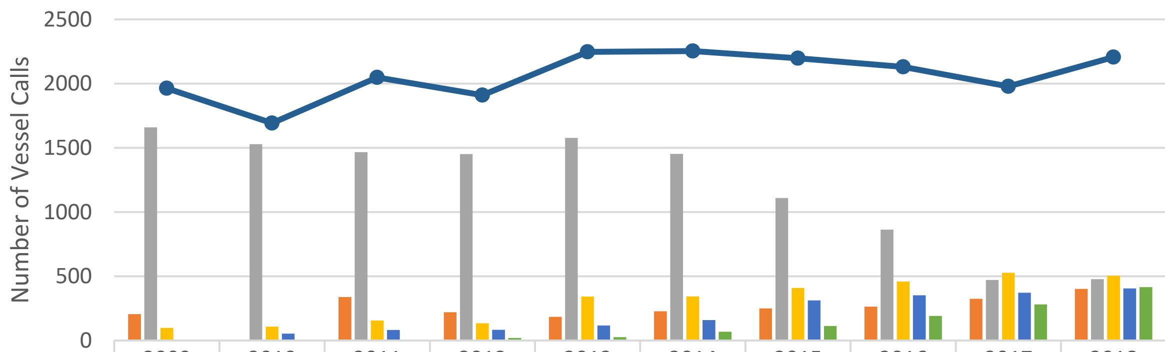
Table 8: Containership Classes

Class	DWT (metric tons)	LOA (feet)	Beam (feet)	Design Draft (feet)
Subpanamax (SPX)	6,500 – 40,000	390 - 730	65 - 103	20 - 40
Panamax (PX)	24,000 – 69,000	558 - 930	105 - 107	27 - 45
Post-Panamax Generation 1 (PPX1)	71,200 – 80,900	930 – 1,000	108 - 133	45 - 47
Post-Panamax Generation 2 (PPX2)	80,901 – 110,000	1,026 – 1,100	134 - 145	46 - 49
Post-Panamax Generation 3 (PPX3)	117,500 – 144,500	1,100 – 1,200	149 - 177	49 - 51
Post-Panamax Generation 4 (PPX4)	150,000 – 194,600	1,201 – 1,308	178 - 194	51 – 52.5

Figure 19 shows historical trends in containership vessel sizes and fleet composition for NYNJ Harbor. As shown, Sub-Panamax vessels continue to be used at a relatively consistent rate.

Panamax size vessels show a dramatic reduction as larger Post-Panamax vessels are used more frequently. The most significant change in vessel size comes with the growth in PPX2 and PPX3 class vessels from 2011 to 2018. As of 2018, 60 percent of calls are from Post-Panamax vessels compared with only 5 percent of calls in 2009.

Figure 19: Containership Vessel Trends



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
SPX	206	0	338	221	184	228	250	264	325	402
PX	1660	1529	1467	1452	1577	1453	1110	863	472	478
PPX1	98	109	156	134	342	344	410	459	528	504
PPX2	0	54	82	83	117	159	313	352	372	406
PPX3	0	0	5	20	27	69	114	192	281	416
Total	1,964	1,692	2,048	1,910	2,247	2,253	2,197	2,130	1,978	2,206

2.4. Container Services

NYNJ Harbor received 40 weekly services and 54 total services in 2019. **Table 9** shows services by region.

Table 9: Container Services

World Region	Services
Asia	11
Indian Subcontinent & Southeast Asia	10
Europe and Mediterranean Region	16
South America and Caribbean	17

Table 10 provides a list of all US ports that share a service with NYNJ. Major US East Coast ports on container services also calling New York include Norfolk Harbor (-50 feet MLLW), Charleston Harbor (-47 feet MLLW), and Savannah Harbor (-48 feet MLLW).

Table 10: US Port Channel Depth and Improvements

US Port	Depth (ft MLLW)
Norfolk	50
Savannah	48
Los Angeles	54
Oakland	50
Charleston	47
Baltimore	43
Port Everglades	42
Philadelphia	42
Houston	45
Miami	50
Boston	38
Wilmington	38
San Juan (PR)	39
Jacksonville	41

2.5. Route Groups

Numerous container services call NYNJ Harbor which are operated by many carriers and have trade routes that originate in various parts of the world. Therefore, services were grouped by the world region they serve. For example, there are a number of services that call on various ports in the Far East, transit the Panama Canal, proceed to ports along the east coast United States and then return to the Far East. As of 2019, 54 unique ocean carrier services used the terminals at NYNJ. Container cargo were aggregated into route groups for forecasting, modeling and presentation purposes based on world regions and vessel composition. Vessel service information was provided by the port authority. That data along with NNOMPEAS data was used to determine route groups. **Table 11** shows the regions, route groups and the distance of each route.

It should be noted that each route group has unique characteristics such as cargo volume, cargo weight, ports of call, vessel types, mix of vessels, etc. and therefore are evaluated separately before being combined as part of the NED analysis. The largest vessels tend to be deployed on Transatlantic routes servicing the Mediterranean and US East Coast, followed by Transpacific Routes with stops along the US East Coast. The smallest vessels (sub-Panamax class) are utilized on the services calling Africa, South America, and the Caribbean.

Table 11: Route Group Information

Route Group Regions	Route Group Name	Distance Distribution		
		Min.	Most Likely	Max.
Africa – South America – Caribbean – Gulf of Mexico - East Coast United States	AF-SA-CAR-ECUS	1,450	7,300	16,100
Europe – Mediterranean – East Coast United States	EU-MED-ECUS	6,300	7,500	11,500
Far East – Panama Canal – East Coast United States, including pendulum routes	FE-PAN-ECUS	19,400	29,800	31,900
Far East – Indian Subcontinent – Southeast Asia – Suez Canal – East Coast United States	FE-SUEZ-ECUS	16,900	25,300	31,400

2.6. Vessel Operations

2.6.1. Navigation Guidelines

The guidelines relevant to this study primarily relate to restrictions around ULCV and super ULCV, which generally correspond to PPX3 and PPX4 class containerships. The Deep Draft Working Group of the Harbor Safety, Operations and Navigation Committee (1 May 2017) set guidelines around these large containerships. They are subject to change but remain the best estimate of current and future operations at NYNJ.

Prior to entering the Port of New York and New Jersey, a suitable berth of destination for a ULCV must be confirmed clear and an anchorage spot should be confirmed available for bailout purposes. Suitable berths have sufficient depth and large enough cranes to unload the vessel. Global Terminal Bayonne (Port Jersey - Port Authority Marine Terminal) has one such berth. ULCVs transiting to Global Terminal Bayonne (Port Jersey - Port Authority Marine Terminal) may draft up to -49 feet. Vessels that draft more than -47 feet must arrive and depart between 1 and 2 hours after high water as measured at the Battery. There cannot be a cruise ship at Bayonne Cruise Terminal and a ULCV at Port Jersey – Port Authority Marine Terminal at the same time; one or the other is acceptable. The approach to Port Jersey - Port Authority Marine Terminal must be made as wide as possible, pushing the north-end of the channel limits. The current width of the Port Jersey Channel is a key factor in the difficulty of maneuvering a ULCV in and out of Port Jersey - Port Authority Marine Terminal. The cross-current of the inbound lane results in substantial difficulty in stopping a ULCV. Vessels are not permitted to back into Global Terminal Bayonne, meaning that they must depart by backing out into Anchorage Channel. The current depth of the Anchorage Channel north of the Port Jersey Channel is not deep enough to facilitate backing out a ULCV in an efficient manner. The efficiency constraint is the result of the extra time spent on completing a complicated maneuver.

Generally, ULCVs may not navigate beyond the Narrows when the maximum sustained winds are greater than 20 knots or maximum gusts are 25 knots or greater. This restriction is critical for the safe navigation of tight spaces such as the Kill Van Kull. Vessels must transit the Kill Van Kull to reach either Elizabeth - Port Authority Marine Terminal/Port Newark or Howland Hook. There are several restrictions specific to the Kill Van Kull. ULCVs are required to transit the Kill Van Kull at slow speeds, posing maneuverability challenges with respect to the wind. Vessels should not transit Bergen Point in sustained winds of 30 knots or greater or gusts greater than 34 knots as measured at Mariners Harbor. The vessels are required to transit the Kill Van Kull within 1 hour on either side of high water or low water as measured at the battery, and the maximum draft is 49 feet. Vessels no larger than 500 feet in length overall are permitted to meet or overtake ULCVs in the Kill Van Kull. This restriction imposes extensive delays on the majority of container, tanker, and other large-vessel traffic transiting to Howland Hook and Elizabeth. ULCV operators would not typically need to wait for the Kill Van Kull to be clear of smaller vessels such as barges. However, no bunker barges are allowed alongside a vessel berthed along the Kill Van Kull while a ULCV passes, and traffic is restricted to one-way from Constable Hook to the Ambrose Channel.

There are additional restrictions on vessels transiting to Global Terminal New York (Howland Hook), and this is largely due to the configuration of the federal channel. A key restriction is the tight turn from the North of Shooter’s Island Reach into the Elizabethport Reach in the Arthur Kill. The vessels that have a destination of Howland Hook must not have an overall length greater than 1,100 feet, a draft greater than -47 feet (high water or low water). The wind restrictions applied to ULCVs navigating beyond the narrows apply to all large container vessels transiting to Howland Hook. The tight turn, the width of the channel, the length of the vessel l, and the wind conditions result in a difficult and perilous navigation situation. What’s more, the largest beam a vessel may have and be safely berthed at Howland Hook is 150 feet. Vessels with beams any larger will violate the channel limits, threatening the safety of passing traffic. Vessels departing Howland Hook must back up out of the terminal and the full length of North of Shooters Island Reach, then executing a k-turn between the South Reach of Newark Bay and Bergen Point. During this operation, traffic is stopped until the k-turn is complete, imposing significant delays.

ULCVs are restricted to a maximum of two channel transits per tide window, which generally means a maximum of four transits per day. Many ULCV calls are located at Elizabeth - Port Authority Marine Terminal, which has several berths and cranes that are suited to accommodate a ULCV. ULCVs have berthed on the face of Elizabeth - Port Authority Marine Terminal and are now more commonly berthed on the Elizabeth Channel side. The width of the South Elizabeth channel is not sufficient to accommodate a ULCV. The maximum draft a vessel may have and transit to Elizabeth - Port Authority Marine Terminal is -49 feet. ULCVs are currently transiting the federal channel light-loaded and have met the -49-foot draft restriction. Transit to and from Elizabeth - Port Authority Marine Terminal through the Newark Bay Channel is restricted to one-way, imposing significant delay on the interacting traffic. ULCVs enter Elizabeth Channel bow-in, which means that the vessels must back out into the Newark Bay Channel in the direction of the Middle Reach (North).

2.6.2. Underkeel Clearance

The measure of underkeel clearance (UKC) for economic studies was applied according to the planning guidance. According to this guidance, UKC is evaluated based on actual vessel operator and pilot practices within a harbor and subject to present conditions, with adjustment as appropriate or practical for with-project conditions. The practices for UKC were determined through interviews with harbor pilots and analysis of actual past and present practices. Generally, analysis uses a minimum UKC of 3 feet. Additional clearance requirements exist for vessel sinkage (**Section 5.1.5.** . For purposes of this analysis, the UKC used in the existing condition for the current channel depth was used with an improved channel.

3. Analysis Overview

The container terminals carried forward in the economic analysis include GCT Bayonne, APM terminals, PNCT, Maher Terminals, and CGT News York. These terminals are included in the -50-foot-deep channel footprint and have berth lengths, crane capabilities, depths and equipment that can accommodate super post-Panamax containerships.

For evaluation purposes, channel pathways were created to analyze cost and benefits by channel segments to terminals mentioned above. The containership terminals are entities that differ in terms of annual throughput, ocean carriers, fleet distribution and volumes of cargo. Difference between terminals is considered throughout the forecast. A pathway represents a combination of channel segments to certain container terminals for the analysis. Benefits will be attributed to each pathway based on commodity growth, fleet mix and transportation cost. Channel deepening and other project cost will be estimated by pathway in order to result in net benefits by pathway. **Figure 20** shows the pathways. **Table 12** shows the terminals analyzed in each pathway.

Figure 20: Pathways for Benefit Analysis

Table 12: Pathway Terminals

Pathways	Terminals
Pathway to EPAMT	**APM, Maher, PNCT**
Pathway to PJPAMT	**GCT Bayonne**
Pathway to Howland Hood	**GCT New York/Howland Hook**

3.1. Pathway to EPAMT

The Pathway to EPAMT includes the channel segments to APM, Maher and PNCT. The channel segment/reaches include the Ambrose Channel, Kill Van Kull and Elizabeth Channel. **Table 13** shows the overview of the terminals in Pathway to EPAMT.

Table 13: Overview of Pathway to EPAMT Terminals

Terminal	Ship Berth Length	Number of Container Cranes	Number of Super Post Panamax Cranes	Number of Ocean Carriers/Services
APM	6,001	15	4	16
Maher	10,128	24	8	14
PNCT	4,400	13	6	7

3.1.1. Pathway to EPAMT Cargo Volumes and Trends

Figure 21 and **Figure 22** show historical cargo volumes imported and exported through the three terminals from 2009 to 2018 in the Pathway to EPAMT. Data was obtained from NNOMPEAS for all container cargo in terms of metric tons. The NNOMPEAS data is approximately 90 percent of the volume that is reported by the Port Authority. However, the volume changes should be accurately represented year by year.

Figure 21: Pathway to EPAMT Containerized (Metric Tons)

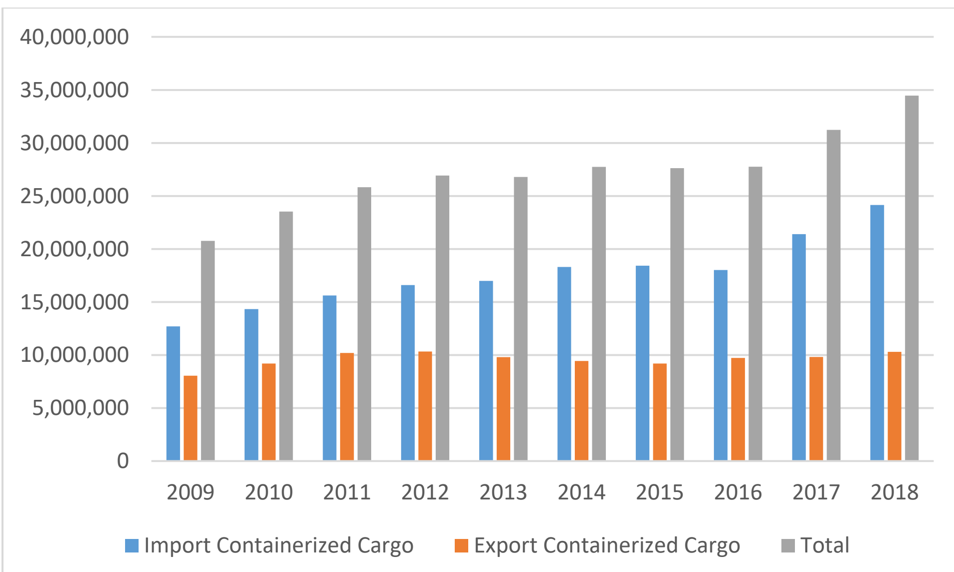
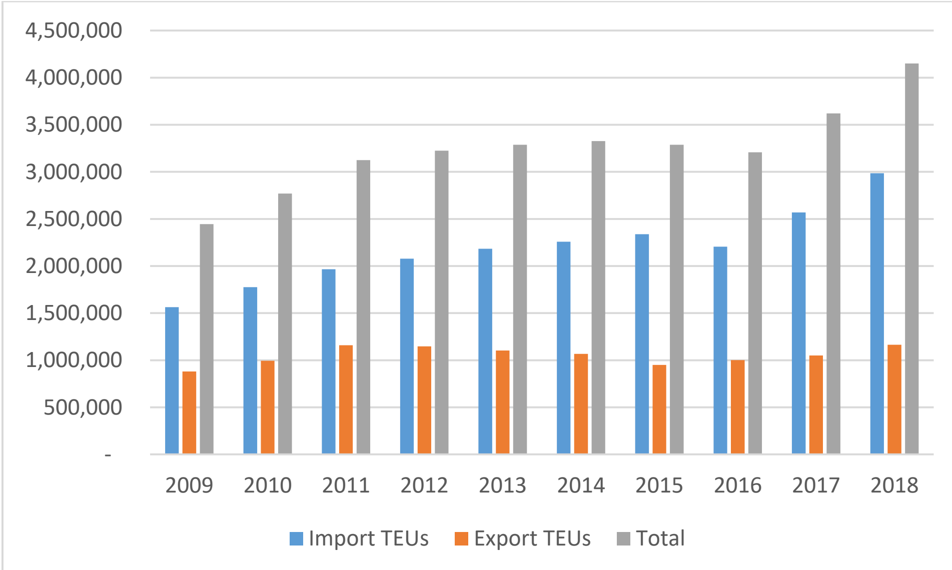


