US Army Corps
of Engineers
Baltimore District

BALTIMORE HARBOR ANCHORAGES AND CHANNELS (BHAC) MODIFICATION OF SEAGIRT LOOP CHANNEL
FEASIBILITY STUDY

FINAL INTEGRATED FEASIBILITY REPORT & ENVIRONMENTAL ASSESSMENT

APPENDIX C:
ECONOMIC ANALYSIS

FEBRUARY 2023

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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 the Baltimore Harbor Anchorages and Channels (BHAC) project – Seagirt Loop Channel 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 scope of the proposed action includes widening and deepening of the Seagirt Loop Channel (up to -50 feet Mean Lower Low Water [MLLW]), re-design of an anchorage to allow 47.5-foot draft vessels to standby within Baltimore Harbor, examining deepening of the South Locust Point Branch Channel and Turning Basin (up to -38 feet MLLW), and considering and evaluating other structural and nonstructural measures that will result in improved transportation efficiencies in Baltimore Harbor.

The current federally authorized depth varies across the multiple channels within the study area. Potential navigation improvements include deepening and widening of navigation channels. The purpose of these improvements is to increase the efficiency of vessel operations within Seagirt Loop, 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 Seagirt Loop channel

The period of analysis is 50 years. The planning horizon starts in year 2028 and ends in year 2077. The analysis uses the vessel operating cost from the Economic Guidance Memorandum (EGM), 20-04, Deep Draft Vessel Operating Costs FY 2019 Price Levels and the federal discount rate from EGM, 22-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year (FY) 2023 of 2.5 percent. 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:

- Waterborne Commerce Statistics Center
- National Navigation Operation & Management Performance Evaluation & Assessment System (NNOMPEAS)
- Maryland Department of Transportation, Maryland Port Administration (MDOT MPA)
- Baltimore Maritime Exchange (BME)

Data on vessel operations, fleet usage, and cargo are key inputs into the HarborSym Model Suite of Tools (HarborSym). HarborSym simulates vessel operations at Baltimore Harbor and evaluate benefits of channel improvements. HarborSym is certified by USACE to meet criteria under Engineer Circulate (EC) 1105-2-412 and is the only approved model for evaluating deep-draft navigation projects for deepening and widening of navigation improvements. Section 5.1. details modeling efforts for this analysis.

2. Existing Condition

The existing conditions are defined in this report as the project conditions that exist as of 2020 plus any changes that are expected to occur prior to the base year, 2028. The year 2020 is the most recent year for which complete data was obtained for containerized cargo volumes and fleet composition. Empirical data from 2018 to 2020 was used in the development of the commodity baseline and forecast. The fleet forecast pulls data from 2017 to 2020.

2.1. Economic Study Area

According to the Waterborne Commerce Statistics Center, in 2019, Baltimore was the 15th largest U.S. container port in terms of TEU throughput. The major trade lanes include Europe, Asia, South America, and the Mediterranean. The Port is comprised of both public and private terminals located in the City of Baltimore and is capable of handling containers, roll on-roll off (ro-ro) automobiles, forest products, and breakbulk. The port services consumers in the Washington-Baltimore metropolitan area and markets in the Midwest, Pennsylvania, and West Virginia. The primary container terminal in this study is Seagirt Marine Terminal (SMT). **Figure 1** identifies the economic hinterland served by container services calling the Port.

Figure 1: Baltimore Harbor Hinterland

(Source: http://letsgetmoving.org/cms/wp-content/uploads/2015/09/1-Port-of-Baltimore.pdf)

Port of Baltimore terminals are accessible via rail or truck. The rail system is served by two Class 1 railroads: CSX Transportation and Norfolk Southern Railroad, which has dedicated facilities and additional support track and rail yards adjacent to the SMT and a short dray trip away respectively. The port is located within 700 miles of major cities and population centers in the Northeast and Midwest. **Figure 2** provides the rail network between Port of Baltimore and major inland population centers.

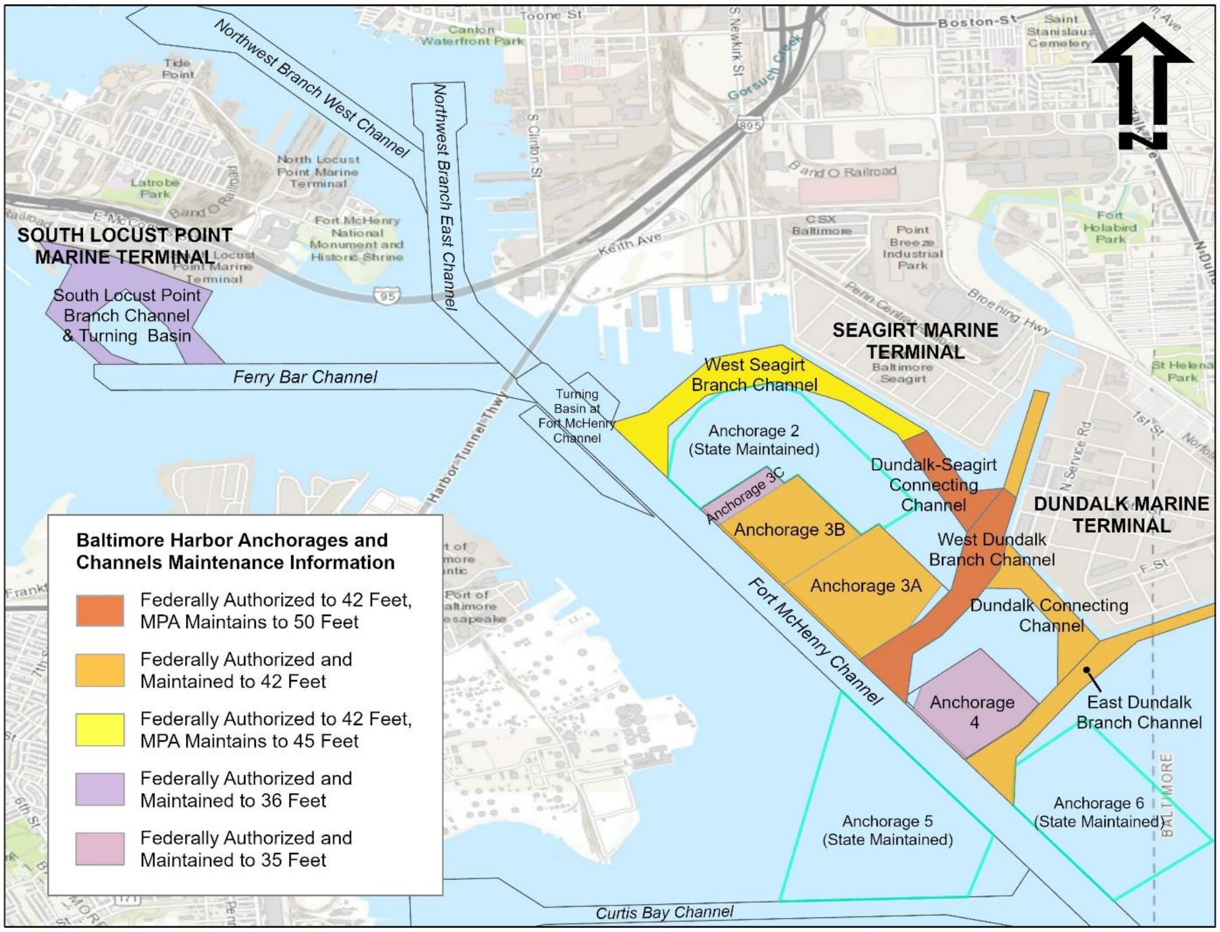
Figure 2: Baltimore Harbor Rail Network

Source: Ports America Chesapeake, 2013

2.1.1. Navigational Features

The Port is located on a 32-square-mile area of the Patapsco River and its tributaries, approximately 12 miles northwest of the Chesapeake Bay. The Port includes three federal projects; the BHAC project (which is dredged to various depths), the 42-Foot Project, and a portion of the 50-Foot Project. The BHAC project was authorized for construction in WRDA 1999 following recommendations in the BHAC Project Feasibility Study of 1998. The project authorization includes the federal navigation branch channels to Seagirt, Dundalk, and South Locust Point Marine Terminals, turning basins, and federal authorization for two anchorages. Construction for the project was completed in 2003. The BHAC project is the focus of this study and is described in the main report. The existing construction as authorized federal channel dimensions for the BHAC project are shown in the figure below. Deepening the West Seagirt Branch Channel is the focus of the evaluation of this study. MPA will continue to maintain the West Dundalk Branch Channel and Dundalk-Seagirt Connecting Channel to 50 feet deep. **Figure 3** provides existing channel conditions in the study area.

Figure 3: BHAC Existing Channel Dimensions



Ships reach the Port by traveling one of two routes along the Chesapeake Bay navigational channel system. Some ships travel south through the C&D Canal which links the Delaware River with the northern end of the Chesapeake Bay. The C&D Canal, which is owned and operated by USACE Philadelphia District, is 35 feet deep, limiting the size of ships able to utilize this channel but making it suitable for roll on-roll off (RORO) carriers. Most ships calling on the Port of Baltimore access from the south utilizing the 50-Foot Channel, which extends 150 nautical miles from the Port of Baltimore to the Atlantic Ocean.

Vessel size at Baltimore Harbor continues to grow. The shift to larger vessels is consistent with world fleet trends as carriers attempt to capitalize on economies of scale afforded by larger vessels.

Seagirt Loop Channel

The Seagirt Loop Channel is currently federally authorized to a depth of -42 feet MLLW, a width of 500 feet, and is approximately 1.0 statute miles long, with widening at both ends. The state has maintained the loop to a depth of -45 feet MLLW in the western branch of the loop and -50 feet MLLW in the eastern branch to accommodate larger vessels.

Dundalk West Channel
The Dundalk West Channel is currently federally authorized to a depth of -42 feet MLLW, state maintained to a depth of -50 feet MLLW, a width of 500 feet, and is approximately 3,800 feet long, with widening at the bends and entrances.

South Locust Point Branch Channel
The South Locust Point Channel is currently authorized and maintained to a depth of -36 feet MLLW, a width of 400 feet, and is approximately 1.0 statute miles long, with widening at the bends and entrances.

Anchorages (3 and 4)
Harbor Anchorage #3 is authorized and maintained at -42 feet MLLW for a width of 2,200 feet and a length of 2,200 feet, and an additional length of 1,800 feet and width of 1,800 feet. The remaining portion of Anchorage #3, just west of the improved areas is currently maintained at a depth of -35 feet MLLW, for a width of 1,500 feet and a length of 300 feet. Harbor Anchorage #4 is maintained at a depth of -35 feet MLLW for a width of 1,800 feet and a length of 1,800 feet.

2.1.2. Terminal Facilities

Analysis focuses on evaluating improvements at Seagirt Marine Terminal. The operations of Seagirt Marine Terminal have been managed by Ports America Chesapeake (PAC) since 2009 via a 50-year Public-Private Partnership agreement. Overall, the port processes up to 43.6 million tons of cargo per year and over $58.4 billion worth of cargo. The terminals serve 11 container carriers including some of the major global alliances.

Seagirt Marine Terminal

The Seagirt Marine Terminal is a state-of-the-art, 284-acre container terminal currently operated by Ports America Chesapeake (PAC). The terminal has two -50 feet MLLW container berths with cranes capable of servicing up to a 16,000 TEU vessel. The two remaining berths are -45 feet MLLW with total alongside length of 1,722 feet. Each berth is capable of servicing 9,200 TEU vessels. The terminal can handle 900,000 container lifts a year; its capacity is expected to grow to 1.4 million container lifts by 2027. The storage yard is capable of handling 2,500,000 TEU. This terminal has direct connection to the Intermodal Container Transfer Facility (ICTF) operated by PAC and is close to I-70, I-81, I-83, I-95, I-97, and I-895. The terminal capacities are sufficient to handle cargo growth that is expected until year 2040. **Table 1** displays the historical inbound and outbound tonnage for Seagirt Marine Terminal.

Table 1: Containerized Tonnage, Seagirt Marine Terminal (Metric Tons)

	2017	2018	2019	2020
Imports	4,651,900	4,951,800	5,082,600	5,008,000
Exports	2,334,200	2,166,100	2,179,700	2,166,200
Total	6,986,100	7,117,900	7,262,300	7,174,200

Figure 4 and **Figure 5** display the inbound and outbound sailing drafts, respectively, for vessels calling Seagirt Marine Terminal. As shown, vessels are using the deeper berth depths with significant growth in the number of vessels sailing at or deeper than 44 feet.

Figure 4: Inbound Sailing Drafts, Seagirt Marine Terminal

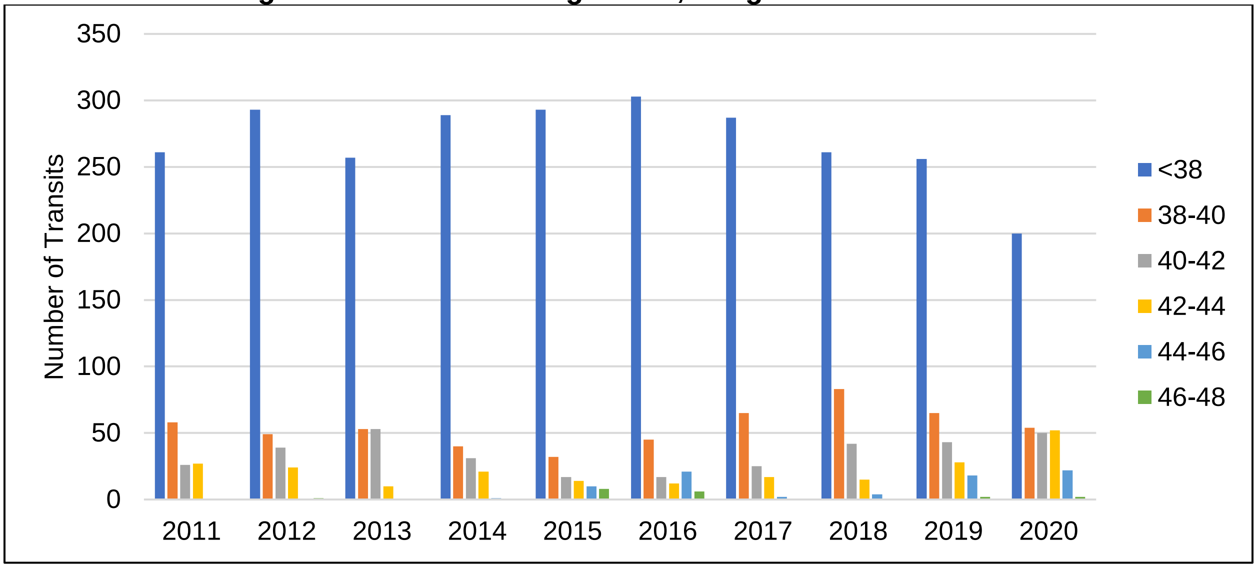
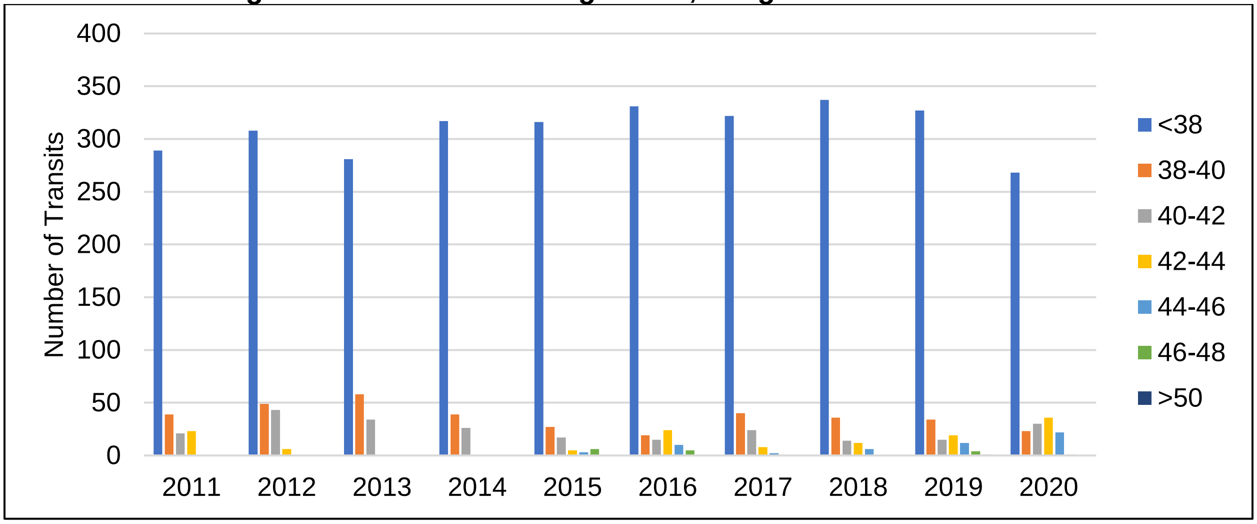


Figure 5: Outbound Sailing Drafts, Seagirt Marine Terminal



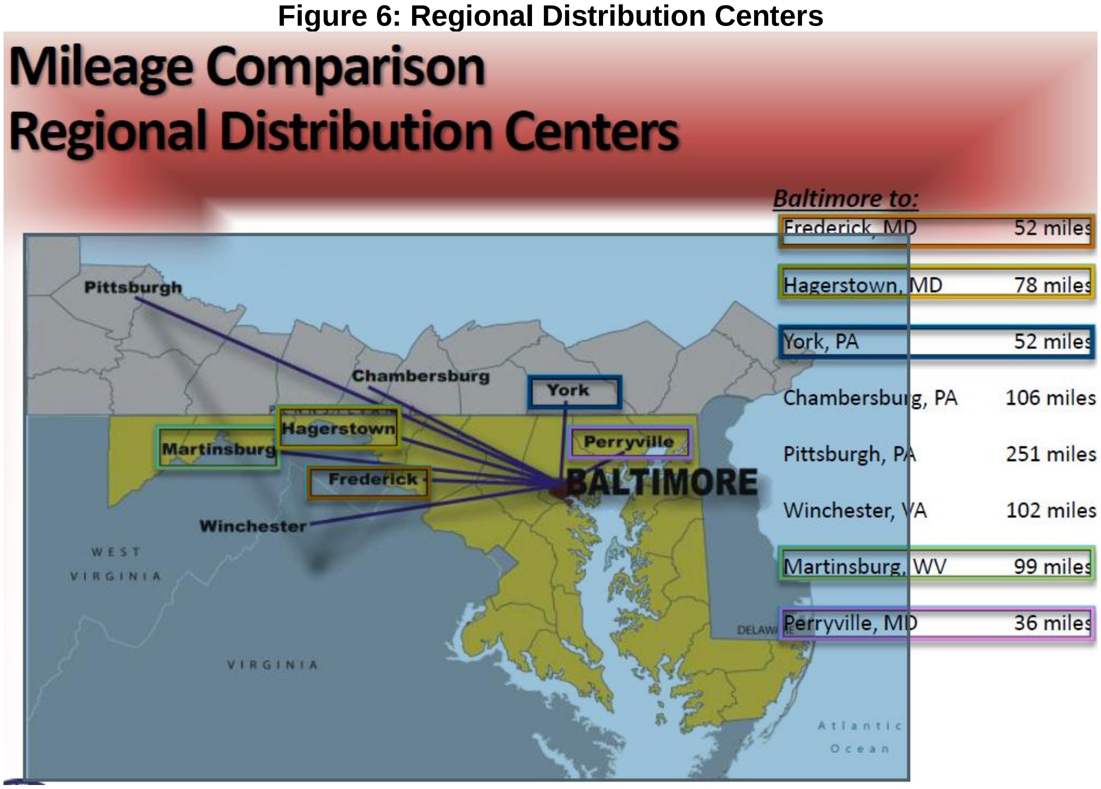
Dundalk Marine Terminal

Dundalk Marine Terminal sits on 570 acres with approximately 9,500 feet in berth length. There are 13 cranes, six of which can serve container carrying vessels. This terminal is the largest and most versatile general cargo facility at the Port. Cargo includes containers, automobiles, farm, construction and other RORO equipment, forest products, steel, breakbulk, and project cargo. The terminal also has direct access to Norfolk Southern Railroads.

2.1.3. Distribution Centers

Distribution Centers (DC) are an integral component of importers and exporters international supply chains. They not only provide the warehousing space necessary for storing the goods received from/delivered to the Port, but in a current business environment characterized by hub-and-spoke supply chains and “last-minute” orders, they oftentimes serve as central nodes in a company’s regional or national logistics network and allow for value-added services such as consolidation/deconsolidation, cross-docking, and trans-loading (removing contents of international marine containers and repackaging in 53’ domestic containers to create economies of scale for domestic delivery). Consequently, DC locations can influence importers’, exporters’, and container shipping lines cargo routing and port selection decisions. Approximately 70% of imports are destined to a storage center within 50 miles of the port, 14% are within 50-100 miles, and 7% are within 100-200 miles. **Figure 6** shows the regional destination hubs.

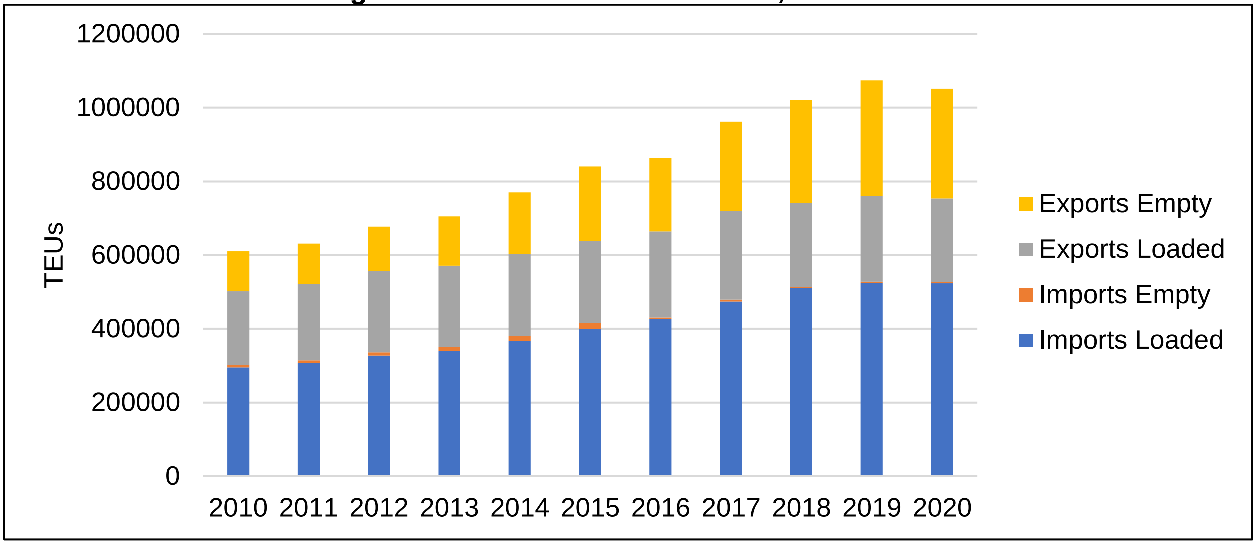
Figure 6: Regional Distribution Centers



2.1.4. Cargo Profile

The Port of Baltimore handled approximately 1.0 million twenty-foot equivalent units (TEUs) in 2020. The lead trading partner is China for both imports and exports. Import volumes from Vietnam, Brazil, India, and Germany round out the top five. For exports, India, Vietnam, Chile, and Columbia are included in the top five trading countries. **Figure 7** shows historical TEUs traded at the port.

Figure 7: Port of Baltimore TEUs, 2010-2020

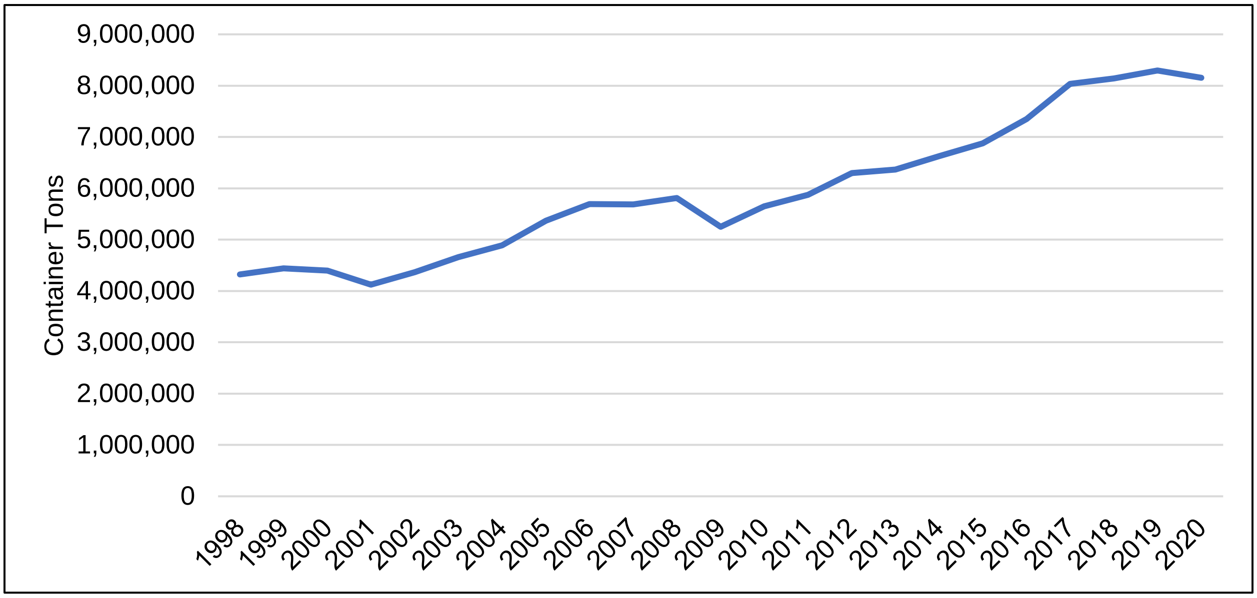


2.2. Historical Commerce

The Port of Baltimore captures 16.2 percent of the North Atlantic market share for imports and exports. The Port is in the heart of Baltimore and provides access to 6.8 million local consumers in the Washington-Baltimore region with one of highest household incomes in the nation. In addition, the Port's rail and truck connections allow shippers to reach 32% of U.S. consumers within 24 hours of calling port.

Based on data for years 2010 to 2020, annual shipments averaged approximately 837,000 TEUs. Of this total, imports accounted for approximately 416,000 TEUs, while exports accounted for 421,000 TEUs, each accounting for approximately 50 percent. **Figure 8** shows historical containerized metric tonnage moving through Baltimore Harbor.

Figure 8: Port of Baltimore Historical Containerized Tonnage, 1998-2020



Source: MDOT MPA

2.3. Fleet Composition

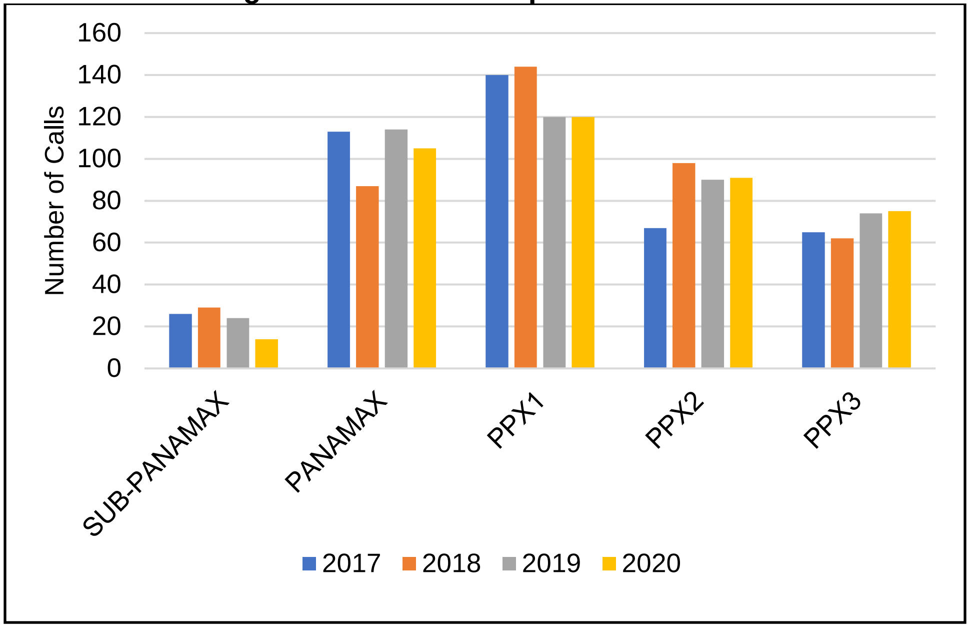
Data for the container fleet was obtained from Waterborne Commerce Statistics Center, the National Navigation Operation & Management Performance Evaluation Assessment System (NNOMPEAs) and the Maryland Port Administration to determine vessel characteristics of the fleet calling the port. The ships are classified as sub-Panamax, Panamax, post-Panamax Generation I (PPX Gen 1), post-Panamax Generation II (PPX Gen 2), post-Panamax Generation III (PPX Gen 3) and post-Panamax Generation III max (PPX Gen 3 max). 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 2** shows the breakdown of the containership class sizes. For the purposes of this analysis, beam width was the characteristic that separated the classes.

Table 2: Containership Classifications

SIZE CLASSIFICATION	DIMENSION	DIMENSION RANGE (FEET)	
		MINIMUM	MAXIMUM
Sub Panamax (TEU size brackets: 0.1-1.3, 1.3-2.9 k)	Beam	34.8	98.2
	Draft	8.2	38.1
	LOA	221.7	813.3
Panamax (TEU size brackets: 1.3-2.9, 2.9-3.9, 3.9-5.2 k)	Beam	98.0	106.0
	Draft	30.8	44.8
	LOA	572.0	967.5
Post Panamax (PPX Generation 1)	Beam	120.0	138.0
	Draft	35.4	47.6
	LOA	920	1,044.7
Super Post Panamax (PPX Generation 2)	Beam	139.0	144.0
	Draft	39.4	49.2
	LOA	910.7	1138
Ultra Large Container Vessels (PPX Generation 3 and Generation 3 max) (MSI size brackets: 5.2-7.6, 7.6-12, 12 k +)	Beam	160.0	176
	Draft	40	52
	LOA	1,098	1,300

Figure 9 shows historical trends in containership vessel sizes and fleet composition for Baltimore Harbor. As shown, the average vessel size calling Baltimore Harbor is increasing from 2017 to 2020 as Sub-Panamax vessels and Panamax vessels are replaced by post-Panamax calls. As shown in Figure 4 and Figure 5, larger vessels tend to call at deeper sailing drafts; however, post-Panamax vessels are required to light-load due to existing channel constraints at Baltimore Harbor.