Figure 22: Pathway to EPAMT Loaded TEUs

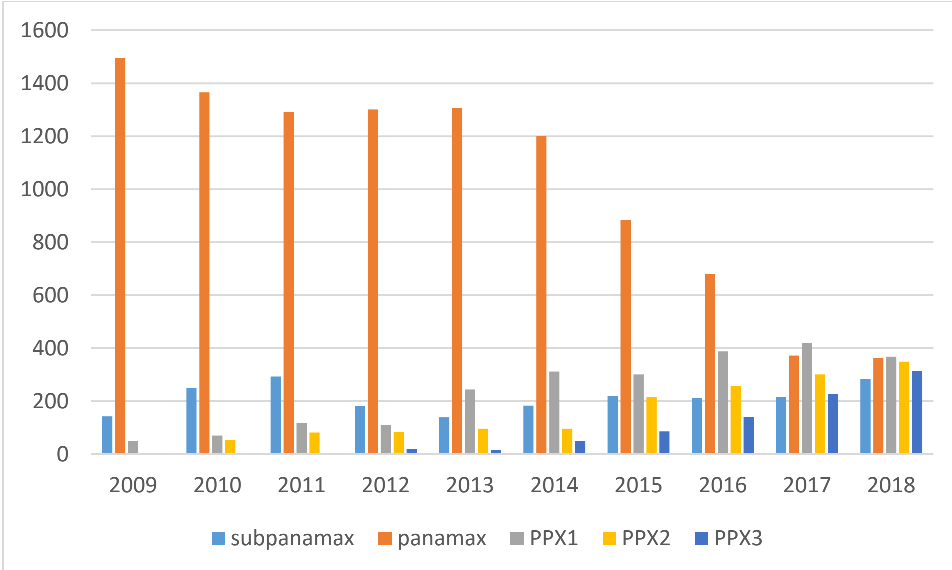


The routes of service that call the Pathway to EPAMT terminals were analyzed and condensed to fit into the route groups displayed in **Table 11**. Vessel service data was collected from the port for 2017 to 2019 to estimate a percentage of tonnage on each route to establish baseline tonnage on each route. **Section 4.2.1.** details the baseline tonnage by route.

3.1.2. Pathway to EPAMT Fleet Characteristics

Data was acquired from the Port Authority, Waterborne Commerce Statistics Center, and NNOMPEAS to acquire containership characteristics of the fleet calling the Pathway to EPAMT. For trend analysis, containerships are divided into classes as shown in **Table 8**. The trend of containership usage for the Pathway to EPAMT is shown in **Figure 23**. From the time period of 2009 through 2018, larger containerships have been deployed to take advantage of economies of scale.

Figure 23: Number of Inbound Vessels by Containership Class



3.2. Pathway to PJPAMT

3.2.1. Pathway to PJPAMT Cargo Volume and Trends

Pathway to PJPAMT includes the GCT Bayonne container terminal. The berth is approximately 2,700 feet long and the terminal has 8 container cranes: 2 Super Post-Panamax and 6 Post-Panamax. **Figure 24** and **Figure 25** show historical cargo volumes imported and exported through the container terminal on the east side of the harbor from 2009 to 2018 in Pathway to PJPAMT. Data was obtained from NNOMPEAS for all container cargo in terms of metric tons.

Figure 24: Pathway to PJPAMT Containerized (Metric Tons)

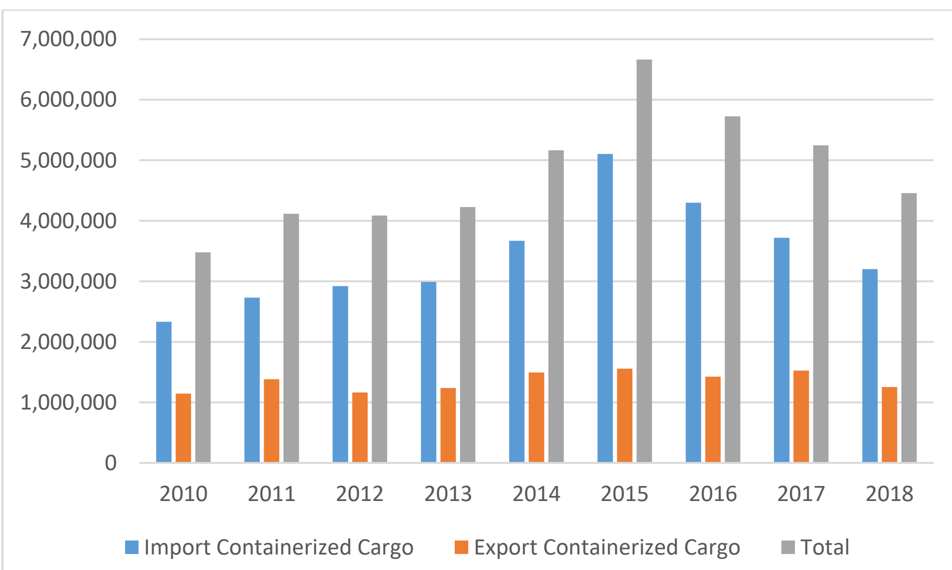
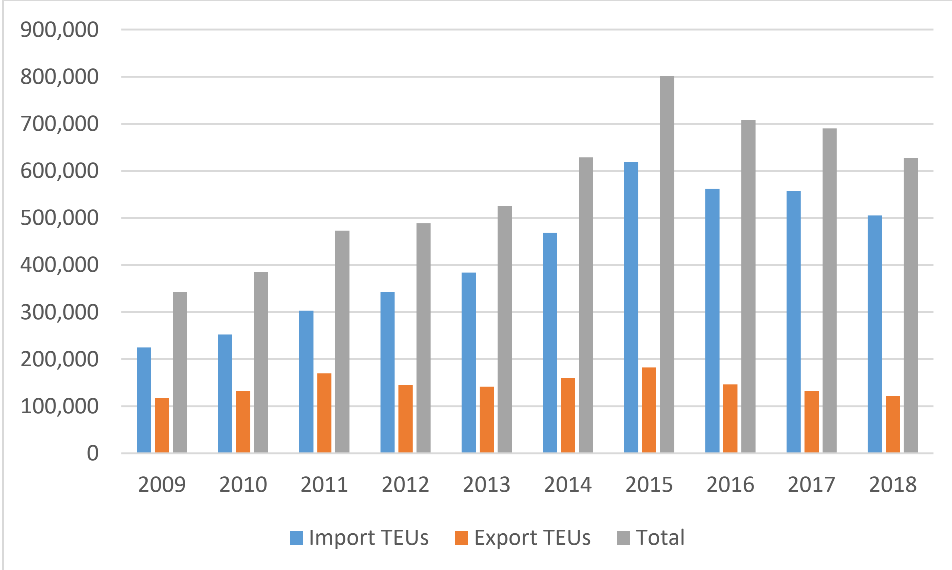


Figure 25: Pathway to PJPAMT Loaded TEUs

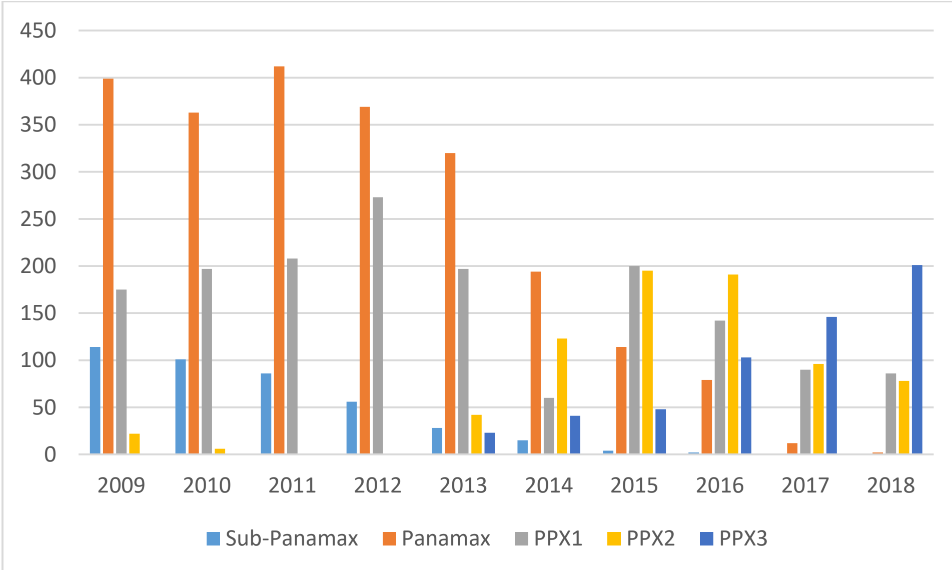


The routes of service that call the Pathway to PJPAMT terminal were analyzed and condensed to fit into the route groups in **Table 9**. Vessel service data was collected from the port for 2017 to 2019 to estimate a percentage of tonnage on each route to establish baseline tonnage on each route. **Section 4.2.1.** details the baseline tonnage by route.

3.2.2. Pathway to PJPAMT Fleet Characteristics

Data was acquired from the Port Authority, Waterborne Commerce Statistics Center, and NNOMPEAS to acquire containership characteristics of the fleet calling the Pathway to PJPAMT. For trend analysis, containerships are divided into classes as shown in **Table 8**. The trend of containership usage for the Pathway to PJPAMT is shown in **Table 22**. From the time period of 2009 through 2018, larger containerships have been deployed to take advantage of economies of scale.

Figure 26: Number of Inbound Vessels by Containership Class



4. Future Conditions

4.1. Vessel Operations

The study assumes that proposed improvements does not change vessel operations throughout the channel. The same vessel classes will call in the future without-project condition as the future with-project conditions. Restrictions related to wind, vessel meeting, and berthing will still apply. However, the study assumes channel deepening will lead to the lifting of the 49-foot draft restriction for container vessels from Sea to EPAMT and Sea to NJPAMT. Tide restrictions will still apply and vessels will need to have sufficient underkeel clearance to transit the channel.

4.2. Commodity Forecast

Estimates of NYNJ Harbor's future commerce for the period of analysis are linked to the Port's hinterland and the extent to which it shares commodity flows with other ports. Under future without and future with project conditions, the same volume of cargo is assumed to move through NYNJ Harbor. The port's share of the commodity projections remains the same as existing condition. However, channel deepening will allow shippers to load vessels more efficiently and take advantage of larger vessels. This efficiency translates to savings and is the main driver of the NED. Cargo projections ultimately drive vessel fleet projections in terms of the numbers and sizes of vessels for without- and with-project conditions.

The top import commodities for NYNJ Harbor are furniture, machinery and appliances, plastic and beverages. Top export commodities in terms of volume are wood pulp, vehicle parts, plastic and wood and articles of wood. As of 2018, the major import growth commodities were apparel, iron and steel, and vehicle parts. The major export growth commodities were food waste, oil seeds and miscellaneous grains and iron and steel.

The methodology to determine the forecast of import and export tonnage used three steps. First, the baseline was established using an average of historical data. Second, the growth rates for each route group were established. Third, growth rates were applied to the baseline to determine the total import and export trade volumes for NYNJ Harbor.

4.2.1. Cargo Baseline

To minimize the impact of potential variances in the trade volumes on long-term forecast, five years of data was used to establish the baseline for the commodity forecast. Empirical data from 2013 to 2017[2] was used to develop a baseline, allowing the forecast to capture both economic prosperity and downturn which occurred over that timeframe. Three years were used to estimate the percent tonnage by trade route. The baseline tonnage represents the starting point from which commerce was forecasted.

4.2.1.1. Pathway to EPAMT Cargo Baseline

Table 14 and **Table 15** show historical containerized imports and exports that moved through the Port from 2013 to 2017. During this time period, imports mostly increased with a slight decrease in 2016, but recovered in 2017. Trade with Asia leads the NYNJ Harbor market for Pathway to EPAMT accounting for nearly 58% of import tonnage.

Table 14: Pathway to EPAMT Historical Containerized Baseline Imports (metric tons)

	2013	2014	2015	2016	2017	Baseline Tonnage	Route Group	Route Group Percent	Baseline Tonnage by Route Group
Import Containerized Cargo	16,987,000	18,311,000	18,431,000	18,025,000	21,404,000	18,631,600	AF-SA-CAR-ECUS	6%	1,060,000
	Rate of Change by Year						EU-MED-ECUS	37%	6,894,000
		8%	1%	-2%	19%		FE-PAN-ECUS	17%	3,167,000
							FE-SUEZ-ECUS	41%	7,639,000

[2] 2018 data was released after development of the commodity forecast. The baseline for the commodity forecast is based off a five-year average (2013-2017). Inclusion of 2018 data would lead to a 5 percent increase in the baseline and subsequent increase in forecasted volume through the study period. This, however, does not necessarily improve forecast accuracy. The forecast is based on a 50-year period of analysis. The study team will continue evaluating data as it is released to determine if the baseline requires updating. Importantly, benefits are not perfectly correlated with changes in the commodity forecast (i.e., a 1% increase in cargo volume leads to a less than 1% change in benefits). As a result, the change in benefits will be relatively minor based on estimated changes associated with including 2018 data in the baseline. 2018 and 2019 data will be evaluated after release of the draft report to determine if it is necessary to update the baseline and forecast. Additional information will be added to Section 4 to explain the baseline's use of 2017 data and impacts of 2018 and 2019 data.

Table 15: Pathway to EPAMT Historical Containerized Baseline Exports (metric tons)

	2013	2014	2015	2016	2017	Baseline Tonnage	Route Group	Route Group Percent	Baseline Tonnage by Route Group
Export Containerized Cargo	9,801,600	9,434,700	9,197,200	9,736,300	9,826,200	9,599,200	AF-SA-CAR-ECUS	5%	513,000
	Rate of Change by Year						EU-MED-ECUS	26%	2,516,300
		-4%	-3%	6%	1%		FE-PAN-ECUS	20%	1,965,000
							FE-SUEZ-ECUS	48%	4,605,000

4.2.1.2. Pathway to PJPAMT Cargo Baseline

The Pathway to PJPAMT includes the channel segments to Global Container Terminal Bayonne which include the Ambrose Channel and the Anchorage Channel. GCT Bayonne handles approximately 10 percent of the port's container volumes. **Table 16** and **Table 17** show the historical volumes of metric tons moving through the terminal.

Table 16: Pathway to PJPAMT Historical Containerized Baseline Imports (metric tons)

	2013	2014	2015	2016	2017	Baseline Tonnage	Route Group	Route Group Percent	Baseline Tonnage by Route Group
Import Containerized Cargo	2,989,900	3,670,100	3,816,900	4,014,300	3,694,100	3,637,000	AF-SA-CAR-ECUS	7%	272,000
	Rate of Change by Year						EU-MED-ECUS	10%	346,000
		23%	4%	5%	-8%		FE-PAN-ECUS	40%	1,451,000
							FE-SUEZ-ECUS	43%	1,569,000

Table 17: Pathway to PJPAMT Historical Containerized Baseline Exports (metric tons)

	2013	2014	2015	2016	2017	Baseline Tonnage	Route Group	Route Group Percent	Baseline Tonnage by Route Group
Export Containerized Cargo	1,238,000	1,494,000	1,311,000	1,333,000	1,349,000	1,345,000	AF-SA-CAR-ECUS	4%	47,500
	Rate of Change by Year						EU-MED-ECUS	5%	67,200
		21%	-12%	2%	1%		FE-PAN-ECUS	47%	632,300
							FE-SUEZ-ECUS	44%	598,100

4.2.2. Trade Forecast Methodology

The long-term trade forecast for NYNJ Harbor combined data from the Port Authority, previous USACE East Coast analyses and a national forecast obtained by the Institute for Water Resources which was developed by IHS Global Insight. The task of estimating commodity growth rates has been completed for numerous USACE deep draft navigation studies along the East Coast in the past decade. Those analyses along with information from the National IHS forecast was used to develop growth rates for application to New York and New Jersey Harbor.

4.2.2.1. IHS Forecast

IHS is a research firm that develops trade forecast and provide economic and financial coverage of countries, regions and industries. The company provides data collection of macro, regional and global economics; financial markets and securities; and international trade.

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

As mentioned, previously completed East Coast analyses and the IHS Global Insight national forecast were used as sources for forecasting the throughput tonnage for NYNJ Harbor during the period of analysis. The most recent containerized tonnage forecast was obtained by IWR in 2017. The information from this forecast provided tonnage through year 2025. Since this was the most recent forecast acquired, forecasting using IHS sources end at year 2025. From 2025 through 2040, Port information is used for forecasting.

4.2.2.2. NYNJ Port Authority Forecast

NYNJ Port Authority provided their growth rates for containerized imports and exports through 2037. The Port Authority developed a long-range port master plan that includes a market analysis to determine the market potential for maritime. To complete the market analysis, the maritime industry trends were analyzed, market area identified and a comparison of Port facilities with competing ports. Based on this assessment, projected regional growth in cargo was estimated. These growth rates were used for years 2026 through 2040.

4.2.3. Cargo Forecast Summary

Using the sources described above, growth rates were estimated from the baseline year of 2018 to the base year 2030 through 2040 where the forecast was held constant through the end of the period of analysis, year 2088. **Table 18** shows the average growth rates for imports and exports for each period shown.

Table 18: Containerized Cargo Growth Rates

IMPORT CONTAINER ANNUAL GROWTH RATES				
	2019-2025	**2026-2030**	**2031-2035**	**2036-2040**
FE-SUEZ-ECUS	4.9%	2.8%	2.5%	2.5%
FE-PAN-ECUS	5.1%	2.8%	2.5%	2.5%
EU-MED-ECUS	3.1%	2.8%	2.5%	2.5%
AF-SA-CAR-ECUS	3.8%	2.8%	2.5%	2.5%
EXPORT CONTAINER ANNUAL GROWTH RATES				
	2019-2025	**2026-2030**	**2031-2035**	**2036-2040**
FE-SUEZ-ECUS	5.2%	2.8%	2.5%	2.5%
FE-PAN-ECUS	5.7%	2.8%	2.5%	2.5%
EU-MED-ECUS	4.2%	2.8%	2.5%	2.5%
AF-SA-CAR-ECUS	4.2%	2.8%	2.5%	2.5%

Using the baseline estimated commerce volumes, the estimated growth rates were applied to forecast import and export tonnage for NYNJ Harbor by route group over the period of analysis. For purposes of analysis, the forecast is held constant after year 2040 through 2088.

Since the Pathways are being analyzed separately, individual commodity forecasts were conducted. Although the tonnage is different based on route group volumes, the growth rates remain the same.

Table 19 and **Table 20** shows the import and export commodity forecast tonnage for the Pathway to EPAMT.

Table 19: Pathway to EPAMT Import Containerized Metric Tons Forecast

Import Forecast	2018 - Baseline	2025	2030	2035	2040 - 2088
FE-SUEZ-ECUS	7,639,000	10,186,000	12,242,000	13,878,000	15,702,000
FE-PAN-ECUS	3,110,000	4,409,000	5,053,000	5,729,000	6,481,000
EU-MED-ECUS	6,823,000	8,451,000	9,685,000	10,980,000	12,422,000
AF-SA-CAR-ECUS	1,060,000	1,376,000	1,576,000	1,787,000	2,022,000

Table 20: Pathway to EPAMT Export Containerized Metric Tons Forecast

Export Forecast	2018 - Baseline	2025	2030	2035	2040 - 2088
FE-SUEZ-ECUS	4,605,000	6,042,000	6,924,000	7,850,000	8,881,000
FE-PAN-ECUS	1,965,000	2,854,000	3,271,000	3,708,000	4,196,000
EU-MED-ECUS	2,516,000	3,266,000	3,743,000	4,244,000	4,801,000
AF-SA-CAR-ECUS	513,000	673,000	771,000	875,000	989,000

Table 21 and **Table 22** shows the import and export commodity forecast tonnage for Pathway to PJPAMT.

Table 21: Pathway to PJPMT Import Containerized Metric Tons Forecast

Import Forecast	2018 - Baseline	2025	2030	2035	2040 - 2088
FE-SUEZ-ECUS	1,569,000	2,092,000	2,514,000	2,850,000	3,225,000
FE-PAN-ECUS	1,451,000	2,057,000	2,358,000	2,673,000	3,024,000
EU-MED-ECUS	346,000	429,000	491,000	557,000	630,000
AF-SA-CAR-ECUS	272,000	353,000	405,000	459,000	519,000

Table 22: Pathway to PJPMT Export Containerized Metric Tons Forecast

Export Forecast	2018 - Baseline	2025	2030	2035	2040-2088
FE-SUEZ-ECUS	598,000	804,000	921,000	1,044,000	1,182,000
FE-PAN-ECUS	632,000	918,000	1,053,000	1,193,000	1,350,000
EU-MED-ECUS	67,000	87,000	100,000	113,000	128,000
AF-SA-CAR-ECUS	48,000	62,000	71,000	81,000	92,000

Table 23 provides estimated total TEU throughput (including empty TEUs) by Terminal. As shown, current terminal capacity will likely be exceeded by 2030 for PJPAMT and 2040 for EPAMT. By 2050 total capacity at EPAMT and PJMPT will be exceeded by approximately 66 percent. The forecast assumes significant port development over the next 10 to 20 years to meet the increasing cargo volume at NYNJ. These development include improved TEU turn time through additional truck and rail access and expanded yard capacity as outlined in the Port Master Plan 2050[3].

[3] https://panynj.maps.arcgis.com/apps/Cascade/index.html?appid=58a11a89cc3a4385a51c3fca596b08da

Table 23: Forecasted TEU Throughput versus Current Port Capacity

Port	2020 Capacity	Forecasted TEU Throughput*		
		2030	2040	2050
EPAMT	7,200,000	6,960,000	8,930,000	11,360,000
PJPMT	900,000	1,280,000	1,650,000	2,100,000
Total	8,100,000	8,240,000	10,580,000	13,460,000

*assumes historical Empty TEU percentages (2013-2018 baseline)

4.3. Vessel Fleet Forecast

4.3.1. Design Vessel

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

For Port of NYNJ, the study team recommends the PPX4 containership class as the design vessel. This selection is meant to incorporate the full range of potential dimensions of the largest, most frequently calling vessel will have over the study period. Vessel of this size are expected to call frequently on services calling the Port of NYNJ. The Port of NYNJ is anticipating the use of these vessels in the future and has made significant investment to do so. The specifications for the recommended design vessel class are as follows:

- 1,308.0 feet length overall (LOA)
- 193.5 feet beam
- 52.5 feet design draft
- 18,000 TEU capacity

4.3.2. World Fleet

To develop projections of the future fleet calling NYNJ Harbor, the study used world fleet data for containerships. The Institute of Water Resources provided general estimates for world fleet containerships based on Clarkson data and Lloyd's Registry-Fairplay through 2025. Sea-web data was also used as a source to for world containership estimates.

4.3.3. Container Fleet Forecast

Using the empirical data for NYNJ Harbor and data sources in **Section 4.3.2.** , the forecast was adapted for NYNJ Harbor to determine the expected fleet composition over the period of analysis. The forecast introduces a Post-Panamax Generation 4 containership vessel based on the historical transition of the fleet and analysis of the vessel orderbook. **Table 24** shows the percent calling capacity by vessel size from 2025 to 2035 based on the fleet forecast adapted for the NYNJ Harbor. The transition to PPX3 and PPX4 class vessels represents the most critical assumption for project benefits. Despite the transition, many services will likely still use smaller, less-efficient vessels based on fleet availability and landside infrastructure constraints along all ports on a service. The distribution of capacity remains constant after 2035.

Table 24: NYNJ Forecasted Calling Capacity

Year	SPX	PX	PPX1	PPX2	PPX3	PPX4
2025	2%	10%	15%	25%	40%	8%
2035	2%	8%	12%	20%	47%	11%

The forecasted commodity volumes presented in **Section 4.2.** were loaded onto a simulated future vessel fleet using the HarborSym Model to determine the anticipated number of calls to NYNJ by year.

5. Transportation Cost Savings Benefit Analysis

The study compares the benefits and costs of channel deepening up to seven feet in one-foot increments for containership transit at NYNJ. Analysis follows evaluation procedures for navigation studies outlined in Engineer Regulation 1105-2-100 (ER 1105-2-100) and grounded in the economic and environmental Principles and Guidelines (P&G).

Section 5.1. describes the methodology used to estimate benefits of the proposed channel improvements at NYNJ. National economic development (NED) benefits were estimated based on the expected transportation cost reduction associated with each project depth. Analysis uses the HarborSym Modeling Suite of Tools (HMST) Version 1.5.8.3 developed by the Institute for Water Resources (IWR) to estimate transportation costs for each alternative depth. The HMST is a certified USACE model, which follows the deep draft navigation evaluation framework established in ER 1105-2-100 and reflects USACE guidelines on transportation cost savings analysis.

Section 5.2. presents the expected vessels calls for each channel depth by port. This vessel call list is run through the HMST to calculate transportation costs for each channel depth and port. **Section 5.3.** provides the total transportation cost summary for each channel depth resulting from the model runs. **Section 5.4.** summarizes each alternative for evaluation and identifies the NED plan based on the analysis presented in **Sections 5.1.** through **5.3.**

5.1. Methodology

The HMST is a discrete event Monte Carlo simulation model and is designed to be a general-purpose tool for use by USACE planners. The model is designed to allow users to forecast a port's future fleet, simulate vessel calls, and estimate transportation costs for comparative analysis of alternative channel depths and configurations. Channel improvements (i.e. channel deepening) result in reduced transportation costs by allowing carriers to more efficiently load cargo on vessels calling NYNJ. This leads to a more efficient fleet mix and less waterway congestion. Additional transportation cost saving benefits result from the channel modifications aimed at reducing congestion and transit time within the harbor. The creation of meeting and passing zones reduces wait times within the harbor. HarborSym allows for detailed modeling of vessel movements and transit rules on the waterway.

To begin, HarborSym was setup with the basic required variables including channel configuration, vessel and port operations, and container service details. The HMST's Container Loading Tool (CLT) was used to generate a vessel call list by pairing the Port of NYNJ's commodity forecast for a given year with the expected fleet distribution and loading practices for that year, factoring in changes in vessel operations caused by channel improvements. The resulting vessel traffic for each channel depth was simulated using HarborSym, producing an estimate of average annual vessel transportation costs. The NED Plan was identified by identifying the plan with the highest net benefits over costs based on estimated transportation cost saving benefits.

5.1.1. HarborSym Model Behavior

For each iteration, the vessel calls in the simulation period are accumulated and placed in a queue based on arrival time. When a vessel arrives at the port, the route to all docks in a vessel call is determined. This route is comprised of discrete legs (contiguous sets of reaches, from the entry to the dock, from a dock to another dock, and from the final dock to the exit). The vessel attempts to move along the initial leg of the route. Potential schedule conflicts with other vessels are evaluated according to the user-defined set of rules for each reach within the current leg, based on information maintained by the simulation as to the current and projected future state of each reach. If a rule activation occurs, such as no passing allowed in each 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 dock. Similarly, the model accounts for vessel sailing draft and UKC at each leg in a vessel call. If channel depth is insufficient to maintain required underkeel clearance (UKC), the vessel waits at the channel entrance or at the nearest available anchorage for which channel depth is sufficient until adequate depth is available.

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

A vessel encountering rule conflicts may be able to move partially along the leg to an anchorage or mooring. If so, and if the vessel can use the anchorage, then HarborSym will direct the vessel to proceed along the leg to the anchorage and wait until it can proceed without causing rule conflicts in the remainder of the leg. The determination of the total time a vessel spends within the system is the summation of time waiting at entry, time transiting the reaches, time turning, time transferring cargo, and time waiting at docks or anchorages. HarborSym collects and reports statistics on individual vessel movements, including time in system, as well as overall summations for all movements in an iteration.

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

Each vessel call has a known (calculated) associated cost, based on time spent in the harbor and ocean voyage and cost per hour. Also, each vessel call's total quantity of commodity transferred to the port (both import and export) is known in terms of commodity category, quantity, tonnage and value. The model allocates the total cost of the call to the various commodity transfers. Each commodity transfer record refers to a single commodity and specifies the import and export tonnage.

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

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

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

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

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

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

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

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

Where:

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

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

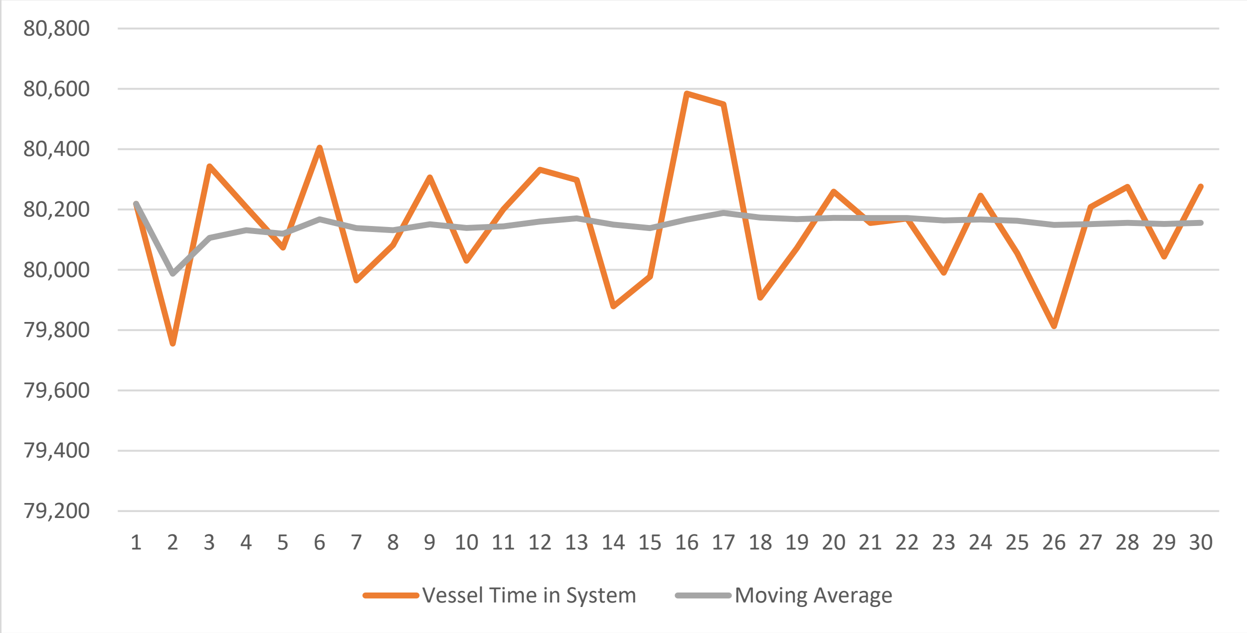
5.1.2. Modeling Data Requirements

The data required to run HarborSym for the NYNJHDCI study are separated into six categories: simulation parameters, physical and descriptive harbor characteristics, general information, vessel speeds and operations, reach transit rules, and vessel operations. Details for each category specific to NYNJ are described below.

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 NYNJHDCI study. The base year for evaluation is 2039. Model runs were performed for 2030, 2040, and 2050. Benefits for Base Year 2039 are interpolated between the 2030 and 2040 model results. Generally, specific commodity studies and fleet distribution forecasts are of limited value for projections beyond 20 years. As a result, benefits are held constant after 2050.