Figure 9: Containership Vessel Trends



2.4. Container Services

Baltimore Harbor currently has 11 regular container services. **Table 3** shows the number of services serving by region as of 2021.

Table 3: Container Services

World Region	Service Name	Average TEU Capacity	Minimum TEU Capacity	Maximum TEU Capacity
Asia	OCEAN Alliance	12,022	8,508	13,900
Asia	Maersk	4,471	4,250	5,100
Asia	2M Alliance	11,036	9,038	13,630
South Asia	MSC Indus 2	7,444	6,402	9,200
Europe and Mediterranean	2M Alliance	8,573	8,034	9,200
Europe	2M Alliance	7,762	6,178	8,241
Europe	ACL	3,809	3,809	3,809
Africa	Grimaldi Line	932	612	1,318
Africa/Caribbean	MSC/Maersk	2,644	1,798	3,674
Caribbean/South America	MSC – ZIM	6,152	5,248	6,969
South/Central America	Maersk Line/Hapag-Lloyd	4,137	3,752	4,544

2.5. Route Groups

For modeling purposes, services were grouped by the world region they serve. Region-specific commodity forecasts were aggregated to route groups based on the world region. Analysis revealed a low likelihood that significant fleet transition would take place on Africa, Caribbean, or South American routes. There is relatively lower opportunity for carriers to realize economies of scale on these routes because they are shorter and face landside constraints at ports in the route. As a result, the study focuses on two route groups: South Asia via the Suez Canal and Mediterranean & Northern Europe to the US East Coast. Carriers on these routes already utilize the largest vessels in the world fleet and deploy post-Panamax vessels to Baltimore. The South Asia and Mediterranean & Northern Europe routes likely realize origin to destination benefits, and therefore is separate from the other services that only have in-harbor benefits. The study also utilized a "default" route group for carriers that will not likely realize origin-destination benefits, but may impact in-port transportation costs. **Table 4** shows the regions, route groups, and the distance of each route.

Table 4: Route Group Information

Route Group Regions	Route Group Name	Distance Distribution		
		Min.	Most Likely	Max.
Default	Default	0	0	0
Far East – Indian Subcontinent – Southeast Asia – Suez Canal – East Coast United States	FE-SUEZ-ECUS	18,000	19,000	20,000
Mediterranean & Northern Europe- East Coast US	Med-NEU	7,000	10,000	12,000

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.

2.6. 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. Generally, practices for UKC are determined through review of written pilotage rules and guidelines, interviews with pilots and vessel operators, and analysis of actual past and present practices based on relevant data for vessel movements. Typically, UKC is measured relative to immersed vessel draft in the static condition (i.e., motionless at dockside). When clearance is measured in the static condition, explicit allowances for squat, trim, and sinkage are unnecessary. Evaluation of when the vessel moves, or initiates transit relative to immersed draft, tide stage, and commensurate water depth allows reasonable evaluation of clearance throughout the time of vessel transit. For purposes of this study, the UKC is assumed to be 2.5 feet based on engineering regulations and pilot input.

2.7. Container Capacity

Current port capacity throughput is approximately 900,000 containers a year and forecasted to be 1.4 million in 2027. The TEU equivalent is 1.4 million TEUs currently and 2.2 to 2.4 million TEUs in 2027 depending on how the number of lifts is converted. In 2020, the port moved 628,000 containers which is approximately 70% utilization.

The projected increase in capacity is driven by investment at Seagirt Marine Terminal, its storage yard, gate complex, and the Howard Street Tunnel. Containers processed in the port can be transported either via rail or truck.

For the two class I rail lines serving the port, the Howard Street Tunnel expansion will allow CSX to double stack containers. In 2017, the ICTF is estimated to be capable of handling 130,000 to 150,000 containers annually. However, it was only handling around 20,000 to 30,000 containers due to the tunnel inefficiencies. An additional 80,000 to 90,000 containers (126,000 and 141,000 TEUs) throughput can be realized immediately once the tunnel expansion comes online.

The current gate complex averages 3,500 truck transactions daily. Qualitatively, the capacity of the complex is not sufficient to support the growing container volume. There are documented cases of the extended truck queue time in recent years. The non-federal investment also addresses the truck throughput capacity concerns.

3. Initial screening

The PDT had initially formulated for improvements at South Locust Point, Anchorage Improvements and deepening the Seagirt Loop. This section discusses the screening of these improvements. Seagirt Loop Deepening was the only improvement that was carried forward for further analysis.

3.1. South Locust Point

The PDT had initially formulated potential for deepening of the South Locust Point Branch Channel and Turning Basin (SLP). SLP is currently maintained to the federally authorized depth of -36 feet MLLW. The USACE team sought clarification from the MDOT MPA on the nature of the problem in SLP to be able to model the existing and conditions in HarborSym. Following further data gathering, analysis, and discussions, the PDT identified no channel constraint or light-loading problem that could be evaluated during formulation as initially identified in discussions during the scoping phase of the study. Instead, the issue appears to be related to navigation channel shoaling of some portions of the federal channel. The issue will be addressed through traditional Operation and Maintenance and the measure has been removed from consideration as part of the feasibility study. Attachment 1 includes data and additional details regarding the SLP analysis.

3.2. Anchorage Improvements

The MDOT MPA and the Association of Maryland Pilots have identified the need for navigation improvements in the BHAC authority to include a 50-foot anchorage in Baltimore Harbor to reduce stand-by delays for larger vessels calling at Port facilities.

The existing anchorage capacity near the port facilities are insufficient for ultra large container vessels (ULCV) to anchor while waiting for vessels to exit the Dundalk-Seagirt Connecting Channel and West Dundalk Branch Channel. In the existing condition, ULCV must wait south of the Chesapeake Bay Bridge at an anchorage near Annapolis, MD while other containerships exit the Seagirt berth and transit the channel to this point. Representatives from the Association of Maryland Pilots stated that ULCV are limited to one way traffic in the channel from Baltimore Harbor to south of the Chesapeake Bay Bridge near Annapolis. The pilots stated that containerships with length overall of 1,150 feet or greater or beam widths of 150 feet or greater are not allowed to pass another ship unless it is a very small vessel for safe operation in the channel. When the outbound vessel clears the Chesapeake Bay bridge, the ULCV may start inbound travel to complete the transit to SMT.

In April 2021, Maryland Environmental Services provided USACE a memo that explains the existing utilization of anchorages by vessels bound for Seagirt Marine Terminal (SMT). The memo explained that containerships anchor south of the Chesapeake Bay Bridge on average twice a month, or approximately 24 times a year. This estimate was used to calculate a percent of occurrence per year. The vessel call count for 2020 was approximately 405 to SMT. Using the estimate of 24 anchorage occurrences per year for containerships, 6% of the fleet is estimated to be impacted. Assuming 6% of the fleet will continue to be impacted in the future, the table below shows the number of vessels that will be impacted in the future. **Table 5** provides the initial vessel forecasted used for screening purposes for the anchorage and does not include a detailed loading analysis. The forecast is held constant from 2040 to the end of the period of analysis.

Table 5: Fleet Vessel Forecast and Impacted Vessels for Anchorage Analysis

Forecast Year	Vessels Calls	Vessels Impacted
2030	472	28
2040	596	36
2050	761	46

With an improved anchorage in the harbor, ULCV can wait closer to SMT and eliminate the wait time for the outbound vessel to clear the Chesapeake Bay Bridge. This reduces the need to wait for the outbound vessel to clear the channel.

Based on AIS data, the vessels wait approximately four hours while the outbound vessel transits the channel to south of the Chesapeake Bay. To calculate the benefit of the anchorage improvement, the number of vessel calls impacted are multiplied times the vessel operating cost for four hours. Using the latest 20-04, Deep Draft Vessel Operating Costs Fiscal Year 2019 price levels, the benefits total $314,000 average annual equivalent (AAE) at the FY21 discount rate of 2.5 percent.

For screening purposes, a first cost estimate of $82,000,000 was annualized to compare to the benefits. The cost used is construction cost only without annual operations and maintenance or other National Economic Development (NED) cost such as interest during construction. The average annual equivalent cost using the FY21 discount rate of 2.5% is $2,891,000. Net benefits are defined as average annual equivalent benefits minus average annual equivalent costs, which equals -$2,577,000. The benefit-cost ratio (BCR) is defined as average annual equivalent benefits divided by average annual equivalent costs, which equals 0.1. **Table 6** shows the summary and results of the benefits and cost of the anchorage improvement.

Table 6: Benefit and Cost Summary for Anchorages at 2.5%

AAEQ Benefits	$314,000
AAEQ Costs	$2,891,000
Net Benefits	($2,577,000)
BCR	0.1

Economic feasibility requires that the BCR be equivalent or greater than one. For the anchorage improvement, this requirement is not met and screened from further evaluation.

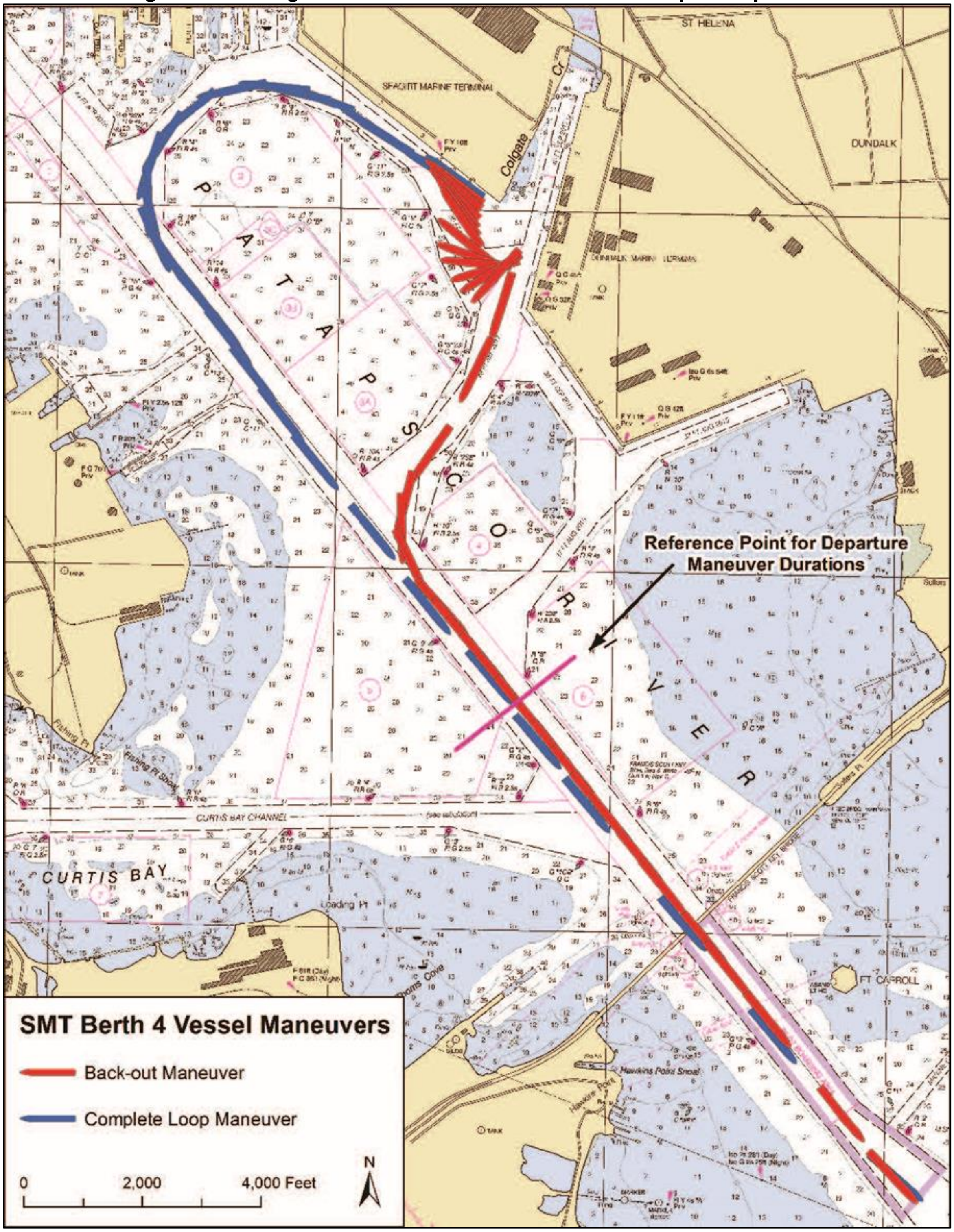
3.3. Seagirt Loop Deepening

Cost reduction benefits result from a decrease in the cost of shipping commodities that reflect the same origin-destination pattern and harbor in all project conditions. In the existing and future without project condition, containerships departing the Seagirt Marine Terminal berth with a sailing draft greater than -42 feet MLLW, must backout of the terminal to the East Dundalk channel. See **Figure 10** with reference to the red vessels for backout maneuver. For the Seagirt Loop evaluation, two types of cost reduction benefits were evaluated based on future conditions at the Port of Baltimore: use of larger vessels and enhanced maneuverability and delay reductions.

As cited in the Institute for Water Resources Report 10-R-4 Section 14.3, carriers may have incentive to use larger vessels with a resulting increase in average load per vessel. This is reflected as a shift in the fleet forecast between the without-project and with-project alternative fleets. Larger vessels at the same draft as smaller vessels can carry larger loads. It is often more cost-effective to transport goods on larger vessels. In the future without project condition, it is assumed large containerships will continue to call SMT. However, the with-project condition allows larger ships to call more efficiently through the reduction of congestion and increased maneuverability, which will allow the design vessel to call more frequently than in the FWOP condition.

Another component of the analysis is the evaluation of deepening and widening of the Seagirt Loop to provide delay reductions resulting in decreased transit time. Currently, the transit of large containerships constrains the approach channels north of the Chesapeake Bay Bridge to one-way traffic based on Association of Maryland Pilots channel operating guidelines due to channel width. Inbound vessels must wait south of the Chesapeake Bay Bridge until the departing containership clears the channels and bridge. According to information provided in a memo by Moffatt and Nichol (Moffatt and Nichol, BHAC_NED_Benefits, September 30, 2021), an advisory firm, the Association of Maryland Pilots stated deepening the Seagirt Loop channel will allow the inbound containership to proceed north in anticipation of the departure of the outgoing containership and pass on opposite sides of the Seagirt Loop. The transit time from the Chesapeake Bay Bridge to SMT is approximately three hours, therefore, this equates to the potential time savings for incoming vessels.

Figure 10: Seagirt Backout Maneuver Verses Loop Completion



4. Future Conditions

4.1. Commodity Forecast

The Port of Baltimore'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 Port of Baltimore. The port's share of the commodity projections remains the same as existing condition. However, the deepening of Seagirt Loop will allow shippers to load vessels more efficiently and take advantage of larger vessels and move vessels through the system faster to gain efficiency from delay reductions. 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.

In 2015, IHS provided an import and export commodity forecast and report for the Port of Baltimore. This forecast was used to help inform trends for analysis of the future conditions. The trends taken from the IHS forecast were applied to the Baltimore existing condition assessment to estimate future throughput over time for containerized cargo. The forecast was held constant beyond the year 2050 through the end of the 50-year period of analysis.