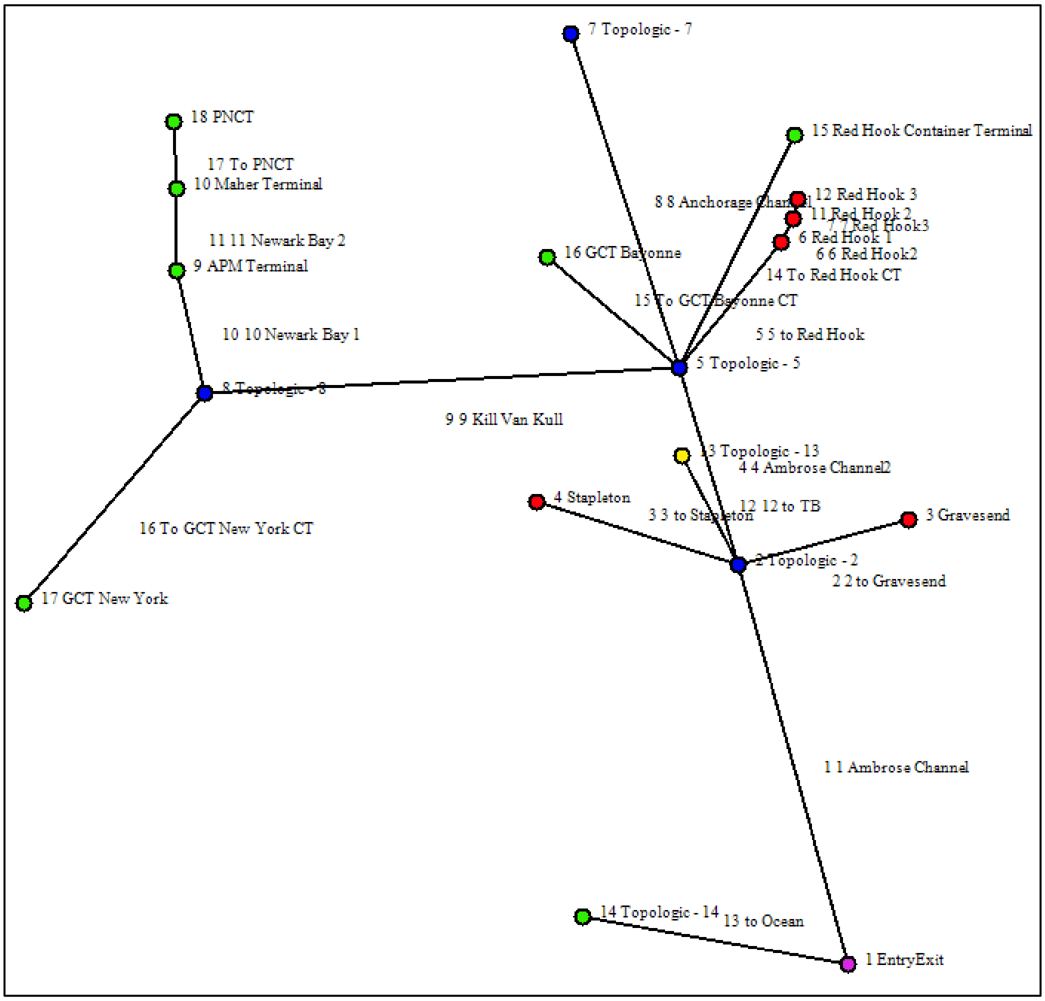
Each model run consisted of 30 iterations. The number of iterations was determined appropriate by comparing the average time of the fleet in the system. **Figure 27** shows the variation in vessel time in the system for the OD model runs in total hours. For the OD model run in 2030, the average total vessel time in the system after 30 iterations was 80,156 hours, with a standard deviation of 195 hours. Importantly, the moving average of vessel time in system does not deviate by more than 1 percent by the 30th iteration. Consequently, the study team believes that 30 iterations is enough to obtain a consistent estimate of transportation costs across alternatives.

Figure 27: HarborSym Iterations – Time in System (Hours)



<u>Physical and Descriptive Harbor Characteristics.</u> These data inputs include the specific transportation network of the Port of NYNJ such as the node location and type, reach length, width, and depth, in addition to ro and current stations. This 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 28** displays the Node network used for Port of NYNJ.

Figure 28. Port of NYNJ Harbor HarborSym Node Network



General Information. General information used as inputs to the model include: specific vessel and commodity classes, route groups (Table 25), commodity transfer rates at each dock (**Table 26**), specifications of turning area usage at each dock, and specifications of anchorage use within the harbor. Distances between the route groups were developed by evaluating the ten trade routes calling on NYNJ in 2018.

Numerous container services call Port of NYNJ (Table 9). **Section 2.4.** describes the carriers and trade lanes included in this analysis. The study combines similar container services into groups for HarborSym modeling. Distances of the services included in the route group were evaluated to determine minimum, most likely, and maximum sailing distances in nautical miles to prior port, next port, and total remaining sailing distance.

Table 25: HarborSym Route Groups

Route	Description	Total Sea Distance		
		Minimum	*Most Likely*	*Maximum*
AF-SA-CAR-ECUS	Africa-South America-Central America-East Coast US	1,450	7,343	16,108
EU-MED-ECUS	Europe-Mediterranean-East Coast US	6,308	7,457	11,534
FE-PAN-ECUS	East Asia-Panama Canal-East Coast US	19,368	29,813	31,908
FE-SUEZ-ECUS	East Asia-Suez Cana-East Coast US	16,884	25,321	31,422

Table 26: HarborSym Commodity Transfer Rates for Containers

Dock Name	Min	Most Likely	Max
APM Terminal	500	800	1,000
Red Hook Container Terminal	500	800	1,000
GCT Bayonne	500	800	1,000
GCT New York	500	800	1,000
Maher Terminal	500	800	1,000
PNCT	500	800	1,000

The analysis also considered prior and next port depths, summarized in **Table 27** for the services calling Port of New York New Jersey between 2013 and 2017. As shippers deploy larger containerships on transpacific services, rotations will continue to evolve to meet international demand. Analysis of container services showed that 24 percent of container volume is traded with ports with channel depths of -51 feet MLLW or deeper. This analysis shows the current limitations on services currently calling NYNJ.

Table 27: Previous and Next Port Depths (2013-2017)

Prior/Next Port Depth	Percent Cargo (2013-2017)
0	100%
40	85%
45	70%
50	46%
51	24%
52	24%
53	15%
54	15%
55	14%
56+	14%

Future routes may change this distribution of prior and next port depths. **Table 28** summarizes major US ports receiving vessel calls on services also calling NYNJ. As shown, major US East Coast ports are preparing for future increases in vessel size with channel deepening. Norfolk Harbor, closest to NYNJ, is planning to deepen to -55 feet MLLW. Charleston, Port Everglades, and Jacksonville also have planned or ongoing channel improvements.

Table 28: US Ports Channel Depth and Improvements on Services Calling NYNJ

US Port	Depth (ft)	Pending Improvements
Norfolk	50	Deepening to 55ft
Savannah	48	
Los Angeles	54	
Oakland	50	
Charleston	47	Deepening to 52ft
Baltimore	43	
Port Everglades*	42	Deepening 48ft
Philadelphia	42	
Houston	45	
Miami	50	
Boston	38	Deepening to 45ft
Wilmington*	38	
San Juan (PR)*	39	
Jacksonville	41	Deepening to 47ft

*ongoing feasibility study

Vessel Speeds and Operations. The speed at which vessels operate in the harbor, by vessel class both loaded and light loaded, were determined for each channel segment by evaluating pilot logs and port records and verifying the data with the pilots. Hourly operating costs while in-port and at-sea were determined for both domestic and foreign flagged containerized vessels. Sailing speeds at-sea were also determined and are based on service speeds and operating expenses obtained from Institute for Water Resources (IWR) Vessel Operating Cost (VOC) spreadsheets and Economic Guidance Memorandum (EGM) 15-04 (dated 28 September 2015), Deep-Draft Vessel Operating Costs FY 2016. Economical or slow-steam speeds at sea and associated costs were included in the evaluation. VOCs and speeds at sea are entered as a triangular distribution (minimum, most likely, maximum). Vessel speed and operations inputs are provided in **Table 29** and **Table 30** for each reach of the node network for containerized vessels. VOCs are not shown as some or much of the information integral to the estimates is considered sensitive or proprietary by commercial sources and is protected from open or public disclosure under Section 4 of the Freedom of Information Act.

Table 29: HarborSym Vessel Speed in Reach for Containerships (knots)

Reach	Speed (knots)
Ambrose Channel	9
Red Hook	10
Anchorage Channel	10
Kill Van Kull	7
Newark Bay	7

Table 30: Containerized Vessel Operations

Vessel Class	Speed at Sea (knots)		
	Minimum	Most Likely	Maximum
Sub-Panamax	19	20	21
Panamax	19	20	21
Post-Panamax 1	20.4	21.5	22.6
Post-Panamax 2	20.2	21.3	22.4
Post-Panamax 3	19.8	20.8	21.8
Post-Panamax 4	15.3	16.1	16.9

Reach Transit Rules. Vessel transit rules for each reach reflect restrictions on passing, overtaking, and meeting in the study area and are used to simulate actual conditions in each reach. The model incorporates UKC clearance requirements and tide forecasts to determine when a vessel can enter the system.

Vessel Calls. The vessel call lists consist of forecasted vessel calls for a given year as generated by the CLT (see **Section 5.1.3.**). Each vessel call list contains the following information: arrival date, arrival time, vessel name, entry point, exit point, arrival draft, import/export, dock name, dock order, commodity, units, origin/destination, vessel type, net registered tons, gross registered tons, dead weight tons, capacity, LOA, beam, draft, flag, tons per inch immersion (TPI) factor, ETTC, and the route group for which it belongs.

5.1.3. Containerized Vessel Call List

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 the CDF and the arrival draft is initially set to this value. The maximum allowable arrival draft is then determined as the minimum of:

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

The tentative arrival draft is then compared to the maximum allowable arrival draft and set to the lesser value.

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

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

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

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

$$Total\ weight\ per\ loaded\ container = Average\ Lading\ Weight\ per\ Loaded\ TEU\ by\ Route\ (tonnes) + Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)$$

Shares of vessel capacity are then calculated as:

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

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

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

Volume capacity limits are calculated as follows:

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

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

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

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

Maximum Volume Restricted Tonnage is then calculated as:

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

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

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

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

The LFA proceeds as follows:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The CLT then calculates the ETTC (estimate of total trip cargo) for each vessel call as the cargo on board the vessel at arrival plus the cargo on board the vessel at departure, in tons (see description and equation for ETTC in **Section 5.1.1.**).

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

5.1.4. Sailing Draft Distribution

There are several data requirements to run the CLT including a commodity forecast (**Section 4.2.**), vessel fleet forecast (**Section 4.2.3.**), and vessel load factors. Vessel sailing draft distributions are a critical input for determining the benefits of channel deepening. In the CLT, vessel drafts are used to determine how much cargo a vessel carries and how many trips are required to satisfy a commodity forecast. The model allows deeper sailing drafts for alternatives with deeper channel depths. Deeper sailing drafts lead to higher cargo volumes per transit, less required vessel calls, and a reduction in total transportation costs.

At NYNJ, vessels with a maximum sailing draft of less than 49 feet (SPX, PX, PPX1, and PPX2) have at least 99 percent channel reliability at maximum sailing draft under the FWOP condition (**Table 31**); therefore, analysis assumes no change to sailing draft distribution for these classes under all alternatives. **Figure 29** and **Figure 30** provide the arrival draft CDFs for PX and PPX1 vessels, respectively. The CDFs were developed by evaluating the arrival drafts of the container class vessels calling on the harbor from 2013 to 2017.

Figure 29: Panamax Sailing Draft CDF

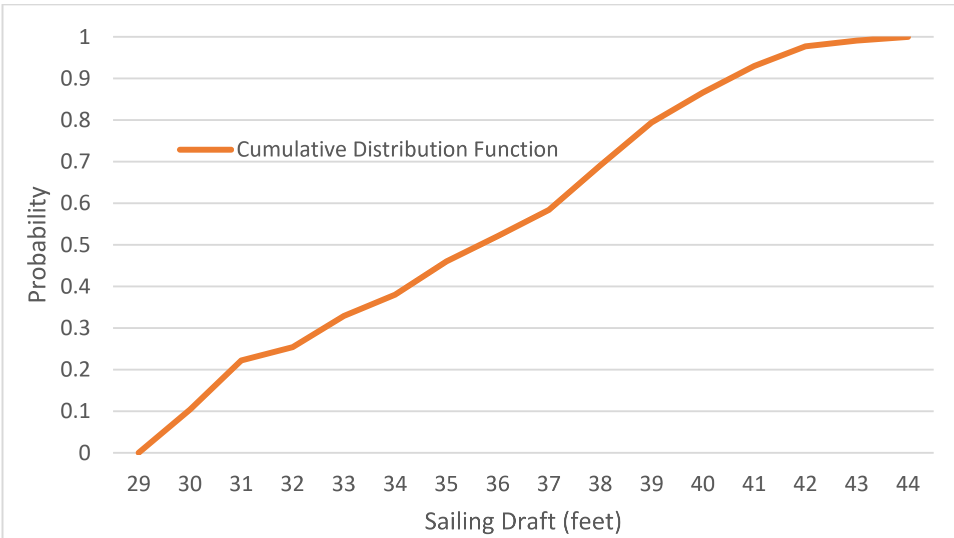
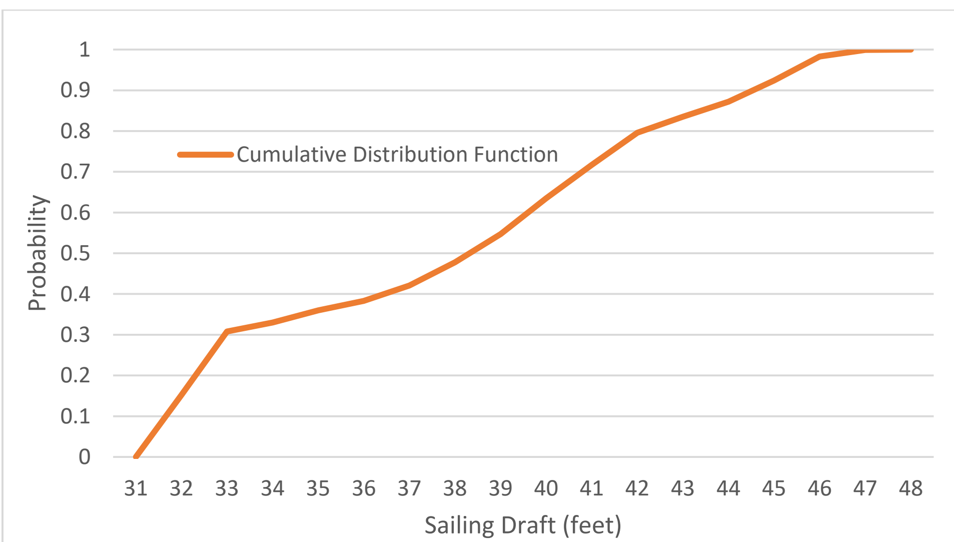


Figure 30: PPX1 Sailing Draft CDF



The CDFs in **Figure 31**, **Figure 32**, and **Figure 33** estimate sailing draft distributions by alternative channel depth of PPX2, PPX3, and PPX4 vessels, respectively. FWOP sailing draft distributions for PPX2 and PPX3 vessels are based on historical vessel calls by class from 2013 through 2017. With-project (-51 feet through -58 feet MLLW) sailing draft CDFs for PPX2, PPX3, and PPX4 vessels were developed with the assistance of the IWR. The analysis assumes for each additional foot of channel depth the average container vessel will load an additional 0.6 to 0.8 feet deeper (0.7 feet on average). Analysis assumes PPX3 vessels can consistently sail at maximum draft with 4 feet of additional channel deepening. The PPX3 sailing draft remains constant with channel deepening beyond 4 feet of deepening. Similarly, analysis assumes PPX4 vessels can consistently load at maximum draft with 5 feet of channel deepening. The sailing draft remains constant for channel deepening alternatives beyond 5 feet.