4.1.1. Cargo Baseline

Empirical data from 2018 to 2020 was used to develop a baseline, allowing the cargo estimate to capture both economic prosperity and downturn which occurred over that timeframe. The baseline tonnage represents the starting point from which cargo is forecasted. **Table 7** and **Table 8** show historical containerized imports and exports that moved through the Port from 2018 through 2020. The containerized cargo is separated based on route groups mentioned above. In 2021, a new service began that serves South Asia (India) and Mediterranean via the Suez Canal. As of the time this report is being written, cargo volumes are unknown for this service. However, there is data for cargo volumes on other Asia routes. Cargo volumes were estimated for this new route using empirical data from the other Asia routes. Data from 2019 and 2020 was analyzed to determine the average inbound and outbound metric tonnage of a PPX2 and PPX3 containership. Given this is a weekly service and metric tons were estimated per vessel call, an annual estimate was made. This tonnage for 2021 is shown in the table below in 2021. However, since the service started in 2021, 2022 would be the first full year of the estimated cargo volume.

Table 7: Containerized Imports (metric tons)

		2018	2019	2020	2021	Baseline Tonnage
Import Containerized Cargo	Containerized Cargo	4,951,800	5,082,600	5,008,000		5,014,100
	South Asia via Suez				1,003,600	1,003,600
	Total					6,017,700

Table 8: Containerized Baseline Exports (metric tons)

		2018	2019	2020	2021	Baseline Tonnage
Export Containerized Cargo	Containerized Cargo	2,166,100	2,179,700	2,166,200		2,170,700
	South Asia via Suez				722,800	722,800
	Total					2,893,500

4.1.2. Trade Forecast Methodology

In 2015, IHS Global, Inc. was engaged to provide commodity flow data and forecast for the Port of Baltimore. The effort involved examining US North and South Atlantic trade and international trade lanes by commodity as well as examining Port of Baltimore's 2015 statistics of commodity shipments. IHS's World Trade Service (WTS) was used to derive the Port of Baltimore commodity forecast. According to the WTS, steady growth is projected to continue throughout the forecast period, primarily due to continued economic expansion of the United States.

4.1.2.1. 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 macroeconomics, 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 WTS database covers all global trade broken down into 103 countries and global regions. In addition, U.S. seaborne trade is broken down into six coastal areas. It covers 155 commodity categories that are mapped to SITC and HS categories.

The forecasts of world trade, in both nominal and real commodity value, are converted to physical volume by transportation mode using standard formulas. Primary modes of transportation include air, overland, and maritime transport, all measured in metric tons as well as in value.

4.1.3. Cargo Forecast Summary

Growth rates were estimated from the baseline year of 2021 to the base year 2030 through 2040 where the forecast was held constant through the end of the period of analysis, year 2079. **Table 9** shows the average growth rates for imports and exports for each period shown.

Table 9: Containerized Cargo Growth Rates

IMPORT CONTAINER ANNUAL GROWTH RATES				
	2021-2025	2026-2030	2031-2035	2036-2040
All Services	3.5%	3.8%	3.6%	2.7%
EXPORT CONTAINER ANNUAL GROWTH RATES				
	2021-2025	2026-2030	2031-2035	2036-2040
All Services	4.2%	3.1%	2.8%	2.5%

Using the baseline estimated commerce volumes, the estimated growth rates were applied to forecast import and export tonnage for Port of Baltimore for the FE-SUEZ-ECUS and aggregated services over the period of analysis. As noted in Section 4.1.1, the first full year assumed for FE-SUEZ-ECUS volumes are 2022, therefore three years of growth is assumed from the baseline to 2025. For purposes of analysis, the forecast is held constant after year 2040 through 2074.

Table 10 and **Table 11** shows the import and export commodity forecast tonnage for the South Asia service and all other services.

Table 10: Import Containerized Metric Tons Forecast

Import Forecast	Baseline	2025	2030	2035	2040 - 2079
FE-SUEZ-ECUS	1,003,600	1,112,000	1,340,000	1,601,000	1,831,000
All Services	5,014,100	5,750,500	6,931,300	8,279,700	9,470,500

Table 11: Export Containerized Metric Tons Forecast

Export Forecast	Baseline	2025	2030	2035	2040 - 2079
FE-SUEZ-ECUS	722,800	817,300	954,300	1,093,000	1,239,000
All Services	2,170,700	2,556,900	2,985,600	3,419,400	3,876,400

Table 12 provides estimated total TEU throughput (including empty TEUs). Current port capacity throughput is 1.4 million. Capacity expansion plans include a truck gate complex expansion, the Howard Street Tunnel Expansion and other storage improvements. These improvements increase the port capacity throughput to 2.2 million TEUs by 2027. Based on the estimated TEUs in **Table 12** and annual throughput volume, TEU capacity is estimated to be reached between years 2035 and 2040. The forecast is held constant throughout the remainder of the period of analysis.

Table 12: Seagirt Marine Terminal Total TEU Forecast

	2030	2035	2040
Forecasted Import TEU	859,531	940,512	1,174,405
Forecasted Export TEU	940,512	1,077,154	1,221,111
Forecasted Total TEU	1,800,043	2,017,666	2,395,516

4.2. Vessel Fleet Forecast

Maritime Strategies Inc. (MSI) was requested by the Port of Baltimore and the US Army Corps of Engineers to forecast the size composition of container vessels calling at the Port of Baltimore for the Baltimore Harbor and Channels 50-Foot study in 2015. The effort included three main tasks: developing a forecast of world fleet containerships, a forecast of container vessels deployed on US Atlantic Coast trade routes by size bands and capacity and a forecast of containerships calling at Baltimore by size bands through 2035. This data was used to inform the vessel fleet calling Seagirt Marine Terminal.

4.2.1. Design Vessel

For deep-draft projects, the design vessel is selected based on 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 Baltimore, the study team recommends the CMA CGM Marco Polo containership class as the design vessel. This selection is meant to incorporate the full range of potential dimensions of the largest vessel that will call most frequently over the period of analysis. Vessels of this size are expected to call frequently on services calling the Port of Baltimore. The Port of Baltimore 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:

- 1,299.0 feet length overall (LOA)
- 175.6 feet beam
- 52.5 feet design draft
- 16,022 TEU capacity

There is inherent uncertainty in design vessel selection. Vessel order books change, and deployment of vessels on services calling Baltimore is based on fluctuating market forces and vessel availability. Vessels larger and smaller than the design vessel will call the Port over the study period. However, there is confidence that the chosen dimensions will remain relevant through the study period.

4.2.2. Container Fleet Forecast

The fleet forecast was adapted for Port of Baltimore to estimate the expected fleet composition over the period of analysis. The forecast introduces a post-Panamax Generation 3-Max containership vessel based on the historical transition of the fleet, which is the design vessel.

MDOT MPA provided containership vessel call data to USACE from 2017 through 2020. By cross referencing the MDOT MPA data with Baltimore Maritime Exchange data, an observed TEU capacity that called Baltimore was calculated. **Table 13** shows the approximate TEU capacity by year and vessel class from 2017 through 2020.

Table 13: Historical TEU Capacity

	2017	2018	2019	2020
Sub Panamax	2%	2%	1%	1%
Panamax	19%	14%	17%	16%
PPX Gen 1	34%	31%	23%	22%
PPX Gen 2	22%	32%	31%	32%
PPX Gen 3	23%	21%	26%	29%

The observed TEU capacity of the distribution by vessel class varied from the 2015 projections, however the overall TEU capacity calling the port was close in comparison. The rates of change were used from the MSI fleet forecast and applied to the historical data for the forecasted period of 2021 through 2050. **Table 14** shows the fleet forecast distribution by TEU capacity for selected years. The PPX Gen3 Max is included in the PPX Gen 3 percentages.

Table 14: Forecasted TEU Calling Capacity

	2020 (actual)	2030	2040
Sub Panamax	1%	0%	0%
Panamax	16%	6%	6%
PPX Gen 1	22%	14%	8%
PPX Gen 2	32%	43%	31%
PPX Gen 3	29%	37%	55%

5. Transportation Cost Savings Benefit Analysis

The study compares the benefits and costs of the Seagirt Loop channel deepening up to five feet in one-foot increments for containership transit at Baltimore. Analysis follows evaluation procedures for navigation studies outlined in Engineer Regulation 1105-2-100 (ER 1105-2-100).

Section 5.1. describes the methodology used to estimate benefits of the proposed channel improvements at Baltimore. National economic development (NED) benefits were estimated based on the expected transportation cost reduction associated with each project alternative. 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 vessels call forecast at each channel depth. This vessel call list is run through the HMST to calculate transportation costs for each alternative.

Section **5.3.** summarizes the transportation cost analysis for each alternative and provides the benefit-cost summary for the initial economic evaluation prior to the Tentatively Selected Plan Milestone (Section **5.3.1.**) and final economic evaluation and plan optimization (Section Error! Reference source not found.).

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 load cargo more efficiently on vessels calling Baltimore. 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.

Model inputs include 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 Baltimore'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 (to another dock or to leave 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 tonnage, value, and allocated cost for imports and exports. 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 Port of Baltimore 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 Baltimore 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 Baltimore study. The base year for evaluation is 2028. Model runs were performed for 2028 and 2040 since the cargo forecast meeting terminal capacity around 2040. Benefits are interpolated between the 2028 and 2040 model results and held constant from 2040 through 2077. Each model run consisted of 30 iterations. Importantly, the moving average of vessel time in system does not deviate by more than 1 percent by the 30th iteration.

Physical and Descriptive Harbor Characteristics. These data inputs include the specific transportation network of the Port of Baltimore such as the node location and type, reach length, width, and depth, in addition to tide 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.

General Information. General information used as inputs to the model include specific vessel and commodity classes, route groups (**Table 15**), commodity transfer rates at each dock (**Table 16**), specifications of turning area usage at each dock, and specifications of anchorage use within the harbor.

The primary route groups expected to benefit from channel deepening are the East Asia to US Coast and Mediterranean and Northern Europe routes. **Section 2.4.** describes the carriers and trade lanes included in this analysis. 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. Routes that were unlikely to benefit from channel deepening were assigned to the default route.

Table 15: HarborSym Route Groups

Route	Description	Total Sea Distance		
		Minimum	*Most Likely*	*Maximum*
EA-SUEZ-ECUS	East Asia-Suez Canal-East Coast US	18,000	19,000	20,000
MED-NEU	Mediterranean & Northern Europe - East Coast US	7,000	10,000	12,000
Default	All Other Routes	0	0	0

Table 16: HarborSym Commodity Transfer Rates for Containers (units per hour)

Dock Name	*Minimum*	*Most Likely*	*Maximum*
Seagirt Marine Terminal	800	900	1,000

Vessel Speeds and Operations. The speed at which vessels operate in the harbor, by vessel class both loaded and light loaded, were estimated for each channel segment. Hourly operating costs while in-port and at-sea were determined for foreign flagged containerized vessels. Sailing speeds at-sea were also determined and are based on service speeds and operating expenses obtained from Economic Guidance Memorandum (EGM) 20-04 (dated 23 June 2020), Deep-Draft Vessel Operating Costs FY 2019. 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 17** 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 17: Containerized Vessel Operations

Vessel Class	Speed at Sea (knots)		
	Minimum	*Most Likely*	*Maximum*
Panamax	19	20	21
Post-Panamax 1	20	21	22
Post-Panamax 2	20	21	22
Post-Panamax 3	20	21	22
Post-Panamax 3-Max	20	21	22

Table 18 presents typical maximum sailing drafts by alternative channel depth incorporating underkeel clearance.

Table 18: Sailing Drafts per Alternative Depth

Alternative Depth	Sailing Draft
-46 feet MLLW	-43.5 feet
-47 feet MLLW	-44.5 feet
-48 feet MLLW	-45.5 feet
-49 feet MLWW	-46.5 feet
-50 feet MLLW	-47.5 feet

Vessel Calls. The vessel call list consists of forecasted vessel calls for a given year as generated by the CLT. 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). 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.

$$\begin{gathered} \textit{Vessel operating cost per } 1000 \textit{ miles is calculated as } 1000 \textit{ miles divided by the applied speed} \\ \textit{times the hourly at sea cost} \\ = (\,1000 \textit{ miles } / \textit{ Applied Speed}) \; X \textit{ Hourly Cost} \end{gathered}$$

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

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

Shares of vessel capacity are then calculated as:

$$\begin{aligned} &\textit{Cargo Share} = \textit{Average Lading Weight per Loaded TEU by Route (tonnes)} \\ &\qquad /\textit{Total weight per loaded container in tonnes} \\ &\textit{Laden Container Share} \\ &\qquad = \textit{Average Container (Box only) Weight per TEU (tonnes)} \\ &\qquad /\textit{Total weight per loaded container in tonnes} \\ &\textit{Empty Container Share} \\ &\qquad = ((\textit{Average Container (Box only) Weight per TEU (tonnes)}) \\ &\qquad * (\textit{Percent Empty TEUs})) \; / \; \textit{Total weight per loaded container in tonnes}) \end{aligned}$$

Volume capacity limits are calculated as follows:

$$\begin{gathered} \textit{Number of vacant slots} = \textit{Nominal TEU Rating} * \textit{Percent vacant slots} \\ \textit{Max Occupied Slots} = \textit{Nominal TEU Rating} - \textit{Number of vacant slots} \\ \textit{Max Laden TEUs} = \textit{Occupied Slots}/(1 + \textit{Percent Empties}) \\ \textit{Max Empty TEUs} = \textit{Occupied Slots} - \textit{Laden TEUs} \end{gathered}$$

Maximum Volume Restricted Tonnage is then calculated as:

$$\begin{aligned} &\textit{Max weight for cargo (tonnes)} \\ &\qquad = \textit{Max Laden TEUs} * \textit{Average Lading Weight per Loaded TEU by Route (tonnes)} \\ &\textit{Max weight for laden boxes (tonnes)} \\ &\qquad = \textit{Max Laden TEUs} * \textit{Average Container (Box only) Weight per TEU (tonnes)} \\ &\textit{Max weight for empties(tonnes)} \\ &\qquad = \textit{Max Empty TEUs} * \textit{Average Container (Box only) Weight per TEU (tonnes)} \\ &\textit{Total volume restricted tonnage (cubed out tonnage)(tonnes)} \\ &\qquad = \textit{Max weight for cargo} + \textit{Max weight for laden boxes} + \textit{Max weight for empties} \end{aligned}$$

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.

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

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

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

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

$$\begin{aligned}Available\ for\ Cargo&\\&= (DWT\ Available\ for\ Vessel\ Draft) - (Approximate\ Variable\ Ballast)\\&- (Allowance\ for\ Operations)\end{aligned}$$

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

$$\begin{aligned}&Available\ for\ Cargo\ adjusted\ for\ volume\ restriction\ if\ any\ (tonnes)\\&= the\ lesser\ of\ Available\ for\ Cargo\ and\ Total\ volume\ restricted\ tonnage\ (cubed\ out\ tonnage)\end{aligned}$$

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

$$\begin{aligned}Distribution\ of\ Space\ Available\ for\ Cargo\ (tonnes)&\\&= Available\ for\ Cargo\ adjusted\ for\ volume\ restriction\ if\ any\ in\ tonnes\\&* Cargo\ Share\ in\ percent\end{aligned}$$

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

$$\begin{aligned}Distribution\ of\ Space\ Available\ for\ Empty\ TEUs\ (tonnes)&\\&= Available\ for\ Cargo\ adjusted\ for\ volume\ restriction\ if\ any\\&* Empty\ Container\ Share\end{aligned}$$

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

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

$$\begin{aligned}Number\ Empty\ TEUs&\\&= Distribution\ of\ Space\ Available\ for\ Empty\ TEUs\\&/Average\ Container\ (Box\ only)\ Weight\ per\ TEU\ (tonnes)\end{aligned}$$

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

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

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, vessel fleet forecast, 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 CDFs for PPX2 (**Figure 11**) and PPX3 (**Figure 12**) vessels were developed by evaluating the arrival drafts of the container class vessels calling on the harbor from 2018 to 2020. Since the vessels using SMT benefit on the outbound transit, CDFs were developed for departure drafts as well.

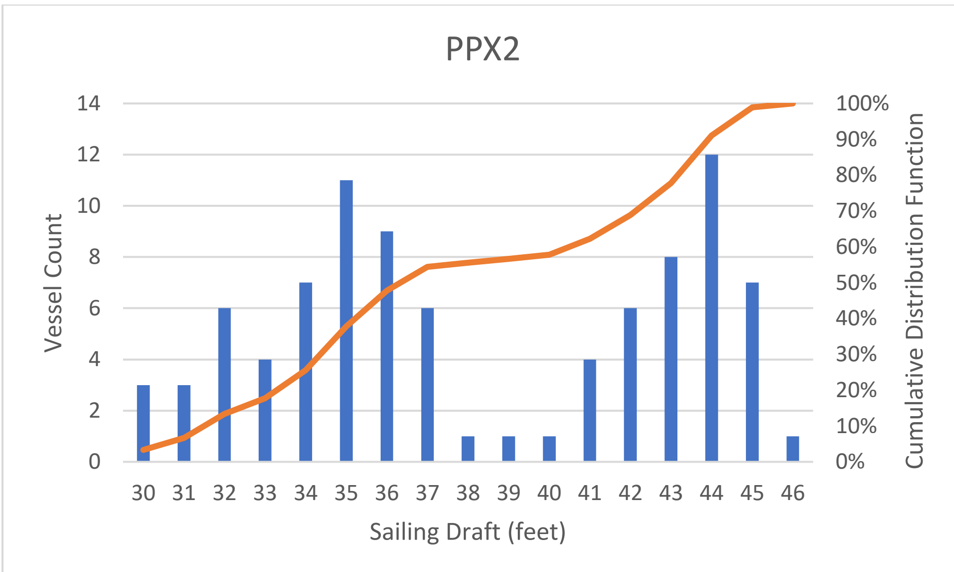


Figure 11: PPX2 Arrival Draft Cumulative Distribution Function

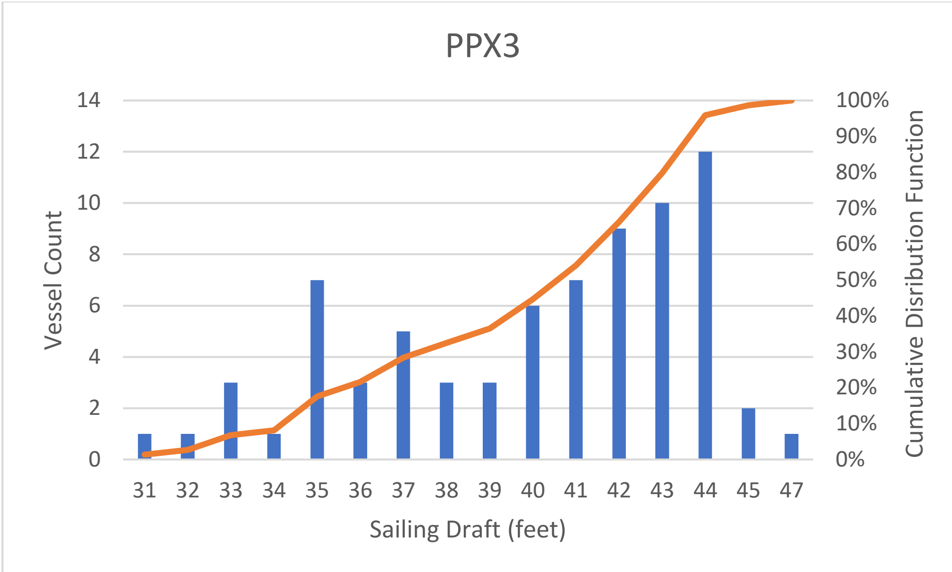


Figure 12: PPX3 Arrival Draft Cumulative Distribution Function

5.1.5. Load Factor Analysis

Table 19 provides the vessel class assumptions used in the load factor analysis (LFA)[1], 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 cargo data at Port of Baltimore from 2017 through 2020. The study assumes this cargo share will remain constant through the study period.

[1] LFA accounts for the components that determine vessel draft. Analysis primarily based loading assumptions on historical vessel loading conditions by vessel class and trade route to estimate future vessel draft conditions.

Table 19: 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
Default	PX	9.8	8.7%	5%	7.1%	14.9%	.30/.15
	PPX1	9.8	8.7%	5%	7.1%	14.9%	.25/.25
	PPX2	9.8	8.7%	5%	7.1%	14.9%	.25/.25
	PPX3	9.8	8.7%	5%	7.1%	14.9%	.23/.2
	PPX3 Max	9.8	8.7%	5%	7.1%	14.9%	.23/.2
FE (Suez Canal)	PPX2	9.8	8.7%	5%	7.1%	14.9%	.25/.25
	PPX3	9.8	8.7%	5%	7.1%	14.9%	.25/.25
	PPX3 Max	9.8	8.7%	5%	7.1%	14.9%	.23/.2
MED NEU	PX	9.8	8.7%	5%	7.1%	14.9%	.30/.15
	PPX1	9.8	8.7%	5%	7.1%	14.9%	.25/.25
	PPX2	9.8	8.7%	5%	7.1%	14.9%	.25/.25
	PPX3	9.8	8.7%	5%	7.1%	14.9%	.23/.2
	PPX3 Max	9.8	8.7%	5%	7.1%	14.9%	.23/.2

*Container weight assumed to be 2.2 metric tons per TEU

5.2. Containerized Vessel Calls

Vessel calls by vessel class for Port of Baltimore SMT are shown in **Table 20**. These are a result of the CLT loading algorithm, the containerized trade forecast for Port of Baltimore, the available vessel fleet by service, and the LFA data inputs.

Table 20: Average Vessel Calls by Vessel Class and Channel Depth

Vessel Class	FWOP	FWP
2030		
Panamax Containership	40	40
PPX Gen1 Containership	99	99
PPX Gen2 Containership	257	252
PPX Gen3 Containership	149	139
PPX Gen3 Max Containership	9	19
Total	**554**	**549**
2040		
Panamax Containership	45	45
PPX Gen1 Containership	77	77
PPX Gen2 Containership	286	281
PPX Gen3 Containership	286	273
PPX Gen3 Max Containership	12	25
Total	**706**	**701**

5.3. Alternatives Benefit Evaluation

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. An abbreviated summary of analysis presented at the Tentatively Selected Plan Milestone is provided in Section **5.3.1.** Section **Error! Reference source not found.**presents detailed plan optimization and the final benefit-cost analysis.

5.3.1. Initial Alternatives Evaluation

The initial alternatives evaluation estimates transportation costs for a 50-year period of analysis. Initial analysis assumed a planning horizon from 2030 through 2079. This was subsequently updated in the final alternatives evaluation to 2028 through 2077 (Section 5.3.2.) The economic evaluation uses HarborSym models for years 2030 and 2040, interpolates transportation costs for intermediate years, and holds transportation costs constant past 2040. Transportation costs were annualized to determine AAEQ costs and savings by discounting the cost stream to base year 2030 at the FY 2022 federal discount rate of 2.25 percent.

A “tipping point” was established for estimating at what point carriers will shift the fleet to larger, PPX3 and PPX4 vessels. The tipping point is assumed to be a departing sailing draft of -44.5 feet MLLW which equates to a -47 feet MLLW channel depth when including UKC. This is based on analysis of services like those calling Baltimore Harbor which deploy PPX3 and PPX4 vessels. Analysis revealed the most common departure draft was between 44 and 45 feet, which would require -47 feet MLLW depth at Baltimore Harbor.

Initial evaluation assumes Berths 1-2 would be deepened to -50 feet MLLW in the FWOP. As a result, carriers would transition to larger vessels and use the -50 feet MLLW berth depth once channel depth reached the “tipping point.” This led to origin destination benefits being fully realized at the -47 feet MLLW channel depth. All other depths realize in-harbor delay reduction benefits only. **Table 21** summarizes the benefit categories used for the initial analysis of Seagirt Loop deepening.

Table 21: Initial Seagirt Loop Benefit Types

Seagirt Loop Depth Alternative	Benefit Type
-46 feet MLLW	In-harbor delay reduction benefits
-47 feet MLLW	Origin to destination (OD) use of larger vessels benefits
-48 feet MLLW	In-harbor delay reduction benefits
-49 feet MLLW	In-harbor delay reduction benefits
-50 feet MLLW	In-harbor delay reduction benefits

Based on the initial alternatives evaluation, alternative depths of -47 feet MLLW through -50 feet MLLW realized similar net benefits based. ER 1105-2-100 Appendix G states that “where two cost effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of output may be less.” As a result, the NED plan at the Tentatively Selected Plan Milestone was identified as -47 feet MLLW.

5.3.2. Final Alternatives Evaluation

In the initial modeling runs, the FWOP condition assumed that Seagirt Marine Terminal Berths 1-2 were deepened to -50 feet MLLW by the non-Federal sponsor regardless of channel depths associated with the deepening and widening of WSBC. Following initial modeling and discussions with the non-Federal sponsor, the PDT agreed that the design vessel would be constrained from using Berth 1-2 as a -50-feet MLLW berth without consistent depth in the access channel, therefore, the Port would not deepen Berths 1-2 beyond the federal channel depth. Analysis conducted after the Tentatively Selected Plan Milestone assumed the depth of Berths 1 and 2 would remain consistent with the federal channel depth. This change led to incremental origin to destination benefits in all alternative depths in addition to in-port delay benefits included in the previous model. Vessels would also be able to use the loop channel for both inbound and outbound traffic to access all berths as is anticipated to occur during normal Port operations[2]. Benefit type by channel depth is summarized in **Table 22**.

Table 22: Final Benefit Type by Channel Depth

Seagirt Loop Depth Alternative	Benefit Type
-46 feet MLLW	In-harbor and Origin to Destination benefits
-47 feet MLLW	In-harbor and Origin to Destination benefits
-48 feet MLLW	In-harbor and Origin to Destination benefits
-49 feet MLLW	In-harbor and Origin to Destination benefits
-50 feet MLLW	In-harbor and Origin to Destination benefits

The final economic analysis uses an updated Base Year of 2028 and performed HarborSym modeling for 2028 and 2040. The study interpolates transportation costs for intermediate years and holds transportation costs constant past 2040. Transportation costs were annualized to determine AAEQ costs and savings by discounting the cost stream to the base year at the FY 2023 federal discount rate of 2.5 percent.

Table 23 shows the annual transportation costs for the Seagirt Loop channel depth alternatives of -46 feet MLLW, -47 feet MLLW, -48 feet MLLW, -49 feet MLLW and -50 feet MLLW. The -46 feet MLLW alternative depth uses the FWOP call list prior to the design vessel calling more frequently. The design vessel calls more frequently for any alternative deeper than -46 feet MLLW.

[2] See Section 4.11 of the Main Report for additional detail.

Table 23: Final Annual Transportation Costs ($1,000s)

Total Transportation Cost Allocated to Port						
Year	FWOP	-46ft MLLW	-47ft MLLW	-48ft MLLW	-49ft MLLW	-50ft MLLW
2028	$66,056	$63,711	$59,323	$58,166	$57,008	$55,851
2040	$96,642	$93,970	$85,194	$84,072	$82,952	$81,830
In-Port Transportation Cost Allocated to Port						
Year	FWOP	-46ft MLLW	-47ft MLLW	-48ft MLLW	-49ft MLLW	-50ft MLLW
2028	$11,283	$11,334	$11,570	$11,625	$11,680	$11,735
2040	$17,209	$17,277	$17,624	$17,657	$17,691	$17,724
At-Sea Transportation Cost Allocated to Port						
Year	FWOP	-46ft MLLW	-47ft MLLW	-48ft MLLW	-49ft MLLW	-50ft MLLW
2028	$54,772	$52,337	$47,753	$46,541	$45,328	$44,116
2040	$79,433	$76,693	$67,570	$66,415	$65,261	$64,106

Table 24 presents transportation costs savings by channel depth. As shown, benefits primarily come from origin-destination transportation cost savings. While individual vessels realize in-port cost savings in each alternative, these benefits are outweighed by the increased operating costs of transitioning to larger vessels.

Table 24: Final Annual Transportation Cost Savings Benefits ($1,000s)

Total Cost Savings					
Year	-46ft MLLW	-47ft MLLW	-48ft MLLW	-49ft MLLW	-50ft MLLW
2028	$2,344	$6,733	$7,890	$9,048	$10,205
2040	$2,672	$11,448	$12,569	$13,691	$14,812
In-Port Cost Savings					
Year	-46ft MLLW	-47ft MLLW	-48ft MLLW	-49ft MLLW	-50ft MLLW
2028	-$50	-$286	-$341	-$396	-$451
2040	-$68	-$414	-$448	-$481	-$515
At-Sea Cost Savings					
Year	-46ft MLLW	-47ft MLLW	-48ft MLLW	-49ft MLLW	-50ft MLLW
2028	$2,395	$7,019	$8,231	$9,444	$10,656
2040	$2,740	$11,863	$13,018	$14,172	$15,327

Table 25 provides the AAEQ transportation costs and cost savings by channel depth for deepening the Seagirt Loop.

Table 25: Final AAEQ Transportation Cost Savings by Alternative Depth

Alternative	AAEQ Transportation Cost Savings/Benefits
-46FT MLLW	$2,605,000
-47FT MLLW	$10,483,000
-48FT MLLW	$11,612,000
-49FT MLLW	$12,740,000
-50FT MLLW	$13,869,000
FY23 discount rate	

Table 26 presents the final alternative costs at current price levels (October 2022). Total economic costs used for alternatives comparison includes project costs, associated costs, operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs, and interest during construction (IDC). IDC represents the cost of foregone opportunity to invest the funds used for project implementation. The hypothetical return for another investment, measured as IDC at the current Fiscal Year discount rate, is an NED cost. The project assumes a construction duration over three calendar years for the IDC calculation and uses the IWR Planning Suite II tool for final calculation of annualized costs.

Table 26: Final Alternatives Costs (October 2022 Price Level, 2.5% Discount Rate)

Depth*	Project First Costs	IDC	Total Econ. Costs	AAEQ Total Investment	AAEQ OMRR&R	Total AAEQ Costs
-46FT MLLW	$64,082,000	$894,000	$64,976,000	$2,291,000	$25,000	$2,316,000
-47FT MLLW	$75,674,000	$1,168,000	$76,842,000	$2,709,000	$25,000	$2,735,000
-48FT MLLW	$80,735,000	$1,284,000	$82,019,000	$2,892,000	$25,000	$2,917,000
-49FT MLLW	$85,953,000	$1,402,000	$87,355,000	$3,080,000	$25,000	$3,105,000
-50FT MLLW	$91,273,000	$1,371,000	$92,644,000	$3,266,000	$25,000	$3,292,000

*Reflects authorized depth. Costs include estimated 2 feet of overdepth dredging.