Figure 31: PPX2 Sailing Draft CDF

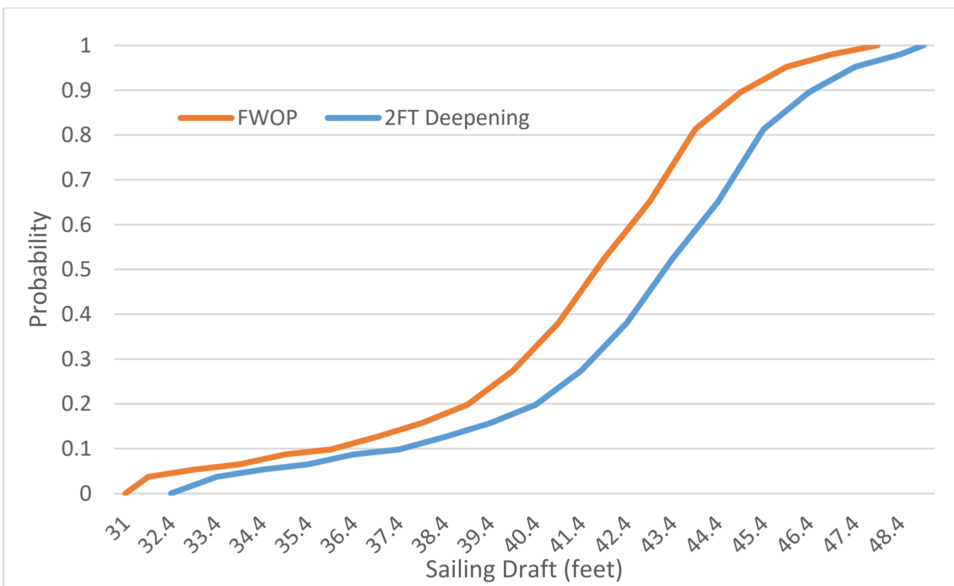


Figure 32: PPX2 Sailing Draft CDF

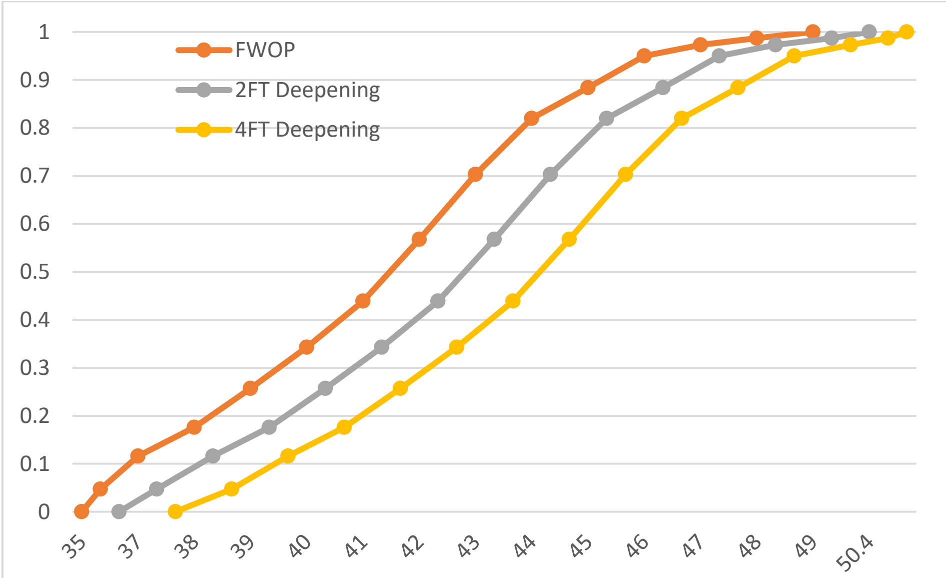
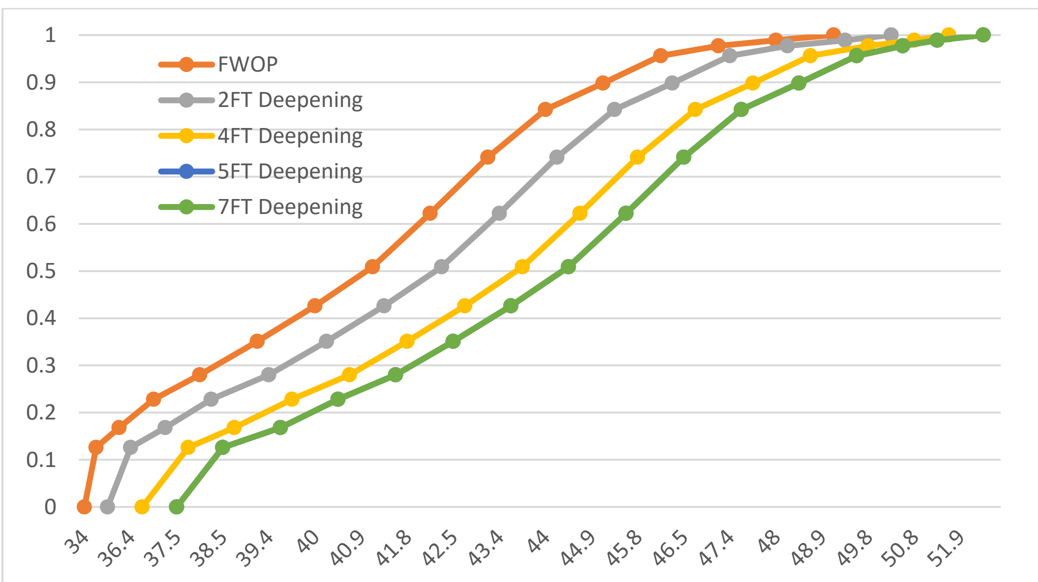


Figure 33: PPX4 Sailing Draft Distribution CDF



Shipping companies use consistently available channel depths to make vessel loading decisions; consequently, shippers would likely avoid loading vessels to any draft beyond 49 feet at NYNJ at the current channel depth, which provides 52 feet of channel depth (49 foot sailing draft plus 3 feet minimum UKC) with 54% percent reliability in an aggregate tidal cycle (**Table 31**). Channel deepening allows vessels to consistently load deeper. Based on analysis conducted by IWR, vessels are expected to load an average of 0.6 to 0.8 feet deeper per each additional foot of channel depth.

This study assumes an average 0.7 feet of additional vessel loading for each additional foot of channel depth. Consequently, an unrestricted PPX4 vessel may load as deep as 52.5 feet, requiring up to 56 feet of water depth for unrestricted transit. In an aggregate tidal cycle at current channel depths, 56 feet of depth is available only 2.5% of the time (**Table 31**). This is insufficient for PPX4 vessels to navigate the channel fully loaded. With 5 feet of channel deepening, vessels could expect approximately 82 percent channel reliability for a fully loaded PPX4 vessel with a sailing draft of 52.5 feet and a minimum 3 feet UKC.

Table 31: Channel Reliability by Alternative Depth

Alternative Depth (MLLW)	52.5' Design Draft Channel Reliability
FWOP	0.6%
2FT Deepening	8.7%
3FT Deepening	29.2%
4FT Deepening	46.8%
5FT Deepening	61.9%
6FT Deepening	81.7%
7FT Deepening	97.5%

5.1.5. Load Factor Analysis

Table 32 provides the vessel class assumptions used in the load factor analysis (LFA)[4], such as average lading weight per TEU, container (tare) weight, vacant slot allotment, variable ballast, etc. These inputs were developed using historical data provided by the Port (Import/Export fractions) and with the assistance of IWR (Lading Weight per Loaded TEU, Empty TEU and Vacant Slot allotment, Operations Allowance, and Variable Ballast). The analysis uses the historical cargo share for imports and exports based on NNOMPEAS Post-Panamax cargo data at NYNJ from 2013 through 2017. The study assumes this cargo share will remain constant through the study period. Cargo share is a key input into the at-sea cost allocation detailed in **Section 5.3.** Load Factor analysis is not included for non-benefitting route groups.

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

Table 32: Vessel Class Inputs

Service	Class	Lading Wt. per TEU*	Empty TEU Allotment	Vacant Slot Allotment	Allowance for Ops. (% of DWT)	Variable Ballast (% of DWT)	Import/ Export Cargo Share
FE (Panama Canal)	PX	8.5	6.5%	7.65%	6.7%	11%	.51/.15
	PPX1	8.5	6.5%	7.65%	6.7%	11%	.47/.13
	PPX2	8.5	6.5%	7.65%	6.7%	11%	.29/.12
	PPX3	8.5	6.5%	7.65%	6.7%	11%	.36/.1
	PPX4	8.5	6.5%	7.65%	6.7%	11%	.24/.2
FE (Suez Canal)	PX	8.5	8.7%	5%	6.7%	11%	.48/.2
	PPX1	8.5	8.7%	5%	6.7%	11%	.24/.15
	PPX2	8.5	8.7%	5%	6.7%	11%	.24/.15
	PPX3	8.5	8.7%	5%	6.7%	11%	.24/.15
	PPX4	8.5	8.7%	5%	6.7%	11%	.24/.15

*Container weight assumed to be 2 metric tons per TEU

Table 33 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 33: Vessel Subclass Inputs

Class	LOA	Beam	Max SLLD	Capacity (DWT)	TEU Rating	TPI	UKC	Sinkage	% Class
SPX CL 7	571	87	31.3	20,643	1,447	87.1	2.7	0.2	2
SPX CL 10	576	92	34.6	24,812	1,778	96.3	2.7	0.2	14
SPX CL 11	603	92	35.6	25,370	1,895	97.1	2.7	0.2	4
SPX CL 13	676	99	37.6	33,887	2,470	117.7	2.7	0.2	80
PX CL 4	846	106	41.2	50,070	3,841	162.7	2.8	0.2	28.3
PX CL 5	907	106	42.5	56,792	4,125	176.7	2.8	0.2	28.4
PX CL 6	887	104	43.4	54,885	3,993	170.4	2.8	0.2	43.3
PPX1 CL 2.00	928	131	41.4	75,623	5,534	214.7	3	0.3	14
PPX1 CL 4.00	900	130	44.4	78,284	4,912	208	3	0.3	4
PPX1 CL 5.00	935	131	46	78,618	5,793	215.1	3	0.3	21
PPX1 CL 5.40	965	132	46.1	80,504	6,295	225.4	3	0.3	19
PPX1 CL 5.30	981	132	46.1	110,448	6,441	230.7	3	0.3	2
PPX1 CL 5.25	984	132	46.1	75,898	6,505	230.9	3	0.3	33
PPX1 CL 5.15	992	132	46.2	102,179	6,600	233.7	3	0.3	7
PPX2 CL 7.00	1,106	143	42.7	104,549	9,148	290.3	3	0.3	3.4
PPX2 CL 9.00	1,018	143	46.1	103,865	7,200	260.3	3.1	0.3	19.3
PPX2 CL 10.00	1,090	142	47.6	104,657	8,212	284.9	3	0.3	39.8
PPX2 CL 10.65	1,099	143	47.6	105,458	8,528	289.2	3	0.3	3.4
PPX2 CL 10.25	1,114	144	47.7	92,875	8,916	293.5	3	0.3	18.2
PPX2 CL 10.15	1,127	145	47.7	96,687	9,294	300.3	3	0.3	15.9
PPX3-1	984	158	48.6	112,729	9,365	394	4.1	0.3	20
PPX3-2	1,106	158	50.9	119,510	10,100	394	4.1	0.3	30
PPX3-3	1,202	158	51.2	148,542	13,102	394	4.1	0.3	50
PPX4-1	1,305	185	52.5	158,200	15,550	453	4.5	0.3	5
PPX4-2	1,299	176	52.5	186,470	16,022	453	4.5	0.3	12
PPX4-3	1,310	194	52.5	195,118	18,340	453	4.5	0.3	45
PPX4-4	1,312	193	52.5	218,000	20,150	453	4.5	0.3	38

Table 34 shows the maximum sailing draft for each vessel class at which vessel cargo capacity is maximized.

Table 34: Maximum Depth by Vessel Class

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

5.2. Containerized Vessel Calls

Vessel calls by vessel class for EPAMT and PJPAMT are shown in **Table 35** and **Table 36,** respectively. These are a result of the CLT loading algorithm, the containerized trade forecast for Port of NYNJ, the available vessel fleet by service, and the LFA data inputs.

Table 35: EPAMT Average Vessel Calls by Vessel Class and Channel Depth (30 iterations)

Vessel Class	FWOP	-52FT	-54FT	-55FT	-57FT
2030					
Panamax Containership	150	150	150	150	150
PPX Gen1 Containership	326	224	153	151	151
PPX Gen2 Containership	620	620	613	613	613
PPX Gen3 Containership	610	610	610	610	610
PPX Gen4 Containership	39	39	39	39	39
Total	**1,745**	**1,643**	**1,565**	**1,563**	**1,563**
2040					
Panamax Containership	125	125	125	125	125
PPX Gen1 Containership	318	215	146	142	142
PPX Gen2 Containership	688	640	603	601	601
PPX Gen3 Containership	890	890	890	890	890
PPX Gen4 Containership	78	78	78	78	78
Total	**2,099**	**1,948**	**1,842**	**1,836**	**1,836**
2050					
Panamax Containership	90	90	90	90	90
PPX Gen1 Containership	373	261	178	178	178
PPX Gen2 Containership	830	790	736	729	729
PPX Gen3 Containership	1,155	1,155	1,155	1,155	1,155
PPX Gen4 Containership	117	117	117	117	117
Total	**2,565**	**2,413**	**2,276**	**2,269**	**2,269**

Table 36: PJPAMT Average Vessel Calls by Vessel Class and Channel Depth (30 iterations)

Vessel Class	FWOP	-52FT	-54FT	-55FT	-57FT
2030					
Panamax Containership	5	5	5	5	5
PPX Gen1 Containership	35	22	13	12	12
PPX Gen2 Containership	93	88	84	84	84
PPX Gen3 Containership	155	155	155	155	155
PPX Gen4 Containership	13	13	13	13	13
Total	**301**	**283**	**270**	**269**	**269**
2040					
Panamax Containership	5	5	5	5	5
PPX Gen1 Containership	35	27	13	11	11
PPX Gen2 Containership	67	60	54	54	54
PPX Gen3 Containership	242	242	242	242	242
PPX Gen4 Containership	26	26	26	26	26
Total	**375**	**360**	**340**	**338**	**338**
2050					
Panamax Containership	5	5	5	5	5
PPX Gen1 Containership	44	23	4	2	2
PPX Gen2 Containership	79	70	63	63	63
PPX Gen3 Containership	309	309	309	309	309
PPX Gen4 Containership	39	39	39	39	39
Total	**476**	**446**	**420**	**418**	**418**

5.2.1. NYNJ Share of World Fleet

The following tables estimate the share of the world fleet required to satisfy the NYNJ fleet forecast. The analysis assumes an average service consists of 8 vessels with at least one vessel calling weekly based on vessel counts for 2019 services. The equivalent vessel numbers are a result of dividing the number of calls in the previous tables by 52 weeks and multiplying by 8 vessels per service. The percent of world fleet value is derived by dividing the equivalent number of vessels per year by the number of vessels in the respective classes by the historical and projected world fleet count.

The purpose of this analysis and presentation is to serve as a check on the projected number of calls by comparing them to the historical and future world fleet. As shown in **Table 37**, the historical share of the world fleet calling NYNJ remained between 6 percent and 7 percent of the total world fleet. As of 2018, NYNJ vessel calls composed nearly 7 percent of the world fleet of vessels calling weekly with the greatest share of vessels in the PPX2 class (21.5 percent of the world fleet dedicated to routes serving NYNJ).

Table 37: NYNJ Share of World Fleet Calling Weekly by Vessel Class, 2008-2017

Vessel Class	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
SPX	1.4%	0.0%	2.2%	1.4%	1.2%	1.6%	1.7%	1.9%	2.5%	3.1%
PX	16.8%	14.8%	14.2%	14.5%	16.4%	15.7%	12.1%	9.3%	5.2%	5.3%
PPX1	3.8%	4.0%	5.2%	4.2%	9.9%	9.5%	11.1%	12.4%	14.1%	13.0%
PPX2	0.0%	3.5%	4.9%	4.7%	6.4%	8.6%	16.8%	18.8%	19.8%	21.5%
PPX3	0.0%	0.0%	0.5%	1.5%	1.5%	3.1%	4.3%	6.4%	8.8%	12.4%
PPX4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	7%	6%	6%	6%	7%	7%	6.7%	6.5%	6.1%	6.7%

Table 38 presents the estimated future percent of the world fleet calling NYNJ. Fleet forecasts are only available through 2035. The analysis extends the 5-year trend from 2035 through 2050 to estimate NYNJ's share of the world fleet through the forecast period. Consistent with historical fleet usage at NYNJ, the analysis assumes the port's share of the world fleet remains under 6 percent for all forecast years. The greatest change from the existing condition is the increased PPX2 usage. The forecast estimates up to 33 percent of the world fleet of PPX2 vessel will call NYNJ by 2030, a 12 percent increase from 2018. The growth in PPX2 usage would continue through 2050 if trends continue. Importantly, NYNJ's share of PPX3 and PPX4 vessels, which are most sensitive to channel deepening, remains relatively constant through the forecast period. This projection will be discussed further as a sensitivity analysis in **Section 6.** The analysis confirms the projected vessel calls for NYNJ do not result in an excessive amount of the total world fleet in the without or with-project conditions.