The study team compared benefits and costs at each alternative depth to determine the Seagirt Loop depth with the highest net benefits. **Table 27** summarizes the results of the benefit cost analysis. As shown, the change in assumptions incorporated into the final benefit-cost analysis results in an NED plan of -50FT MLLW. The study does not evaluate alternatives deeper than -50FT MLLW at the request of the Non-Federal Sponsor. Per ER 1105-2-100, it is not required to analyze project plans deeper than the plan desired by the sponsor. There may be additional benefits for deepening beyond -50FT MLLW; however, incremental benefits are likely significant less than the increase in cost associated with deepening beyond the -50 feet MLLW alternative[3].

Table 27: Benefit-Cost Summary (October 2022 Price Level, 2.5% Discount Rate)

Depth	Total AAEQ Costs	Total AAEQ Benefits	Total Net Benefits	Benefit/Cost Ratio
-46FT MLLW	$2,316,000	$2,605,000	$289,000	1.12
-47FT MLLW	$2,735,000	$10,483,000	$7,748,000	3.83
-48FT MLLW	$2,917,000	$11,612,000	$8,695,000	3.98
-49FT MLLW	$3,105,000	$12,740,000	$9,635,000	4.10
-50FT MLLW	$3,292,000	$13,869,000	$10,577,000	4.21

6. Socioeconomics

This section will 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 13 provides a map of the 7 counties and jurisdiction given consideration for this analysis within the Baltimore-Columbia-Towson, MD Metropolitan Statistical Area (MSA): Anne Arundel, Baltimore, Carroll, Harford, Howard, Queen Anne’s Counties and Baltimore City.

[3] Per conversation with MDOT MPA, the non-federal sponsor does not see a need to evaluate deepening the Seagirt Loop beyond 50-feet with allowable overdepth. A 50-foot draft with allowable overdepth would accommodate the largest vessels able to call at the Port of Baltimore considering current Air Draft Clearance constraints and limitations posed by the existing 50-foot depth of the approach channels leading into the Port of Baltimore and the Seagirt Loop Channel.

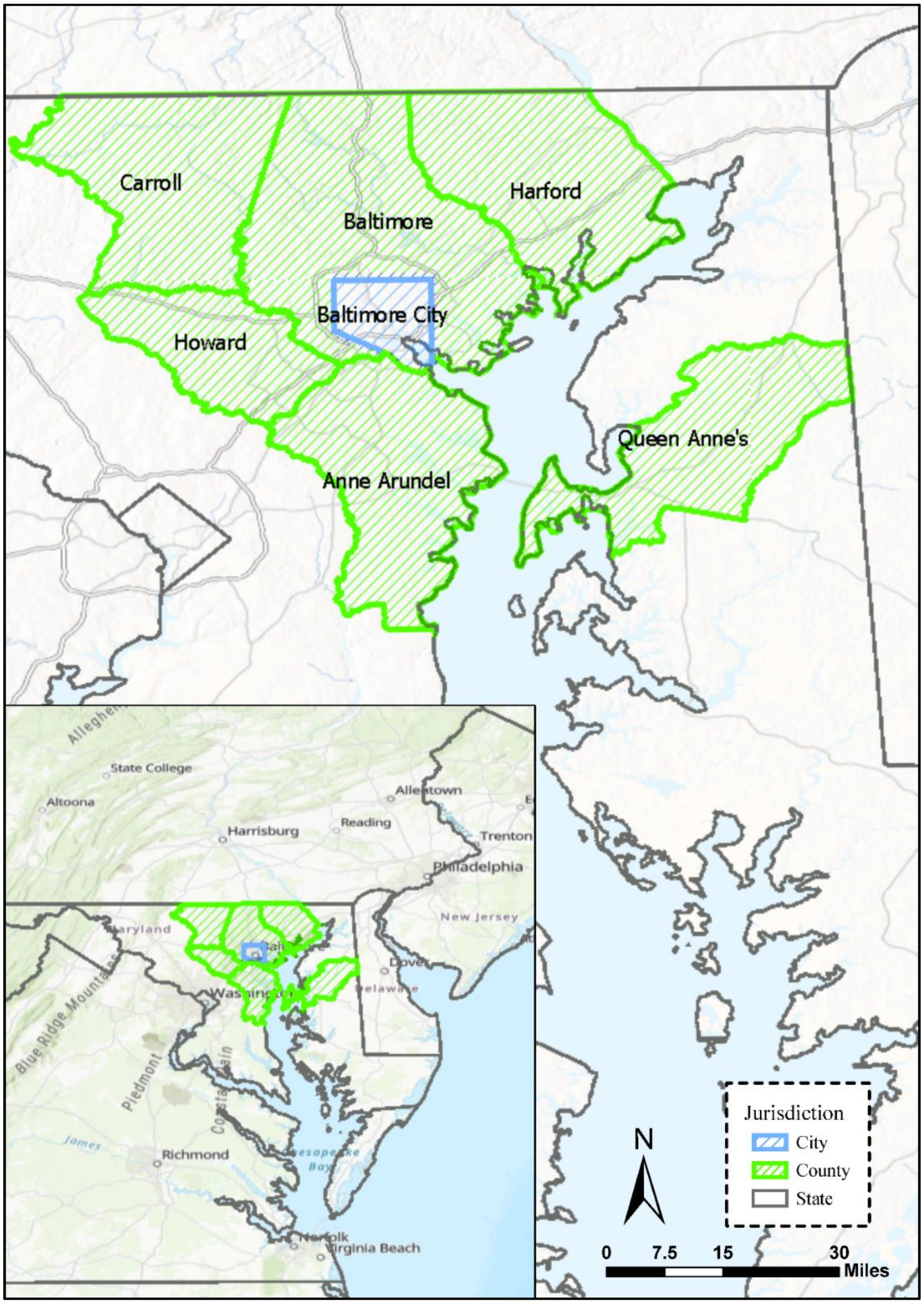


Figure 13: Regional Economic Impact Area

6.1. 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.

6.1.1. Population

Located in Maryland, the Baltimore-Columbia-Towson MSA is estimated in 2019 to have population of 2,800,000. 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, Baltimore-Columbia-Towson MSA's population increased by 0.3 percent. This growth rate was approximately one-half the national growth rate and the average growth rate of all MSAs over the same period (**Table 28**).

Table 28: Study Area Population Growth (2010 - 2019)

Geographic Area	Population		Compound Annual Growth Rate (2010-2019)
	2010	2019	
Baltimore-Columbia-Towson MSA	2,716,000	2,800,000	0.3%
Maryland	5,774,000	6,046,000	0.5%
All US MSAs	**263,660,000**	**282,829,000**	**0.8%**
United States	**309,322,000**	**328,240,000**	**0.7%**

Source: 2019 American Community Survey, Census Bureau

6.1.2. Employment and Income

Estimated employment in 2019 totaled 1,426,000. **Table 29** presents employment by sector at the latest available year, 2018. Total employment in 2018 for the Baltimore-Columbia-Towson MSA was 1,196,000. The largest sector by number of employees was NAICS Sector 62: Health Care and Social Assistance with 11,083,000 employees. Retail Trade was the next largest sector in 2018 (140,000 employees) followed by Professional, Scientific, and Technical Services (136,000 employees), and Accommodation and Food Services (120,000 employees).

Table 29: 2017 Employment and Income by Sector

NAICS		Annual Payroll ($1,000)	Number of Employees
11	Agriculture, forestry, fishing, and hunting	$18,000	388
21	Mining, quarrying, and oil and gas extraction	$52,000	735
22	Utilities	$793,000	5,870
23	Construction	$4,625,000	72,221
31-33	Manufacturing	$3,772,000	55,232
42	Wholesale trade	$3,676,000	51,994
44-45	Retail trade	$4,031,000	139,801
48-49	Transportation and warehousing	$2,449,000	44,598
51	Information	$1,914,000	22,638
52	Finance and insurance	$6,051,000	56,356
53	Real estate and rental and leasing	$1,401,000	22,658
54	Professional, scientific, and technical services	$13,198,000	135,861
55	Management of companies and enterprises	$3,063,000	33,181

NAICS		Annual Payroll ($1,000)	Number of Employees
56	Administrative and support and waste management and remediation services	$3,472,000	82,751
61	Educational services	$3,295,000	60,348
62	Health care and social assistance	$11,083,000	210,085
71	Arts, entertainment, and recreation	$950,000	24,361
72	Accommodation and food services	$2,452,000	120,422
81	Other services (except public administration)	$2,029,000	56,300
99	Industries not classified	$2,000	41
0	**Total for all sectors**	**$68,328,000**	**1,195,841**

Median household incomes for Baltimore-Columbia-Towson MSA in 2019 are shown in **Table 30**. The MSA median household income is 27 percent above the national median.

Table 30: Median Income in Study Area (2019)

Geographic Area	2019 Median Household Income	% National Median Income
Baltimore-Columbia-Towson MSA	83,160	127%
Maryland	86,738	132%
United States	**65,712**	**100%**

Source: 2019 American Community Survey, Census Bureau

The estimated unemployment rate for the Baltimore-Columbia-Towson MSA was 2.9 percent in 2019, same as the national average. State unemployment level for Maryland is 0.1 percent higher than the MSA and national average. **Table 31** provides the estimated 2019 unemployment rate for the study area.

Table 31: 2019 Unemployment Rate in Study Area

Geographic Area	Unemployment Rate, 2019
Baltimore-Columbia-Towson MSA	2.9%
Maryland	3.0%
United States	**2.9%**

Source: 2019 American Community Survey, Census Bureau

6.1.3. Racial Composition

Baltimore-Columbia-Towson MSA has a higher minority population than the national average but less than Maryland. Black or African American is the single largest minority population in the MSA comprising approximately 30 percent of the MSA. Additionally, 6 percent of the MSA identifies as Hispanic or Latino compared with 18 percent nationally and 11 percent for the state (**Table 32**).

Table 32: 2019 Racial Composition of Study Area (Population in Thousands)

Race	Baltimore-Columbia-Towson MSA		Maryland		United States	
	Pop.	%	Pop.	%	Pop.	%
White	1,659	59%	3,297	55%	236,475	72%
Black or African American	832	30%	1,830	30%	41,990	13%
American Indian and Alaska Native	8	0%	19	0%	2,847	1%
Asian	159	6%	386	6%	18,637	6%
Native Hawaiian and Other Pacific Islander	1	0%	2	0%	629	0%
Some other race	50	2%	305	5%	16,353	5%
Two or more races	90	3%	206	3%	11,309	3%
All races	**2,800**	**100%**	**6,046**	**100%**	**328,240**	**100%**

Source: 2019 American Community Survey, Census Bureau

6.1.4. Age Distribution

The age characteristics of the MSA are shown in **Table 33**. As of 2019, the MSA has lower median age than the state of Maryland. The median age is 0.1 years higher than the national median.

Table 33: 2019 Age Distribution in Study Area (Population in Thousands)

Age	Baltimore-Columbia-Towson MSA		Maryland		United States	
	Pop.	%	Pop.	%	Pop.	%
Under 18	610	22%	1,332	22%	72,968	22%
18-64	1,745	62%	3,754	62%	201,198	61%
65 and over	446	16%	960	16%	54,074	16%
Median Age	38.6	-	39.0	-	38.5	**-**

Source: 2019 American Community Survey, Census Bureau

6.1.5. Income and Poverty

The US Census Bureau American Community Survey income and poverty data for the Baltimore-Columbia-Towson MSA are summarized in **Table 34**. Around 9 percent of the MSA is determined to be poverty status, approximately 3 percent below the national average.

Table 34: Regional Income and Poverty in Study Area

Regional Income and Poverty Data	Baltimore-Columbia-Towson MSA	Maryland	United States
Median Household Income	$83,160	$ 86,738	$65,712
Population Below Poverty Level	258,075	532,241	39,490,096
Percent of Population Below Poverty Level	9.4%	9.0%	12.3%

Source: 2019 American Community Survey, Census Bureau

For full evaluation of Other Social Effects of the recommended plan, see Section 4 of the Main Report and Section 8.3 of this Appendix.

7. Risk and Uncertainty Analysis

The study team assumes the cargo and fleet forecast scenario presented in Section 5 is the most likely future condition at Baltimore Harbor over the 50-year period of analysis. The team recognizes the uncertainty in long-term forecasting, especially in the maritime transportation industry. Consistent with the Principles and Guidelines (P&G) and subsequent Engineering Regulation (ER) 1105-2-100, this section characterizes, to the extent possible, the degree of risk and uncertainty in plan selection.

7.1. Key Uncertainties

The primary uncertainty associated with evaluation and comparison of alternatives for the study are related to the cargo growth forecast and fleet transition. The cargo forecast is used to estimate total traffic volume required per model year. Cargo volume tends to impact the magnitude of benefits across all alternative depths. The fleet transition estimates the mix of vessels anticipated to call over the period of analysis. Faster fleet transition indicates more frequent use of large vessels. This typically leads to higher transportation costs and inefficiencies associated with the existing channel depth. Fleet transition tends to impact both the magnitude of benefits across alternative depths and the relative difference in benefits between alternatives. As a result, fleet transition assumptions typically involve higher risk for plan selection.

7.1.1. Cargo Uncertainty

The cargo forecast is a key input to alternatives evaluation. Higher cargo volume is positively related with the forecasted total vessel calls over the study period. Section 5 indicates a high probability that all alternative depths are economically justified. Consequently, risk is higher in low cargo volume growth scenarios. To assess the risk associated with this uncertainty, the study team modeled a no cargo growth scenario holding cargo volumes consistent from the base year through the end of the period of analysis. The resulting benefit-cost summary is presented in **Table 35**. As shown, the impact of low cargo growth is unlikely to jeopardize project justification. Additionally, the relative difference between plans in the “no-growth” scenario is relatively constant. The depth which maximizes net benefits is in bold.

Table 35: No Cargo Growth Scenario Benefit Cost Summary[4]

Alternative	AAEQ Cost	AAEQ Benefit	Net Benefit	BCR
-46FT MLLW	$2,316,000	$2,344,000	$28,000	1.01
-47FT MLLW	$2,735,000	$6,733,000	$3,998,000	2.46
*-48FT MLLW**	$2,917,000	$7,890,333	$4,973,333	2.70
*-49FT MLLW**	$3,105,000	$9,047,667	$5,942,667	2.91
-50FT MLLW	**$3,292,000**	**$10,205,000**	**$6,913,000**	**3.10**

*Interpolation

7.1.2. Fleet Transition Uncertainty

Vessel deployment hinges on the operational, tactical, and strategic planning decisions of carriers. As a result, estimating fleet transition over the period of analysis involves significant uncertainty. Fleet transition tends to be a highly influential input to alternatives evaluation and comparison. Faster transition to larger vessels is positively related to total project benefits: as carriers deploy larger vessels, there is more opportunity to capitalize on economies of scale afforded by deeper channel depths.

The NED plan is already the maximum channel depth in the alternatives array. As a result, there is low probability that faster fleet transition to larger vessels will impact plan selection. To assess the risk of slower fleet transitions, the study models two low-growth

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[4] The study does not evaluate alternatives deeper than -50FT MLLW at the request of the Non-Federal Sponsor. Per ER 1105-2-100, it is not required to analyze project plans deeper than the plan desired by the sponsor. There may be additional benefits for deepening beyond -50FT MLLW, however, cost likely increase significantly.”

fleet scenarios. The first assumes no fleet transition past the base year and limits the PPX3-max portion of all PPX3 vessels to 10 percent. This is based on the PPX3-max composition of comparable services currently calling the US East Coast. Similar services operated by the same carrier already call Baltimore Harbor; therefore, this is seen as a reasonable minimum fleet transition scenario. **Table 36** presents the results of this scenario. As shown, -50 feet MLLW remains the NED plan and is economically justified. In this scenario, the -47 feet alternative is not justified.