Table 38: Estimate Future Percent of World Fleet Calling NYNJ Once per Week

Vessel Class	2030		2040		2050	
	Vessels	% World Fleet	Vessels	% World Fleet*	Vessels	% World Fleet*
FWOP (-50FT MLLW)						
PX	24	1.8%	20	1.6%	15	1.3%
PPX1	57	4.8%	56	3.1%	66	2.4%
PPX2	112	33.2%	119	33.5%	143	38.4%
PPX3	121	14.1%	178	14.4%	231	12.8%
PPX4	8	1.0%	16	1.1%	25	0.9%
Total	**322**	**5.1%**	**390**	**4.8%**	**479**	**4.5%**
-52FT MLLW						
PX	24	1.8%	20	1.6%	15	1.3%
PPX1	39	3.3%	38	2.1%	45	1.6%
PPX2	112	33.0%	110	31.0%	135	36.3%
PPX3	121	14.1%	178	14.4%	231	12.8%
PPX4	8	1.0%	16	1.1%	25	0.9%
Total	**303**	**4.8%**	**364**	**4.5%**	**450**	**4.2%**
-54FT MLLW						
PX	24	1.8%	20	1.6%	15	1.3%
PPX1	26	2.2%	25	1.4%	29	1.0%
PPX2	110	32.4%	103	29.1%	126	33.7%
PPX3	121	14.1%	178	14.4%	231	12.8%
PPX4	8	1.0%	16	1.1%	25	0.9%
Total	**289**	**4.5%**	**344**	**4.3%**	**425**	**3.9%**
-55FT MLLW						
PX	24	1.8%	20	1.6%	15	1.3%
PPX1	26	2.2%	24	1.3%	28	1.0%
PPX2	110	32.4%	103	29.0%	125	33.4%
PPX3	121	14.1%	178	14.4%	231	12.8%
PPX4	8	1.0%	16	1.1%	25	0.9%
Total	**289**	**4.5%**	**342**	**4.3%**	**423**	**3.9%**
-57FT MLLW						
PX	24	1.8%	20	1.6%	15	1.3%
PPX1	26	2.2%	24	1.3%	28	1.0%
PPX2	110	32.4%	103	29.0%	125	33.4%
PPX3	121	14.1%	178	14.4%	231	12.8%
PPX4	8	1.0%	16	1.1%	25	0.9%
Total	**289**	**4.5%**	**342**	**4.3%**	**423**	**3.9%**
*Extrapolated from 5-year trend						

5.3. Transportation Cost Savings Benefits by Project Depth

Transportation cost benefits were estimated using the HarborSym Economic Reporter, a tool developed by IWR to summarize HarborSym results from multiple simulations and present benefit-cost summaries. This tool collects the transportation costs from various model run output files and generates the transportation cost reduction for all project years, then produces an Average Annual Equivalent (AAEQ) value for comparison.

5.3.1. Elizabeth-Port Authority Marine Terminal (EPAMT) Transportation Cost Savings

Transportation costs were estimated for a 50-year period of analysis for the years 2039 through 2088. The study team developed HarborSym models for 2030, 2040, and 2050, interpolated transportation costs for intermediate years, and held transportation costs constant past 2050. Transportation costs were annualized to determine AAEQ costs and savings by discounting the cost stream to Base Year 2039 at the current FY 2020 Federal Discount rate of 2.75 percent. Estimates were determined for each alternative project depth and pathway. Final benefit cost estimates in Section 5.4.4. update the recommended plan using FY21 discount rate and price level.

Table 39 provides the annual transportation costs in total and for the at-sea and in-port portions for channel deepening to EPAMT. At-sea cost savings are primarily the result of the reduction in the number of total vessels required to transport the same cargo volume under deeper channel conditions. In-port transportation cost savings are the result of fewer vessels calling NYNJ and an overall reduction in channel congestion. The study does not model vessel interaction with non-containerized vessel calls. The primary congestion reduction is likely realized by containerized vessels. As a result, the study assumes the model captures all congestion-related benefits through modeling containerized vessel calls only. The table consists of three subtables. The first subtable shows total costs by year for origin-destination (OD) at-sea and in-port transportation costs allocated to NYNJ. The second subtable shows the in-port proportion of total transport costs. The third subtable shows the at-sea proportion of total costs. The total cost is the sum of the in-port and at-sea transportation costs by year. The transportation cost saving benefit is provided in **Table 40** using the same three subtables.

Table 39: EPAMT Origin-Destination Annual Transportation Costs ($1,000s)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($1,000s)					
Year	**FWOP**	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$1,942,106	$1,854,381	$1,782,534	$1,779,828	$1,779,828
2039	$2,444,352	$2,311,873	$2,217,227	$2,211,966	$2,211,966
2040	$2,500,158	$2,362,706	$2,265,526	$2,259,982	$2,259,982
2050	$3,156,758	$3,015,331	$2,891,214	$2,883,231	$2,883,231
In-Port Transportation Costs ($1,000s)					
Year	**FWOP**	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$136,129	$135,365	$134,464	$134,409	$134,409
2039	$172,821	$170,787	$169,483	$169,429	$169,429
2040	$176,897	$174,722	$173,375	$173,320	$173,320
2050	$224,034	$223,360	$221,525	$221,486	$221,486
At-Sea Transportation Cost Allocated to Port ($1,000s)					
Year	**FWOP**	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$1,805,977	$1,719,016	$1,648,070	$1,645,419	$1,645,419
2039	$2,271,532	$2,141,086	$2,047,744	$2,042,538	$2,042,538
2040	$2,323,260	$2,187,983	$2,092,152	$2,086,662	$2,086,662
2050	$2,932,723	$2,791,971	$2,669,689	$2,661,746	$2,661,746

Table 40: EPAMT Origin-Destination Transportation Cost Savings Benefits by Channel Depth ($1,000s)

Change in At-Sea and In-Port Vessel Transportation Costs ($1,000s)				
Year	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$87,726	$159,572	$162,278	$162,278
2039	$132,479	$227,125	$232,386	$232,386
2040	$137,452	$234,631	$240,176	$240,176
2050	$141,427	$265,543	$273,526	$273,526
In-Port Transportation Cost Reduction Benefit by Alternative ($1,000s)				
Year	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$764	$1,665	$1,719	$1,719
2039	$2,034	$3,337	$3,392	$3,392
2040	$2,175	$3,523	$3,578	$3,578
2050	$675	$2,509	$2,549	$2,549
Change in At-Sea Vessel Transportation Costs ($1,000s)				
Year	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$86,962	$157,907	$160,559	$160,559
2039	$130,445	$223,788	$228,994	$228,994
2040	$135,277	$231,108	$236,598	$236,598
2050	$140,752	$263,034	$270,977	$270,977

Table 41 provides the AAEQ transportation costs and cost savings by channel depth for deepening

to EPAMT. **Table 42** presents cost statistics for the benefits estimate. As shown, benefits are maximized with a -55FT channel deepening. There is no additional benefit estimated for deepening past 5 feet.

Table 41: EPAMT Origin-Destination AAEQ Transportation Costs by Alternative Depth ($1,000s)

Alternative	AAEQ Transportation Cost	AAEQ Transportation Cost Savings
FWOP	$3,014,023	$-
-52FT	$2,873,627	$139,281
-54FT	$2,755,375	$255,474
-55FT	$2,747,925	$264,532
-57FT	$2,747,925	$264,532

Table 42: EPAMT Origin-Destination AAEQ Cost Statistics by Alternative and Depth ($1,000s)

Statistic	FWOP	-52FT	-54FT	-55FT	-57FT
Mean	$3,014,023	$2,873,627	$2,755,376	$2,747,926	$2,747,926
SD	$4,524	$5,276	$5,570	$5,611	$5,611
Median	$3,014,652	$2,873,128	$2,754,343	$2,746,604	$2,746,604
Min	$3,001,310	$2,860,842	$2,745,389	$2,736,236	$2,736,236
Max	$3,026,150	$2,886,344	$2,768,655	$2,763,595	$2,763,595
Range	$24,840	$25,502	$23,266	$27,358	$27,358
Confidence of Mean +/-	$1,773	$2,069	$2,184	$2,199	$2,199

Confidence calculation assumes a normal distribution and 95% confidence level.
Transportation costs include only those allocated to subject port.

5.3.2. PJPAMT Transportation Cost Savings

Table 43 provides the estimated transportation costs for PJPAMT. Again, transportation costs for Base Year 2039 are based on interpolation between 2030 and 2040 model runs. Values are also interpolated between 2040 and 2050. All costs are held constant after 2050. **Table 44** presents transportation cost savings for channel deepening to PJPAMT.

Table 43: PJPAMT Origin-Destination Annual Transportation Costs ($1,000s)

Total At-Sea and In-Port Transportation Cost Allocated to Port ($1,000s)					
Year	**FWOP**	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$478,433	$452,427	$435,062	$434,478	$434,478
2039	$583,493	$558,056	$530,998	$528,965	$528,965
2040	$595,167	$569,793	$541,658	$539,463	$539,463
2050	$759,268	$717,847	$680,847	$678,948	$678,948
In-Port Transportation Costs ($1,000s)					
Year	**FWOP**	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$24,674	$24,478	$24,414	$24,341	$24,341
2039	$31,213	$31,341	$31,138	$31,107	$31,107
2040	$31,940	$32,103	$31,885	$31,858	$31,858
2050	$42,146	$41,956	$41,537	$41,586	$41,586
At-Sea Transportation Cost Allocated to Port ($1,000s)					
Year	**FWOP**	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$453,759	$427,950	$410,648	$410,137	$410,137
2039	$552,280	$526,716	$499,860	$497,858	$497,858
2040	$563,227	$537,690	$509,773	$507,605	$507,605
2050	$717,121	$675,891	$639,311	$637,361	$637,361

Table 44: PJPAMT Origin-Destination Transportation Cost Savings Benefits by Channel Depth ($1,000s)

Change in At-Sea and In-Port Vessel Transportation Costs ($1,000s)				
Year	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$26,005	$43,370	$43,954	$43,954
2039	$25,437	$52,495	$54,528	$54,528
2040	$25,374	$53,509	$55,703	$55,703
2050	$41,421	$78,421	$80,320	$80,320
Change in In-Port Vessel Transportation Costs ($1,000s)				
Year	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$196	$260	$332	$332
2039	$(127)	$76	$107	$107
2040	-$163	$55	$82	$82
2050	$191	$610	$560	$560
Change in At-Sea Vessel Transportation Costs ($1,000s)				
Year	**-52FT MLLW**	**-54FT MLLW**	**-55FT MLLW**	**-57FT MLLW**
2030	$25,809	$43,111	$43,622	$43,622
2039	$25,564	$52,419	$54,422	$54,422
2040	$25,537	$53,454	$55,621	$55,621
2050	$41,230	$77,811	$79,760	$79,760

Table 45 provides the AAEQ transportation costs and cost savings by channel depth for deepening

to EPAMT. **Table 46** presents cost statistics for the benefits estimate. Like channel deepening alternatives to EPAMT, benefits are maximized with a 5-foot channel deepening. There is no additional benefit estimated for deepening past 5 feet.

Table 45: PJPAMT Origin-Destination AAEQ Transportation Costs by Alternative Depth ($1,000s)

Alternative	AAEQ Transportation Cost	AAEQ Transportation Cost Savings
FWOP	$723,677	$-
52FT	$685,693	$37,984
54FT	$650,631	$73,046
55FT	$648,675	$75,002
57FT	$648,675	$75,002

Table 46: PJPAMT Origin-Destination AAEQ Cost Statistics by Alternative and Depth ($1,000s)

Statistic	FWOP	52FT	54FT	55FT	57FT
Mean	$723,677	$685,693	$650,631	$648,675	$648,675
SD	$4,524	$5,276	$5,570	$5,611	$5,611
Median	$722,862	$685,708	$650,971	$648,281	$648,281
Min	$718,242	$680,365	$646,248	$642,852	$642,852
Max	$731,475	$692,397	$659,649	$656,747	$656,747
Range	$13,233	$12,032	$13,401	$13,895	$13,895
Confidence of Mean +/-	$1,152	$984	$1,137	$1,163	$1,163

Confidence calculation assumes a normal distribution and 95% confidence level.
Transportation costs include only those allocated to subject port.

5.4. Alternatives Benefit-Cost Analysis

The study team completed the alternatives benefit-cost analysis in three phases:

- Phase I: determine the increment with the highest net benefits. The study team evaluates channel deepening benefits by Pathway for each depth (2 feet to 7 feet deepening).
- Phase II: determine the second added increment. The study team evaluates the incremental costs and benefits of channel deepening the second Pathway, assuming construction of the first Pathway.
- Phase III: evaluate additional navigation efficiency components. The study team evaluates economic justification of channel widening at the eastern entrance of the Kill van Kull.

5.4.1. Phase I Benefit-Cost Analysis

Table 47 presents alternative costs including IDC, OMRR&R, and local service facility improvement cost assumptions. Estimated first costs include the cost to construct the proposed depth, including contingency, PED and CM costs presented at current price levels (October 2019). IDC is based on an assumed 16-year construction duration, depending on the alternative, calculated to the midpoint of construction. Total economic costs represent implementation costs and includes project first costs, IDC (calculated using total economic costs), and local service facility costs.

Table 47: Alternatives Costs ($1,000s, October 2019 Price Level, 2.75% Discount Rate)

Depth	Project First Costs	IDC	Berth Costs	Total Econ. Costs	AAEQ Total Investment	AAEQ OMRR&R	Total AAEQ Costs
Sea to EPAMT							
-52FT	$2,805,008	$433,696	$112,791	$3,351,495	$124,103	$4,147	$128,250
-53FT	$3,065,290	$558,241	$126,410	$3,749,941	$138,725	$4,147	$142,872
-54FT	$3,328,028	$728,070	$139,691	$4,195,789	$155,125	$4,147	$159,272
-55FT	$3,634,007	$884,762	$138,123	$4,656,892	$173,676	$4,147	$177,823
-56FT	$3,994,782	$1,073,855	$137,979	$5,206,616	$193,124	$4,147	$197,272
-57FT	$4,285,876	$1,226,566	$147,960	$5,660,402	$210,168	$4,147	$214,315
Sea to PJPAMT							
-52FT	$345,284	$34,986	$27,412	$407,682	$15,101	$136	$15,237
-53FT	$410,393	$47,966	$27,747	$486,106	$18,006	$136	$18,142
-54FT	$477,958	$71,148	$28,132	$577,238	$21,381	$136	$21,517
-55FT	$543,702	$89,873	$28,010	$661,585	$24,506	$136	$24,642
-56FT	$664,243	$132,254	$27,955	$824,452	$30,538	$136	$30,674
-57FT	$791,507	$185,365	$28,080	$1,004,952	$36,224	$136	$36,360

The study team compared benefits and costs for both pathways (Sea to EPAMT and Sea to PJPAMT) at each alternative depth to determine the Pathway and depth with the highest net benefits. **Table 48** summarizes the results of the benefit cost analysis.

Table 48: Benefit-Cost Summary Assuming Pathway to EPAMT to 4FT ($1,000s, 2019 Price Level, 2.75% Discount Rate)

Depth	Total Economic Costs	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
SEA TO EPAMT					
-52FT	$3,351,495	$128,250	$139,281	$11,031	1.1
-53FT	$3,749,941	$142,872	$197,377	$54,505	1.4
-54FT	**$4,195,789**	**$159,272**	**$255,474**	**$96,202**	**1.6**
-55FT	$4,656,892	$177,823	$264,532	$86,709	1.5
-56FT	$5,206,616	$197,272	$264,532	$67,260	1.3
-57FT	$5,660,402	$214,315	$264,532	$50,217	1.2
SEA TO PJPAMT					
-52FT	$407,682	$15,237	$37,984	$22,747	2.5
-53FT	$486,106	$18,142	$55,515	$37,373	3.1
-54FT	**$577,238**	**$21,517**	**$73,045**	**$51,528**	**3.4**
-55FT	$661,585	$24,642	$75,002	$50,360	3.0
-56FT	$824,452	$30,674	$75,002	$44,328	2.4
-57FT	$1,004,952	$36,360	$75,002	$38,642	2.1

The benefit-cost analysis indicates benefits for both Pathways maximize with a 4-foot deepening. Sea to EPAMT deepening to -54FT MLLW yields the highest net benefits of any alternative.

5.4.2. Phase II Benefit-Cost Analysis

Analysis then determines the second Pathway increment which maximizes net benefits. Phase II benefit-cost analysis only evaluates incremental costs of channel improvements beyond 4-foot deepening from Sea to EPAMT. **Table 49** presents alternative costs of deepening to PJPAMT assuming 4-foot deepening from Sea to EPAMT. Costs include incremental IDC (calculated using total economic costs), OMRR&R, and local service facility improvement costs for deepening to PJPAMT by channel depth. Total economic costs represent implementation costs and includes project first costs, IDC, and local service facility costs. Approximately $345 million in joint costs are attributed to Sea to EPAMT under the -54 feet MLLW deepening and $364 million under the -55 feet MLLW deepening.

Table 49: Phase II Costs ($1,000s, October 2019 prices, 2.75% Discount Rate)

Depth	Project First Costs	IDC	Associated Costs	Total Econ. Costs	AAEQ Total Investment	AAEQ OMRR&R	Total AAEQ Costs
PJPAMT Optimization (assuming EPAMT deepened to -54FT MLLW)							
-52FT	$199,485	$20,213	$27,412	$247,110	$9,216	$73	$9,289
-53FT	$215,627	$25,202	$27,747	$268,576	$10,011	$73	$10,084
-54FT	$231,770	$27,089	$28,132	$286,991	$10,693	$73	$10,766
-55FT	$297,515	$44,288	$28,010	$369,812	$13,761	$73	$13,834
-56FT	$418,055	$76,104	$27,955	$522,115	$19,266	$73	$19,340
-57FT	$545,320	$127,709	$28,080	$701,109	$25,736	$73	$25,809

Table 50 summarizes the results of Phase II benefit-cost analysis. Costs are incremental costs assuming Pathway to EPAMT is dredged to -54FT MLLW. The analysis shows NED benefits are maximized with a 4-foot deepening.

Table 50: Pathway to PJPAMT Incremental Benefit-Cost Summary ($1,000s, October 2019 Price Level, 2.75% Discount Rate)

Depth	Total Economic Costs	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
*PJPAMT INCREMENTAL ANALYSIS (Assuming Elizabeth deepened **4FT**)*					
-52FT	$247,110	$9,289	$37,984	$28,695	4.1
-53FT	$268,576	$10,084	$55,515	$45,431	5.5
-54FT	**$286,991**	**$10,766**	**$73,045**	**$62,279**	**6.8**
-55FT	$369,812	$13,834	$75,002	$61,168	5.4
-56FT	$522,115	$19,340	$75,002	$55,662	3.9
-57FT	$701,109	$25,809	$75,002	$49,193	2.9

Like the Pathway to EPAMT, the Pathway to PJPAMT maximizes net benefits with 4-feet of channel deepening. The results of Phase I and Phase II analysis indicates NED benefits are maximized at 4FT for both Pathways.

5.4.3. Phase III Benefit-Cost Analysis

In Phase III the study team evaluates navigation efficiency components. Of the three efficiency components originally formulated, NYNJ pilots determined two as necessary for navigation. The study team evaluated an efficiency component at the eastern entrance of Kill Van Kull. This component is a widening meant to allow vessels to meet and pass. The location of the potential widening component also allows vessel to navigate closer to the Kill Van Kull to pass outbound vessels.

The study assumes vessels would use the passing component in place of the Gravesend Anchorage. This would allow vessels to proceed to the east entrance of the Kill Van Kull to pass vessels, saving approximately 15 minutes of wait time. The study assumes 30 percent of container vessels will take advantage of the efficiency component based on the historical percentage of container vessels using the Gravesend Anchorage. The study team developed models for 2030, 2040, and 2050. Benefits are interpolated for intermediate years and held constant after 2050. **Table 51** summarizes the benefit-cost estimate for the efficiency component.

Table 51: Efficiency Component Benefit-Cost Summary (October 2019 Price Level, 2.75% Discount Rate)

Total Economic Costs	AAEQ Costs	AAEQ Benefits	Net Benefits	Benefit-Cost Ratio
$28,883,000	$1,074,000	$367,000	$(707,000)	0.34

5.4.4. Recommended Plan

The study team identified the recommended plan as channel deepening up to -55 feet MLLW. NED benefits are maximized at -54 feet MLLW, but the study team chose to carry 5 feet deepening forward for additional analysis. The sensitivity of both the -54 feet and -55 feet deepening plans is described in **Section 6.** More detailed cost estimate was performed for the 4-foot deepening and 5-foot deepening. **Table 52** and **Table 53** present the updated benefit-cost analysis for 4-foot deepening and 5-foot deepening, respectively. As shown, net AAEQ benefits are maximized with a 4-foot deepening.

Table 52: Updated -54FT Deepening Benefit-Cost Analysis for (Oct 2020 Price Level, 2.50% Discount)

Project Phase	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
Phase I: -54FT	$145,812,826	$255,854,000	$110,041,174	1.75
Phase II: -54FT	$22,917,315	$73,252,000	$50,334,685	3.20
Total	**$168,730,141**	**$329,106,000**	**$160,375,859**	**1.95**

Table 53: Updated -55FT Deepening Benefit-Cost Analysis (Oct 2020 Price Level, 2.50% Discount)

Project Phase	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
Phase I: -55FT	$156,052,331	$264,876,000	$108,823,669	1.70
Phase II: 55FT	$24,685,974	$75,206,000	$50,520,026	3.05
Total	**$180,738,305**	**$340,082,000**	**$159,343,695**	**1.88**

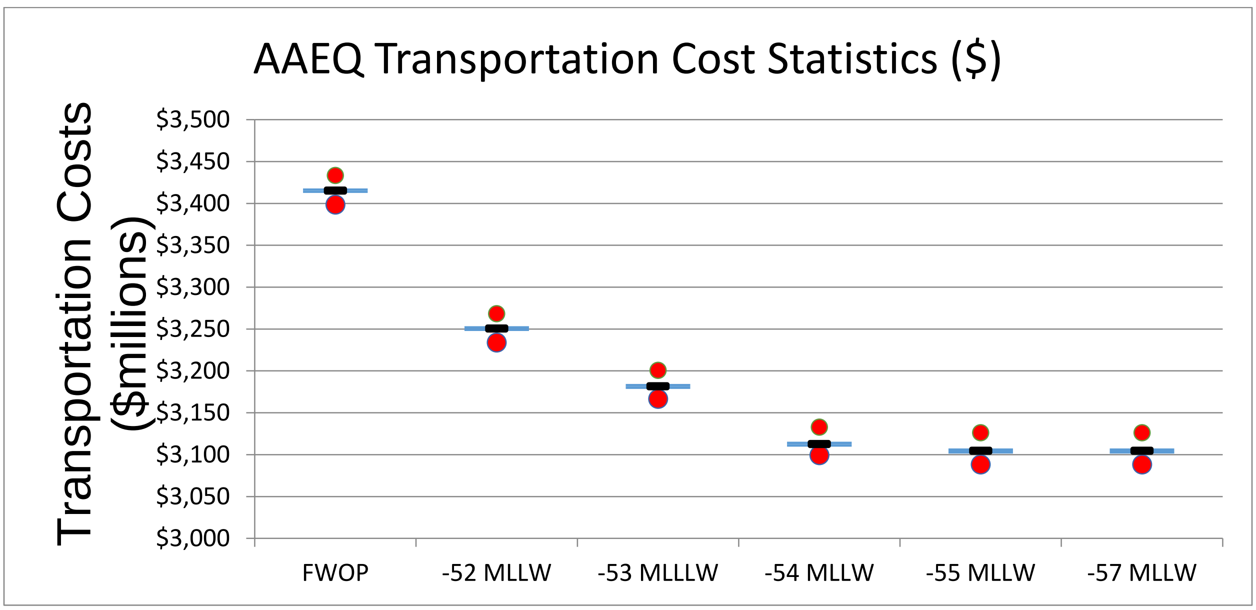
6. Sensitivity Analysis

The Principles and Guidelines (P&G) and subsequent Engineering Regulation (ER) 1105-2-100 recognize the inherent variability to water resources planning. Navigation projects and container studies are especially fraught with uncertainty given the volatility of international trade.

6.1. Model Uncertainty

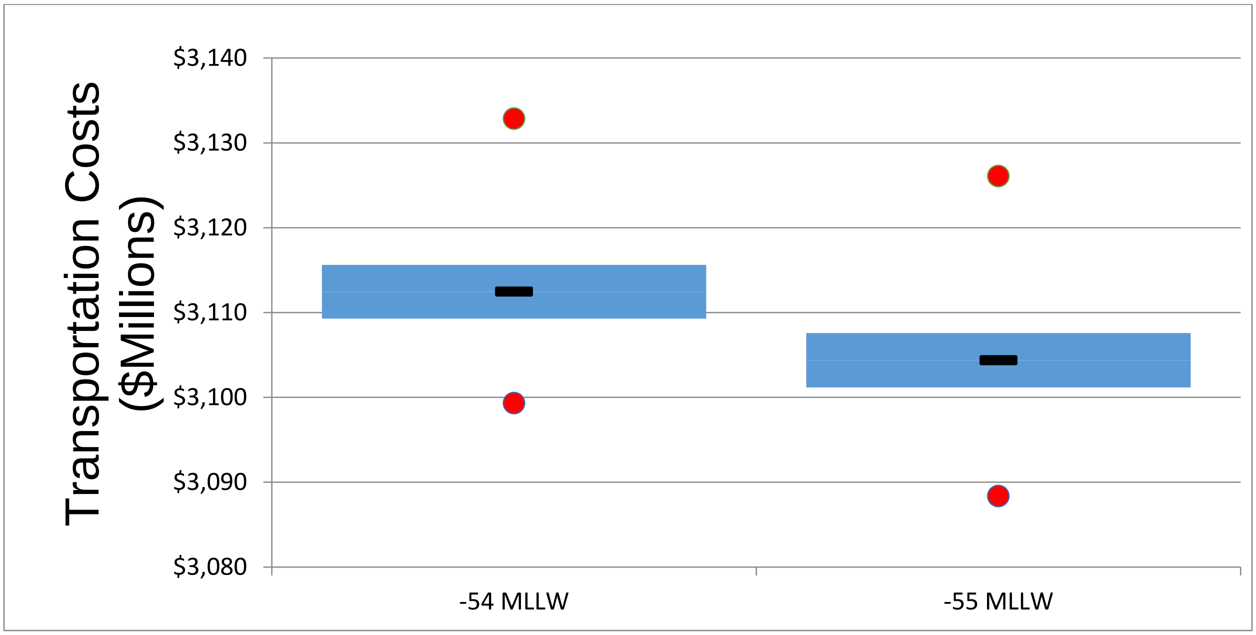
Port and individual operations are subject to change based on various conditions including weather, congestion, labor availability, schedule, pilot practices, and other factors leading to variability. The HarborSym model included variations or ranges for many of the variables involved in the vessel costs, loading, distances, speeds, etc. **Figure 34** plots mean of transportation costs computed by the HarborSym model for each depth alternative (black marker), the 95 percent confidence interval (blue marker), and the minimum and maximum values for 30 iterations. The distribution shows variation in the total transportation costs; however, there is minimal overlap in total transportation cost between alternatives.

Figure 34: AAEQ Transportation Cost Statistics



Additional consideration is given to the difference between the 4-foot and 5-foot deepening plan. Section 5 presents 54 feet as the depth which maximizes net benefits. Additional benefits in excess of the 4-foot deepening could be realized with a 5-foot deepening. Specifically, PPX4 vessels could fully load more consistently. **Figure 35** shows the difference in the mean transportation costs between a 4-foot deepening and 5-foot deepening and provides the 95 percent confidence interval for both plans. The figure shows at least a 95 percent confidence in the difference of means between transportation costs and, therefore, transportation cost savings between the 4-foot deepening and 5-foot deepening. Construction cost ranges are not available for this study. However, when incorporating the difference in costs between the 54-foot and 55-foot plan, the difference in net benefits is more pronounced.

Figure 35: Transportation Cost Sensitivity Analysis (54FT vs 55FT)



The lack of overlap between plans is because variability built into the model primarily addresses in-port vessel operations. For this study, in-port transportation costs account for only 6 to 7 percent of total transportation costs. As a result, assumptions based on the commodity forecast, fleet forecast, and vessel loading assumptions have greater impact on total transportation costs and the difference between plans.

6.2. Commodity and Fleet Uncertainty

The long-term trade forecast assumes compound average annual growth of 3.5 percent through 2050. While the study assumes long-term positive GDP growth will drive continued increases in containerized trade, future trade volumes are difficult to predict with certainty. Commodity flows are subject to the ups and downs of the business cycle, individual commodity markets, and political influence. The COVID-19 pandemic, for example, created significant uncertainty in GDP growth and trade volumes, especially in the short and medium-term.

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

Analysis will develop alternative scenarios to test the sensitivity of the recommended plan prior to the release of the Final Report. Analysis will primarily focus on low growth scenarios as these are most likely to impact plan selection and project justification. The study will test the impact of both slower fleet transition and lower than expected commodity growth. These results will be compared to the baseline scenario to determine the level of confidence in the results of the analysis.

7. 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 a deeper channel to more efficiently operate larger containerships. Larger containerships alone do not drive growth for the harbor. Many factors may influence the growth of a particular harbor: landside development and infrastructure, location of Distribution Centers for imports, source locations for exports, population and income growth, location, port logistics and fees, business climate and taxes, carrier preferences, labor stability and volatility, and business relationships. Harbor depth is just one of many factors involved in determining growth and market share for a port. Additionally, growth in total trade is not dependent on cargo diversion from other US ports. The analysis based the commodity forecast on the assumption that NYNJ's share of East Coast cargo would remain constant between the FWOP and FWP conditions.

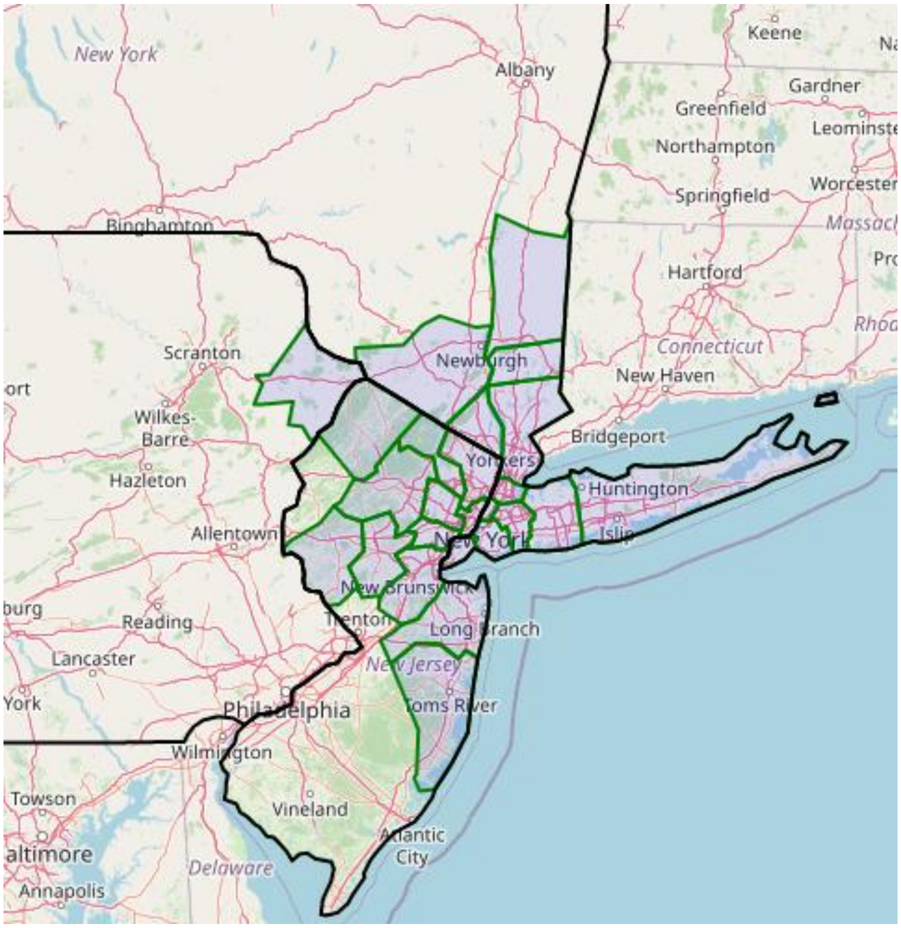
To restate the multiport considerations in another way, justification of the recommendation for this study is not reliant on cargo shifting to NYNJ from other locations. The analysis assumes NYNJ receives the same share of regional cargo volumes with or without channel deepening.