Table 36: Low PPX3-Max Transition Scenario

Alternative	AAEQ Cost	AAEQ Benefit	Net Benefit	BCR
-46FT MLLW	$2,316,000	$2,344,000	$28,000	1.01
-47FT MLLW	$2,735,000	$2,049,000	$(686,000)	0.75
*-48FT MLLW**	$2,917,000	$3,614,000	$697,000	1.24
*-49FT MLLW**	$3,105,000	$5,179,000	$2,074,000	1.67
-50FT MLLW	**$3,292,000**	**$6,744,000**	**$3,452,000**	**2.05**

*Interpolation

The second fleet transition scenario compares alternatives assuming no transition to PPX3-max vessels. This scenario could result from overly burdensome constraints placed on the PPX3-max class resulting from issues like overhead clearance, maneuvering issues, or excessive delay costs associated with the larger vessel. The result indicates the NED depth remains at -50 feet MLLW (**Table 37**).

Table 37: No PPX3-Max Transition

Alternative	AAEQ Cost	AAEQ Benefit	Net Benefit	BCR
-46FT MLLW	$2,316,000	$2,344,000	$28,000	1.01
-47FT MLLW	$2,735,000	$1,619,000	$(1,116,000)	0.59
*-48FT MLLW**	$2,917,000	$3,120,000	$203,000	1.07
*-49FT MLLW**	$3,105,000	$4,621,000	$1,516,000	1.49
-50FT MLLW	**$3,292,000**	**$6,122,000**	**$2,830,000**	**1.86**

*Interpolation

7.2. Risk Assessment

In each scenario presented, the NED depth remains at -50 feet MLLW. This indicates relatively low risk to project justification and plan selection associated with alternative cargo and fleet growth scenarios. Importantly, the analysis also indicates that benefits realized from channel deepening far outweigh the importance of fleet transition.

8. Four Planning Accounts

Four accounts are established to facilitate evaluation and display of effects of alternative plans. The four accounts include the national economic development (NED), environmental quality (EQ), the regional economic development (RED), and the other social effects (OSE) account. The NED account was first evaluated and presented in Sections 1 through 5.

8.1. Environmental Quality

The PDT also evaluated differences in the EQ for the alternative plans. The results of the EQ evaluation are summarized for the No Action Alternative and NED Plan in Table 38. The plan remains within regulatory thresholds and require no mitigation actions. The primary environmental quality concerns are related to minor impacts resulting from increases in air quality emissions including pollutants of concern and GHG during construction, minor impacts in noise during construction, and potential impacts on air quality and noise to Environmental Justice communities adjacent to the Port facilities. There are also minor impacts associated with turbidity during construction and aesthetic/viewshed impacts from larger vessels calling at the Port from Fort McHenry and two National Scenic/Historic Trails. More information on the EQ analysis is included in **Table 38** and Section 6 of the Main Report.

Table 38: Summary of EQ Impacts

RESOURCE	NO ACTION	NED PLAN
Environmental Justice	Temporary, Negligible to Minor	Temporary, Negligible to Minor
Topography and Bathymetry	Permanent, Negligible to Minor	Permanent, Minor
Geology, Soils, and Sediments	No Effect	No Effect
Water Resources and Water Quality	Temporary, Negligible to Minor	Temporary to Permanent, Minor
Essential Fish Habitat	Temporary, Negligible to Minor	Temporary, Minor
Fish and Wildlife	Temporary, Negligible to Minor	Temporary, Minor
Benthic Fauna	Temporary, Minor	Temporary, Minor
Threatened and Endangered Species	Temporary, Insignificant	Temporary, Insignificant
Cultural Resources	No Effect	Permanent, Minor
Recreation	Temporary, Negligible	Temporary, Negligible to Minor
Aesthetics and Scenic Resources	No Effect	Permanent, Negligible to Minor
Hazardous, Toxic, and Radioactive Waste	Temporary, Minor	Temporary, Minor
Air Quality	No Effect	Temporary, Minor
Greenhouse Gases (GHG)	No Effect	Temporary, Negligible
Noise and Vibration	No Effect	Temporary, Minor

8.2. Regional Economic Development (RED) Benefits

The U.S. Army Corps of Engineers (USACE) Institute for Water Resources, Louis Berger, and Michigan State University have developed a regional economic impact modeling tool, RECONS (Regional ECONomic System), that provides estimates of jobs and other economic measures such as labor income, value added, and sales that are supported by USACE programs, projects, and activities. This modeling tool automates calculations and generates estimates of jobs, labor income, value added, and sales using IMPLAN®'s multipliers and ratios, customized impact areas for USACE project locations, and customized spending profiles for USACE projects, business lines, and work activities. RECONS allows the USACE to evaluate the regional economic impact and contribution associated with USACE expenditures, activities, and infrastructure. In this section, RED benefits are presented for the -50-foot MLLW alternative.

8.2.1. Channel Depth -50 Feet MLLW

This RED analysis estimates the benefits associated with the recommended plan. Local service facility improvements are the responsibility of the non-federal sponsor and not counted as an RED benefit of the project. Of the total project costs less LSF of $63,942,000, approximately $44.5 million will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the Civil Works expenditures $63,942,000 support a total of 550 full-time equivalent jobs, $46.7 million in labor income, $57.4 million in the gross regional product, and $85.2 million in economic output in the local impact area. More broadly, these expenditures support 870 full-time equivalent jobs, $70.1 million in labor income, $95.6 million in the gross regional product, and $164.1 million in economic output in the nation. **Table 39** summarizes the impacts.

Table 39: Overall Summary of Impacts -50ft MLLW Alternative Depth

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$44,500,000	360.0	$32,700,000	$32,800,000
Secondary Impact		$40,700,000	190.0	$14,100,000	$24,600,000
Total Impact	$44,500,000	$85,200,000	550.0	$46,700,000	$57,400,000
State					
Direct Impact		$44,700,000	380.0	$32,700,000	$32,900,000
Secondary Impact		$41,600,000	200.0	$14,300,000	$25,100,000
Total Impact	$44,700,000	$86,400,000	580.0	$47,000,000	$58,000,000
US					
Direct Impact		$60,800,000	450.0	$37,700,000	$39,600,000
Secondary Impact		$103,300,000	430.0	$32,400,000	$56,000,000
Total Impact	$60,800,000	$164,100,000	870.0	$70,100,000	$95,600,000

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

8.3. Other Social Effects (OSE)

The USACE Institute for Water Resources defines Other Social Effects (OSE) as "how the constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness, are affected by some water resources condition or proposed intervention” (USACE 2013-R-03). This OSE evaluation considers impacts resulting from implementation of the Recommended Plan which is dredging of the WSBC to 50 feet with 2 feet of underkeel and includes wideners developed through consultation with the Association of Maryland Pilots through the ERDC ship simulation where safety concerns were identified in the FWOP condition. The construction is expected to occur across 3 calendar years (2025-2027) and will be completed with minimal direct impact. All dredging work will be conducted from the waterside, including placement into an approved DMCF. No roadwork, bridge modification, or alterations to other public utilities are anticipated, therefore no landside impacts such as increased traffic are anticipated. With or without the proposed project improvements, calls to the Port are projected to increase. However, the improvements to the Seagirt Loop and the movement of cargo using post-Panamax vessels are projected to improve efficiency, with lower cost and environmental impact per metric ton and increased safety. Additionally, other projects including the modernization of the SMT (ongoing) and the Howard Street Tunnel Improvement project (construction initiated in 2021) focus on increased efficiency at the Port. Since the proposed Seagirt dredging project is in part related to a larger effort to improve efficiency and safety at the Port, potential OSE are considered for the cumulative plans, including landside improvements. This assessment finds that, overall, direct project-related impacts would be minor and short-term, while project upgrades and continued community outreach are expected to have a cumulative long-term benefit to the residents of the State of Maryland and the surrounding communities of Baltimore, especially related to economic growth and increased jobs in the region.

This evaluation considers OSE related to the deepening and widening the WSBC as compared to the No Action Alternative (FWOP) and identifies that, as the world fleet transitions to larger class vessels, without improvements to the WSBC which serves the SMT there is the potential for loss of carriers and large draft vessels that would call at the Port which results in a reduction in the associated benefits. The OSE evaluation for the No Action Alternative and the NED Plan is described below and summarized in **Table 40** below.

Vessel Safety and Efficiency

Through the ERDC ship simulation study, Pilots were able to test maneuvers in order to optimize the proposed channel design and assess safety risks. Pilots’ comments and assessments of vessel runs under various scenarios with environmental conditions were captured by ERDC and are included as Appendix B4. ERDC simulated the vessel runs with environmental conditions using an existing hydrodynamic model and simulated winds as the primary hydrodynamic variable in the modeled area. The modeled area has limited influence due to currents, tides, and waves as detailed in Appendix B4. Through this exercise significant reduction in risk related to completion of the loop to 50-feet was identified. Pilots reported that the 50-foot depth under both a light-loaded (44.5-foot draft) and fully-loaded (47.5-foot draft) vessels was preferred because it allowed for a straightforward maneuver, rather than backing out and turning in the turning basin. The use of the turning basin requires heavy reliance on tug assist, extended period of exposure to wind, and a greater potential for allision with berthed vessels. The Pilots' noted that the time it took to complete the turning maneuver versus traversing the loop was double, which also doubled the time the vessel was at risk, maneuvering near other berthed vessels. One Pilot explained that turning a fully-loaded vessel in the basin required all available control mechanisms and any failure point would not be recoverable. They noted that the fully-loaded vessel (47.5' draft) worked four tugs at maximum effort, and likely under these conditions would not be able to recover if there was a tug casualty and that excessive speed was needed to complete the maneuver.

Although 47.5-foot vessels can access SMT Berths 3 and 4 in the FWOP, the reduction in risk of collisions, allisions, and other vessel safety issues are not fully realized since back-out procedures would still need to be conducted on some of the largest, most difficult to maneuver vessels in order to depart from Berth.

The USACE estimated the typical delay time due to the backup maneuver as three hours, but this duration was considered to be an underestimate by two representatives from the Association of Maryland Pilots, who board and conduct (navigate) ships within the Chesapeake Bay. Pilots are in a strong position to estimate the delay due to the backup maneuver because large ships currently back out of the existing 50-foot berth at Seagirt. The two representatives agreed that the estimate of the typical delay to the next ship due to a large ship conducting a backup maneuver was around four hours.

Further, the Pilots noted situations when the delay could be much longer due to wind or mechanical failure on tugboats. When winds are high, pilots must sometimes "cancel" the turning of a large containership due to safety concerns. This type of cancellation would mean that the vessel stays at berth until weather conditions improve, and any incoming vessel holding south of the Bay Bridge cannot proceed until the outgoing vessel departs. An increase in the number of large containerships combined with expected increases in intense storms in the future could correspond to an increase in the number of cancellations and ships waiting south of the Bay Bridge generating a higher annual average wait time per backup maneuver.

A side effect of frequent cancellations could be a perception that using the Port of Baltimore is a risky endeavor, causing shipping lines to choose other routes. Also, delays due to backup maneuvers have the potential to create congestion or inefficiencies as the number of large ships increases.

8.3.1. Health and Safety

Direct impacts of the project on human health due to air quality related to implementation of the Recommended Plan will be temporary and minor and are addressed in section 2.13. The study area is zoned as a Marine Industrial District, formally referred to as the Marine Industrial Zoning Overlay District, which was enacted in 2004 (Baltimore City Ordinance 04-804) to protect Baltimore's maritime industries from pressures to convert waterfront industrial properties to mixed-use with residential. The intent of the designation was to delineate an area where maritime shipping can be conducted without intrusion of non-industrial uses and where investment in maritime infrastructure and related jobs is encouraged. The dredging related to this study is considered part of normal Port operations and consistent with its designation as a marine industry. Since the surrounding area is highly developed as industrial, with the closest community being more than 1 mile away, and the dredging related to this project being relatively small-scale and short-term, there are no additional measurable impacts to health related to noise, vibration, or lighting expected as compared to the FWOP. Sediments in the study area contain contaminants from industrial and municipal sources as well as from non-point sources as a result of the current and past uses in an urbanized/industrialized region (USACE 2016). Some priority pollutants, including several heavy metals, are present in dredged material in Baltimore Harbor (EA EST 2012). The sediments related to this project do not qualify for beneficial use and will be placed at Cox Creek DMCF. Once placed at the DMCF, they may be used in Innovative Beneficial Reuse (IBRU) programs implemented by MDOT MPA. These state projects repurpose dredged material in the development or manufacturing of commercial, industrial, horticultural, agricultural, and other projects following the MDE criteria which details monitoring requirements, public health standards and long-term management needs.

MDOT MPA operates and manages discharges from Cox Creek DMCF by an individual permit issued under the NPDES permit program and has waste load allocations for nutrients that are consistent with the Bay and Baltimore Harbor TMDLs. No negative impacts to health related to placement are expected. Temporary and minor adverse impacts to water quality that result from project-construction dredging and continued channel maintenance operations include increased TSS, turbidity, and nutrient levels near the study area and have the potential to affect recreational boaters. Longer term water quality impacts related to this study would be similar to existing conditions and are not expected to have an additional impact on health, recreation, or overall quality of life in the study area regardless of dredging depth.

With increased cargo and ship traffic anticipated regardless of this project, improvements to the channel to the 50-foot depth reduce the potential for ship collisions and groundings, therefore helping to minimize potential release of hazardous materials such as fuel or hazardous cargo into the nation's waterways. Additionally, as discussed in Section 6.14.2, the increase in post-Panamax vessels that tend to have newer, more efficient technology with fewer emissions versus older vessels is likely to result in cargo moving into the region with lower overall impact to metrices such as GHG emissions per metric ton. Corresponding landside modernization of the SMT offers additional increased safety and efficiency OSE benefits. The SMT Berth 3 modernization project (completed in 2022) will enhance the safety of the terminal's longshoremen, even with the anticipated increase in cargo handling, through repairing wharf structures, resurfacing pavement, and providing the infrastructure for modern technology and equipment. An example of safety improvements is the installation of modern cranes with Smart Landing Systems technology that automatically profiles the working area and decreasing the opportunity for accidents to occur. The upgrade to the Smart Landing System automates cargo movement which also reduces on-dock noise. The SMT Berth 3 modernization study, which was conducted in order to evaluate improvements needed to effectively accommodate a 50-foot draft vessel, also explains that without the improvements to the Port of Baltimore, cargo may be diverted to nearby ports such as New York and New Jersey; Norfolk, Virginia; or Canada, which would be a loss in revenue to the region and would result in an increased number of trucks needed to meet the requirements of shipment volumes in and out of the Baltimore region. Improvements to the SMT enable containers to arrive and depart from Baltimore, rather than entering the U.S. at another port and being trucked to Baltimore. This benefits all users of the regional transportation system through reduced congestion, improved road safety, and better air quality that will follow the traffic reduction. By reducing the number of trucks on the roads, accidents, fatalities, injuries, and property damage will be reduced.