8. Socioeconomic and Regional Analysis

This section will also address the regional economic development impact of the proposed project. The study will estimate local capture rates from the navigation investment, impacts on employment and labor income, as well as economic value added to the regional economy. The parameters used to describe the demographic and socioeconomic environment include population data, private sector employment, wage earnings, race, age, poverty levels, and environmental justice (EJ).

Figure 36 provides a map of the 25 counties given additional consideration for this analysis within the New York-Newark-Jersey City, NY-NJ-PA Metropolitan Statistical Area (MSA): Bergen (NJ), Essex (NJ), Hudson (NJ), Hunterdon (NJ), Middlesex (NJ), Monmouth (NJ), Morris (NJ), Ocean (NJ), Passaic (NJ), Somerset (NJ), Sussex (NJ), Union (NJ), Bronx (NY), Dutchess (NY), Kings (NY), Nassau (NY), New York (NY), Orange (NY), Putnam (NY), Queens (NY), Richmond (NY), Rockland (NY), Suffolk (NY), Westchester (NY), Pike (PA). Additional consideration is given to the counties immediately adjacent to EPAMT and PJPAMT container facilities (Hudson (NJ), Essex (NJ), and Union (NJ) counties).

Figure 36: Regional Economic Impact Area



8.1. Socioeconomic Overview

This section provides an overview of the socioeconomic conditions immediately adjacent to the study area and in the surrounding areas likely impacted by project implementation. Data for this overview is based on publicly available data from the US Census Bureau's American Communities Survey.

8.1.1. Population

The New York-Newark-Jersey City MSA is the largest MSA in the US with an estimated 2019 population of 19,216,000. The MSA experienced relatively slow population growth over the past 10 years, growing at a compound annual growth rate (CAGR) of less than 1 percent. Between 2010 and 2019, New York-Newark-Jersey City MSA's population increased by 1.5 percent (**Table 54**). This growth rate was one-quarter the national growth rate and one-fifth the growth rate of all US MSAs over the same period.

Table 54: Study Area Population Growth (2010-2019)

Geographical Area	Population		Compound Annual Growth Rate (2010-2019)
	2010	2019	

New York-Newark-Jersey City MS	18,923,407	19,216,182	0.2%
New Jersey	8,801,624	8,882,190	0.1%
New York	19,392,283	19,453,561	0.0%
Pennsylvania	12,709,630	12,801,989	0.1%
All US MSAs	**263,659,728**	**282,828,515**	**0.8%**
United States	**309,349,689**	**328,239,523**	**0.7%**

8.1.2. Employment and Income

Estimated employment in 2019 totaled 15,584,000. **Table 55** presents employment by sector for the latest available year, 2017. Total employment in 2017 for the New York-Newark-Jersey City MSA was 16,446,000. The largest sector by number of employees and total annual payroll was NAICS Sector 62: Health Care and Social Assistance. Professional, scientific, and technical services was the next largest sector in 2017 (1,595,000 employees) followed by wholesale trade (994,000 employees), retail trade (963,000 employees), and accommodation and food services (789,000 employees).

Table 55: 2017 Employment and Income by Sector

2017 NAICS		Sum of Annual payroll ($1,000)	Sum of Number of employees
22	Utilities	$4,686,000	42,855
31-33	Manufacturing	$19,545,000	324,200
42	Wholesale trade	$82,211,000	994,163
44-45	Retail trade	$29,474,000	962,724
48-49	Transportation and warehousing	$17,278,000	333,736
51	Information	$39,096,000	331,931
52	Finance and insurance	$122,419,000	614,115
53	Real estate and rental and leasing	$12,841,000	210,074
54	Professional, scientific, and technical services	$151,210,000	1,594,982
56	Administrative and support and waste management and remediation services	$40,934,000	775,989
61	Educational services	$5,293,000	157,108
62	Health care and social assistance	$165,997,000	3,303,152
71	Arts, entertainment, and recreation	$18,183,000	383,634
72	Accommodation and food services	$19,531,000	788,707
81	Other services (except public administration)	$25,411,000	640,872

Median household incomes for New York-Newark-Jersey City MSA in 2019 are shown in **Table 56**. The MSA median household income is 23 percent above the national median.

Table 56: Median Income in Study Area (2019)

Geography	Median Income, 2019	% National Median Income
New York-Newark-Jersey City	$61,392	123%
New Jersey	$61,132	122%
New York	$56,534	113%
Pennsylvania	$50,695	101%
United States	$50,078	100%
Source: 2019 American Community Survey, US Census Bureau		

The estimated unemployment rate for the New York-Newark-Jersey City MSA was 4.6 percent in 2019, 0.1 percent higher than the national average. State unemployment levels for New Jersey, New York, and Pennsylvania are all within 0.2% of the MSA and national average. **Table 57** provides the estimated 2019 unemployment rate for the study area.

Table 57: 2019 Unemployment Rate in Study Area

Geographical Area	Unemployment Rate
New York-Newark-Jersey City	4.6%
New Jersey	4.7%
New York	4.4%
Pennsylvania	4.5%
United States	4.5%
Source: 2019 American Community Survey, US Census Bureau	

8.1.3. Racial Composition

As shown in **Table 58**, New York-Newark-Jersey City MSA has a higher minority population than each individual state and the nation. Black or African American is the single largest minority population in the MSA comprising approximately 18 percent of the MSA. Additionally, 25 percent of the MSA identifies as Hispanic or Latino compared with 18 percent nationally.

Table 58: 2019 Racial Composition of Study Area

Race	NY-Newark-Jersey City		New Jersey		New York		Pennsylvania		United States	
	Pop.	%	Pop.	%	Pop.	%	Pop.	%	Pop.	%
All races	19,216	100	8,882	100	19,454	100	12,802	100	328,240	100
White	10,970	57.1	5,964	67.1	12,294	63.2	10,194	79.6	236,475	72
Black or African American	3,368	17.5	1,204	13.6	3,084	15.9	1,455	11.4	41,990	12.8
American Indian and Alaska Native	60	0.3	18	0.2	74	0.4	27	0.2	2,847	0.9
Asian	2,209	11.5	857	9.6	1,680	8.6	454	3.5	18,637	5.7

Native Hawaiian and Other Pacific Islander	6	0	3	0	8	0	4	0	629	0.2
Some other race	1,977	10.3	571	6.4	1,664	8.6	336	2.6	16,353	5
Two or more races	626	3.3	264	3	649	3.3	333	2.6	11,309	3.4

8.1.4. Age Distribution

The age characteristics of the MSA are shown in **Table 59**. As of 2019, the MSA has lower median ages than the states of New Jersey, New York, and Pennsylvania. The median age is 0.6 years higher than the national median.

Table 59: 2019 Age Distribution in Study Area

Age	New York-Newark-Jersey City		New Jersey		New York		Pennsylvania		United States	
	Pop.	%	Pop.	%	Pop.	%	Pop.	%	Pop.	%
Under 18	4,534	24%	2,155	24%	4,523	23%	2,977	23%	81,872	25%
18-64	11,567	60%	5,252	59%	11,634	60%	7,436	58%	192,293	59%
65 or above	3,115	16%	1,475	17%	3,296	17%	2,388	19%	54,074	16%
Median Age	39.1	-	40.2	-	39.2	-	40.8	-	38.5	-

Source: US Census (American Community Survey, 2019)

8.1.5. Income and Poverty

The US Census Bureau American Community Survey income and poverty data for the New York-Newark-Jersey City MSA are summarized in **Table 60**. Nearly 12 percent of the MSA is determined to be poverty status, less than one percent below the national average.

Table 60: Regional Income and Poverty in Study Area

Regional Income and Poverty Data	New York-Newark-Jersey City	New Jersey	New York	Pennsylvania	United States
Median Household Income	$61,392	$61,132	$56,534	$50,695	$50,078
Total for whom poverty status is determined	18,877,126	8,712,974	18,932,499	12,387,178	320,118,791
Percent of Persons Below Poverty Level	11.6%	9.2%	13.0%	12.0%	12.3%
Source: US Census Bureau, 2019 American Community Survey					

8.2. Regional Economic Development Analysis

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

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

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

The navigation construction expenditures associated with the proposed project at New York Harbor and Newark Bay are $4.15 billion. This amounts to the total project cost less LSF. LSF is not included in the Regional analysis as it is not a federally cost-shared feature and would have a unique regional economic impact compared to navigation construction expenditures. The RECONS model estimates the local impact area will capture $3.05 billion of the total expenditure. The region (New York, New Jersey, and Pennsylvania) and nation capture $3.18 billion and $3.93 billion, respectively. Direct expenditures associated with the project also generate additional economic activity, often called secondary or multiplier effects. RECONS measures jobs supported in full-time equivalent (FTE) jobs, defined as one full-time job for one year. Jobs supported by this project would only last over the construction period, and actual employment impact and duration will vary by function.

The Civil Works expenditure supports approximately 18,270 full-time equivalent job years over the construction period, $1,87 billion in labor income, $2.8 billion in the gross regional product, and $4.64 billion in economic output in the local impact area. More broadly, these expenditures support approximately 39,000 full-time equivalent jobs over the construction period, $3,09 billion in labor income, $4.77 billion in the gross regional product, and $8.91 in economic output in the nation.

Table 61 summarizes the results of the regional analysis by impact area. **Table 62, Table 63,** and **Table 64** present the detailed impacts for the local impact area, state, and nation, respectively. The model assumes the local impact area captures 73 percent of the total project expenditure. The model assumes the proposed project generates a total of $8.9 billion in direct and secondary impacts.

Table 61: Overall Summary of Regional Economic Development Benefits

Area	Local Capture ($000)	Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
Local					
Direct Impact		$3,049,770	10,533.2	$1,256,502	$1,781,148
Secondary Impact		$1,590,546	7,737.4	$618,132	$1,021,711
Total Impact	$3,049,770	$4,640,315	18,270.6	$1,874,634	$2,802,860
State					
Direct Impact		$3,184,384	11,901.6	$1,285,435	$1,823,411
Secondary Impact		$2,075,176	10,423.7	$757,265	$1,257,105
Total Impact	$3,184,384	$5,259,560	22,325.2	$2,042,700	$3,080,516
US					
Direct Impact		$3,927,733	15,638.9	$1,529,929	$2,130,673
Secondary Impact		$4,986,763	23,729.5	$1,556,356	$2,638,807
Total Impact	$3,927,733	$8,914,497	39,368.3	$3,086,286	$4,769,480

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

Table 62: Local Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$374,063	1,995	$165,405	$215,206
105	All other food manufacturing	$20,563	51	$3,643	$4,444
156	Petroleum refineries	$48,221	8	$2,242	$12,761
205	Cement manufacturing	$4,099	7	$575	$1,258
217	Iron and steel mills and ferroalloy manufacturing	$6,909	6	$679	$1,064
254	Valve and fittings, other than plumbing, manufacturing	$15,571	39	$4,048	$6,116
271	All other industrial machinery manufacturing	$2,699	9	$949	$1,107
334	Switchgear and switchboard apparatus manufacturing	$4,197	10	$1,047	$1,355
363	Ship building and repairing	$141,148	514	$48,549	$55,664
395	Wholesale trade	$126,803	405	$48,130	$86,494
399	Retail - Building material and garden equipment and supplies stores	$17,202	132	$7,776	$11,611
408	Air transportation	$2,095	4	$509	$954
409	Rail transportation	$3,107	9	$1,031	$1,070
410	Water transportation	$2,527	2	$393	$884
411	Truck transportation	$16,884	90	$5,866	$6,916
413	Pipeline transportation	$1,006	2	$311	$600
437	Insurance carriers	$71,430	104	$19,339	$46,086
455	Environmental and other technical consulting services	$24,489	228	$26,328	$15,687
462	Office administrative services	$289,097	1,712	$244,546	$255,906
502	Limited-service restaurants	$31,088	229	$8,010	$20,446
507	Commercial and industrial machinery and equipment repair and maintenance	$641,257	2,539	$319,306	$495,207
535	Employment and payroll of federal govt, non-military	$540,313	2,439	$347,819	$540,313
5001	Private Labor	$665,000	-	$0	$0
	Direct Impact	$3,049,770	10,533	$1,256,502	$1,781,148
	Secondary Impact	$1,590,546	7,737	$618,132	$1,021,711
	Total Impact	$4,640,315	18,271	$1,874,634	$2,802,860

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

Table 63: State Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$374,063	2,132	$165,405	$215,206
105	All other food manufacturing	$27,048	68	$4,792	$5,845
156	Petroleum refineries	$84,546	14	$3,931	$22,374
205	Cement manufacturing	$24,779	43	$4,105	$9,711
217	Iron and steel mills and ferroalloy manufacturing	$37,646	32	$3,697	$6,278
254	Valve and fittings, other than plumbing, manufacturing	$25,030	63	$6,507	$9,831
271	All other industrial machinery manufacturing	$6,625	23	$2,330	$2,717
334	Switchgear and switchboard apparatus manufacturing	$10,981	27	$2,830	$3,546
363	Ship building and repairing	$153,013	573	$52,630	$60,344
395	Wholesale trade	$126,803	430	$48,130	$86,494
399	Retail - Building material and garden equipment and supplies stores	$19,190	159	$8,675	$12,952
408	Air transportation	$2,095	4	$509	$954
409	Rail transportation	$3,259	10	$1,081	$1,240
410	Water transportation	$2,527	3	$393	$884
411	Truck transportation	$19,225	103	$7,013	$8,174
413	Pipeline transportation	$2,942	5	$1,843	$1,962
437	Insurance carriers	$71,837	125	$19,449	$46,348
455	Environmental and other technical consulting services	$25,242	254	$27,137	$16,169
462	Office administrative services	$289,097	2,037	$244,546	$255,906
502	Limited-service restaurants	$31,865	258	$8,210	$20,957
507	Commercial and industrial machinery and equipment repair and maintenance	$641,257	2,815	$319,306	$495,207
535	Employment and payroll of federal govt, non-military	$540,313	2,724	$352,914	$540,313
5001	Private Labor	$665,000	-	$0	$0
	Direct Impact	**$3,184,384**	**11,902**	**$1,285,435**	**$1,823,411**
	Secondary Impact	**$2,075,176**	**10,424**	**$757,265**	**$1,257,105**
	Total Impact	**$5,259,560**	**22,325**	**$2,042,700**	**$3,080,516**

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

Table 64: US Impacts

		Output ($000)	Jobs*	Labor Income ($000)	Value Added ($000)
	Direct Impacts				
58	Construction of other new nonresidential structures	$374,063	2,281	$165,405	$215,206
105	All other food manufacturing	$71,315	182	$12,635	$15,412
156	Petroleum refineries	$249,593	41	$11,872	$80,948
205	Cement manufacturing	$28,217	48	$4,675	$11,479
217	Iron and steel mills and ferroalloy manufacturing	$76,186	66	$7,482	$14,060
254	Valve and fittings, other than plumbing, manufacturing	$73,968	187	$19,229	$29,453
271	All other industrial machinery manufacturing	$26,031	91	$9,154	$10,675
334	Switchgear and switchboard apparatus manufacturing	$38,139	95	$9,831	$13,392
363	Ship building and repairing	$441,306	1,653	$154,340	$174,037
395	Wholesale trade	$127,482	457	$48,388	$86,957
399	Retail - Building material and garden equipment and supplies stores	$22,338	188	$10,098	$15,077
408	Air transportation	$2,096	4	$509	$954
409	Rail transportation	$4,577	14	$1,518	$2,462
410	Water transportation	$2,547	3	$396	$891
411	Truck transportation	$24,282	130	$8,858	$10,323
413	Pipeline transportation	$6,926	12	$5,273	$4,980
437	Insurance carriers	$72,728	136	$19,691	$46,923
455	Environmental and other technical consulting services	$41,563	419	$44,683	$26,623
462	Office administrative services	$290,938	2,814	$246,103	$257,535
502	Limited-service restaurants	$41,563	373	$10,708	$27,335
507	Commercial and industrial machinery and equipment repair and maintenance	$706,563	3,511	$351,824	$545,639
535	Employment and payroll of federal govt, non-military	$540,313	2,936	$387,254	$540,313
5001	Private Labor	$665,000	-	$0	$0
	Direct Impact	**$3,927,733**	**15,639**	**$1,529,929**	**$2,130,673**
	Secondary Impact	**$4,986,763**	**23,730**	**$1,556,356**	**$2,638,807**
	Total Impact	**$8,914,497**	**39,368**	**$3,086,286**	**$4,769,480**

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