OSE benefits due to increased cargo handling efficiency at SMT related to the Howard Street Tunnel Project should also be considered. The Environmental Assessment for the Howard Street Tunnel Project found no additional impacts in noise or vibration related to operation of the new double-stacked trains. However, the study finds that improvement of the regional air quality would result in the transfer of freight volume from highways to the rail system and the subsequent decrease of vehicle emissions as the optimized travel mode of freight by train replaces on-road vehicles. Transporting freight by railroad, especially in a double stacked intermodal container configuration, produces significantly fewer emissions than if the same quantity of freight were moved by truck, and double stacking reduces the number of trains used to transport the expected growth in East Coast freight traffic. An estimated reduction of 137 million gallons of fuel and 1.2 billion truck miles traveled is estimated in the 30-year period of assessment (FRA 2021). This increase in efficiency and reduction in impacts to OSE criteria as more cargo moves into SMT on post-Panamax and is transported by the improved rail system results in benefits to the entire region, as Baltimore’s inland location ensures that the movement of freight to the country’s Midwest shipping hubs results in a reduction in emissions and other impacts related to VMT.

8.3.2. Economic Vitality

For more than 300 years, the Port has served as a vital point for commerce and shipbuilding. Its legacy and connection to the surrounding community continue today. For over 30 years, MDOT MPA has been engaging and partnering with communities throughout the Baltimore region through its DMMP and Planning and Environmental Management Programs. Recognizing that many in the surrounding communities are underserved or disadvantaged, MDOT MPA focuses activities on advancing stakeholder inclusion, enhancing the local environment, and making socially responsible decisions (MDOT MPA 2020).

The Port of Baltimore is one of the largest job creators in the State of Maryland and MDOT MPA has been a strong advocate of connecting employers and prospective employees from neighborhoods throughout Baltimore. The 2017 report “Economic Impact of the Port of Baltimore in Maryland” shows that the Port generated approximately 15,300 direct jobs, with nearly 140,000 jobs overall linked to Port activities. The report also shows that the Port was directly responsible for $3.3 billion in personal wages and salary and $395 million in state and local tax revenues with an additional $2.6 billion in business revenue. MDOT MPA and the Baltimore Port Alliance collaborate on developing and distributing fact sheets about available Port-related training and job resources. In 2019, MDOT MPA supported the Baltimore Port Alliance’s first Hiring and Career Expo that helped connect 215 prospective employees with more than 30 Port businesses and organizations and followed up with a virtual event in 2021 that attracted over 275 job seekers. The SMT Berth 3 modernization study points out that efficiency at the Port will result in increased direct jobs (estimated 400 full-time equivalent) and goes on to explain that job creation will have a “domino effect”.

8.3.3. Outreach and Education

Through programs such as "Port 101," which provides presentations, terminal, and facilities tours, MDOT MPA works to establish a shared understanding of the needs, concerns, and priorities with community representatives. Twice each year, MDOT MPA hosts terminal tours that give the surrounding communities an opportunity to see the Port up close. When possible, MDOT MPA builds relationships through community engagement at public events and volunteer opportunities. Finally, when appropriate, MDOT MPA will often invest time and resources to provide technical and other support to communities to help advance mutual goals.

Widely accessible educational opportunities and equitable collaboration with Port stakeholders is a top priority. In partnership with the Living Classrooms Foundation and National Aquarium, Masonville Cove offers a variety of environmental education programs to students and citizens in the surrounding neighborhoods. Through the Terrapin Education and Research Partnership MDOT MPA engages Maryland students in a first-hand study of terrapin biology and participate in animal care and research, all while learning about the Port and its Poplar Island ecosystem restoration and habitat development project. The Port also sponsors the Baltimore Environmental Education Science, Math, and Reading Trailblazers summer program that combats summer learning loss and promotes literacy through environmental science. The 2020 program was converted to a 100 percent virtual delivery platform with 53 student participants; by the end of the program, 100 percent of students increased their literacy level.

8.3.4. Social Connectedness

The relationship between the Port and the surrounding community may be considered relatively unique. Where other Ports operate outside of the public eye, the Port's success continues to be a major source of pride and social identity to residents of the City of Baltimore. The Port is one of only four East Coast ports with a 50-foot access channel and it is essential that it remain competitive and continue as a source of pride to the economically distressed city, which has over 20% of its population living in poverty: according to the 2019 American Community Survey.

As the Port's expansion continues, the changes in the surrounding viewshed only increases the perception of the Port as a vital part of the economics in the region. This was seen in the outpouring of support as the new post-Panamax cranes traveled up the Chesapeake Bay to be installed at SMT. Recreational boaters and landside onlookers posted unknown numbers of social media posts and local news sources continued to cover the expansion with enthusiasm and pride, noting the importance of the Port to the economics of the region.

Working to enhance the connectedness and quality of life of the Baltimore community it serves, MDOT MPA invests in projects such as the Masonville Cove Partnership, which recently celebrated 10 years of serving the adjacent communities of Brooklyn, Curtis Bay, Cherry Hill and Baybrook, with free and engaging experiences in the Environmental Education Center. In 2019, the Port awarded an MDOT's Secretary's Grant to the Fleming Park Shoreline IRBU project which will use Baltimore Harbor channel dredged material to make significant improvements to Fleming Park, located in Turner Station, a historically African American community. The improvements, using sediments that meet the IRBU state guidelines for intended use, will provide the community with multiple benefits, including flood risk protection, shoreline restoration, coastal resiliency, aquatic ecosystem, and water quality improvements as well as enhanced waterfront recreational opportunities.

Additionally, MDOT MPA continually strives to be a good neighbor. Outreach activities are held regularly to connect with the nearby St. Helena community (identified as an environmental justice community). Trash cleanups and tree plantings sponsored by the MDOT MPA, and their partners are held regularly. For example, in 2019, 70 MDOT MPA volunteers planted more than 100 trees along Broening Highway to help improve air and water quality.

MDOT MPA continues to look for ways to improve equitable representation and are prioritizing recruitment of DMMP committee members and engagement of stakeholders that reflect the diversity of the communities adjacent to, and impacted by, the Port to ensure the benefits of MDOT MPA restoration projects and programs are distributed equitably without disproportionate impacts on vulnerable populations.

Table 40: Summary of OSE Impacts

METRIC		NO ACTION	NED Plan
Health and Safety	**Mental Health**	No effect	No effect
	Physical Health	Potential increase in accidents and decrease in regional air quality related to diversion of calls to other Ports	Minor temporary due to increase in air pollutants, noise related to construction.
	Vessel Safety	Minor long-term decrease in safety due to existing maneuverability issues	Safety improvements are greatest at 50-foot depth with all vessels able to complete the loop without the need to complete back-out maneuvers
	Traffic Impacts	No effect	No effect
Economic Vitality	**Financial Impacts**	No effect	Moderate long-term effect due to the small scale of the project resulting in some increases in efficiency.
	Employment Opportunities	No effect	Moderate short-term increase employment opportunities related to the dredging project
Outreach and Education	**Public Engagement**	No effect	No effect
	Education and Outreach	No effect	No effect
Social Connectedness	**Community Investment**	No effect	No effect
	Community Identity	No effect	No effect
	Equitable Inclusion in Decisions	No effect	No effect

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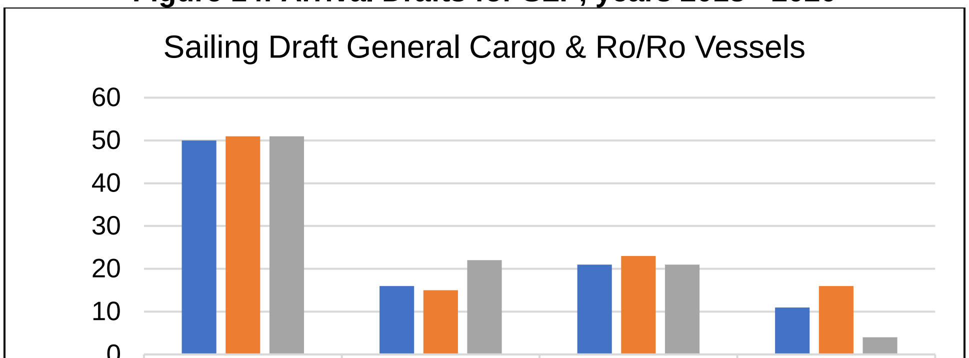
Attachment 1: South Locust Point Draft Information

Baltimore exchange data is the source of ship calls to South Locust Point (SLP) from 2018 to 2020 is used to show the following information. The authorized and maintained channel depth is currently 36 feet. Figure 1 shows vessel arrival draft of roll on/roll off (ro/ro) and general cargo vessels calling SLP from 2018 to 2020 by draft category. As shown most vessels are arriving at the 20 foot to 30-foot draft. However, vessels are using the authorized channel depth up to 36 feet.

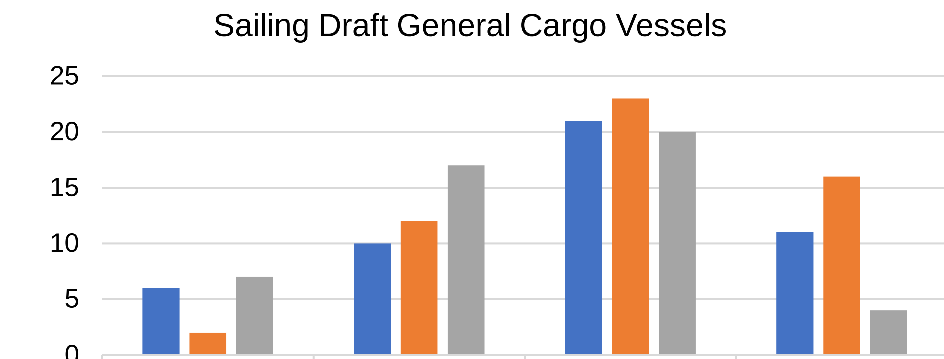
Figure 14: Arrival Drafts for SLP, years 2018 - 2020



	20 - 30	31 - 32	33 - 34	35 - 36
2018	50	16	21	11
2019	51	15	23	16
2020	51	22	21	4

Noted from discussions with MDOT MPA, general cargo vessels would benefit from a deeper channel depth greater than 36 feet. Figure 2 shows general cargo vessel sailing drafts for South Locust Point. General cargo vessels arrive between 33 feet and 34 feet approximately 43% of the time.

Figure 15: Arrival Drafts of General Cargo Vessels, years 2018 - 2020



	20 - 30	31 - 32	33 - 34	35 - 36
2018	6	10	21	11
2019	2	12	23	16
2020	7	17	20	4

Table 41 shows the design drafts of the fleet related to the data in Figure 2. These are general cargo vessels calling South Locust Point. The vessel with the greatest design draft is 35.2 feet.

Table 41: Design Drafts of Vessels Calling SLP, years 2018 - 2020

Design Draft	Percent of Vessel Calling
34.7	6%
34.8	48%
35.1	12%
35.2	34%

Table 42 presents vessel utilization using the data from 2018 through 2020. The top row of data shows the percent of capacity utilization. The second row of data shows the percent of calls from 2018 to 2020 that utilized the capacity. The data shows that 42% of vessels that called during this time reached 96% to 100% cargo capacity.

Table 42: General Cargo Vessel Utilization

Cargo Capacity Utilization	70% - 80%	81% - 90%	91% - 95%	96% - 100%
Percent of Calls	3%	22%	33%	42%

Attachment 2: Current Utilization of Seagirt Channels and Anchorages Memorandum, dated April 22, 2021

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Memorandum

To: Maryland Environmental Service

From: Stan Borrell

Date: April 22, 2021

Subject: Current Utilization of Seagirt Channels and Anchorages

Project: BHAC and Seagirt Loop Channel

Reviewed: Jeff Oskamp, PE
Approved: Eric Smith, PE

The purpose of this memorandum is to summarize the existing utilization of the access channels to Seagirt Marine Terminal (SMT) and the use of anchorages by vessel bound for SMT as input to the USACE Economics Team in developing a cost benefit analysis for the proposed project alternatives.

Moffatt & Nichol (M&N) has obtained, processed, and analyzed vessel automatic identification system (AIS) data published by the U.S. Coast Guard (USCG) for the time period of January 2018 – June 2020 to support MDOT MPA and MES in determining the economic benefit of deepening the Seagirt Marine Terminal (SMT) Loop and deepening the harbor anchorages. The AIS data obtained from the USCG was used to analyze vessel anchorage events south of the Chesapeake Bay Bridge near Annapolis, MD as well as vessel maneuvering at SMT and Dundalk Marine Terminal (DMT) in Baltimore Harbor.

Data Request

This memo addresses the following questions posed by the USACE Economics Team regarding vessel movements and purpose with Baltimore Harbor Approached Channels and Seagirt Loop.

Anchorages

1. What vessel classes wait at Annapolis Anchorage?
2. How long do they wait?

Seagirt Loop

1. How many times a year do vessels back out of Berth 4 at SMT?
2. What vessel classes/dimensions need to back out?
3. How long does it take a vessel to backout and exit Dundalk West Channel?
4. How many tugs are required for this operation, and are they required every call?
5. What is the impact to Dundalk for Seagirt vessels backing out?
6. Do vessels have to back out only if they are greater than 40' draft?

7. What impact does this operation have on vessels at Dundalk? Are they delayed due to operations at Seagirt, if so by how long?
8. How long will a vessel need to exit the loop?

Use of Annapolis Anchorages

Anchorage events near Annapolis (Figure 1) were evaluated to determine the types of anchored vessels as well as the anchoring duration. The distribution of anchorage events by vessel type are shown in Figure 2 where the vessels of interest that call at SMT or DMT Berths 1-6 (i.e., container ships, Ro-Ro carriers, and vehicle carriers) are outlined in red. The vessels of interest account for approximately 15% of the total anchorage events identified from the AIS data while bulk carriers (e.g. coal colliers) were observed to anchor most frequently near Annapolis.

The identified anchorage events for the vessels of interest are shown spatially in Figure 3 while a histogram of the anchorage event durations are shown in Figure 4. The anchorage durations greater than 10 days were solely Ro-Ro and vehicle carriers while the greatest anchorage duration for a container ship was seven days. A summary of the anchorage event durations by vessel type is also given in Table 1. It should be noted that the median anchorage duration for container ships and vehicle carriers is significantly less than the average duration. There were rare instances of prolonged anchoring (e.g., a week or more) that can artificially inflate the average anchoring duration. Therefore, the median value of the data may be more representative of a typical anchoring duration.

To assess the reasons for containership anchorage in the Chesapeake Bay, further analysis of vessel transiting locations in the Baltimore Harbor was conducted. The number of vessels (length overall (LOA) ≥ 1,080 ft) that entered/exited Baltimore Harbor (i.e., transited beneath the Francis Scott Key Bridge), arrived/departed from SMT Berth 4 and Anchorage 3, and were transiting in the navigation channel were counted during times of containership anchoring. These findings are displayed in Figure 5 – Figure 7 for each container ship anchorage event and summarized per year (2018 – 2020) in Table 2. It was found that 24% - 30% of the vessels that entered or exited Baltimore Harbor during anchorage times arrived or departed from SMT (all berths) while 6% - 11% of the vessels arrived or departed from SMT Berth 4. Vessels that entered or exited Baltimore Harbor were found to rarely anchor at or depart from Anchorage 3 during times of container ship anchorage near Annapolis.

Input from the Association of Maryland Pilots has suggested that the large draft container ships often transit the channel between Annapolis and Baltimore Harbor in a one-way direction to avoid vessel passing for safety reasons. Therefore, container ship anchorage near Annapolis could be due to the allowable channel capacity for safe transits where anchored container ships cannot transit to Baltimore Harbor until the channel is cleared from departing vessels. This appears to be the primary reason for use of the anchorages. Figure 5, Figure 6, and Figure 7 show that there is at least one vessel either transiting the channels or approaching/departing a berth during the anchorage events. Combined with a median duration of 4 hours, most anchorage events can be correlated with other vessel movements in the Harbor.

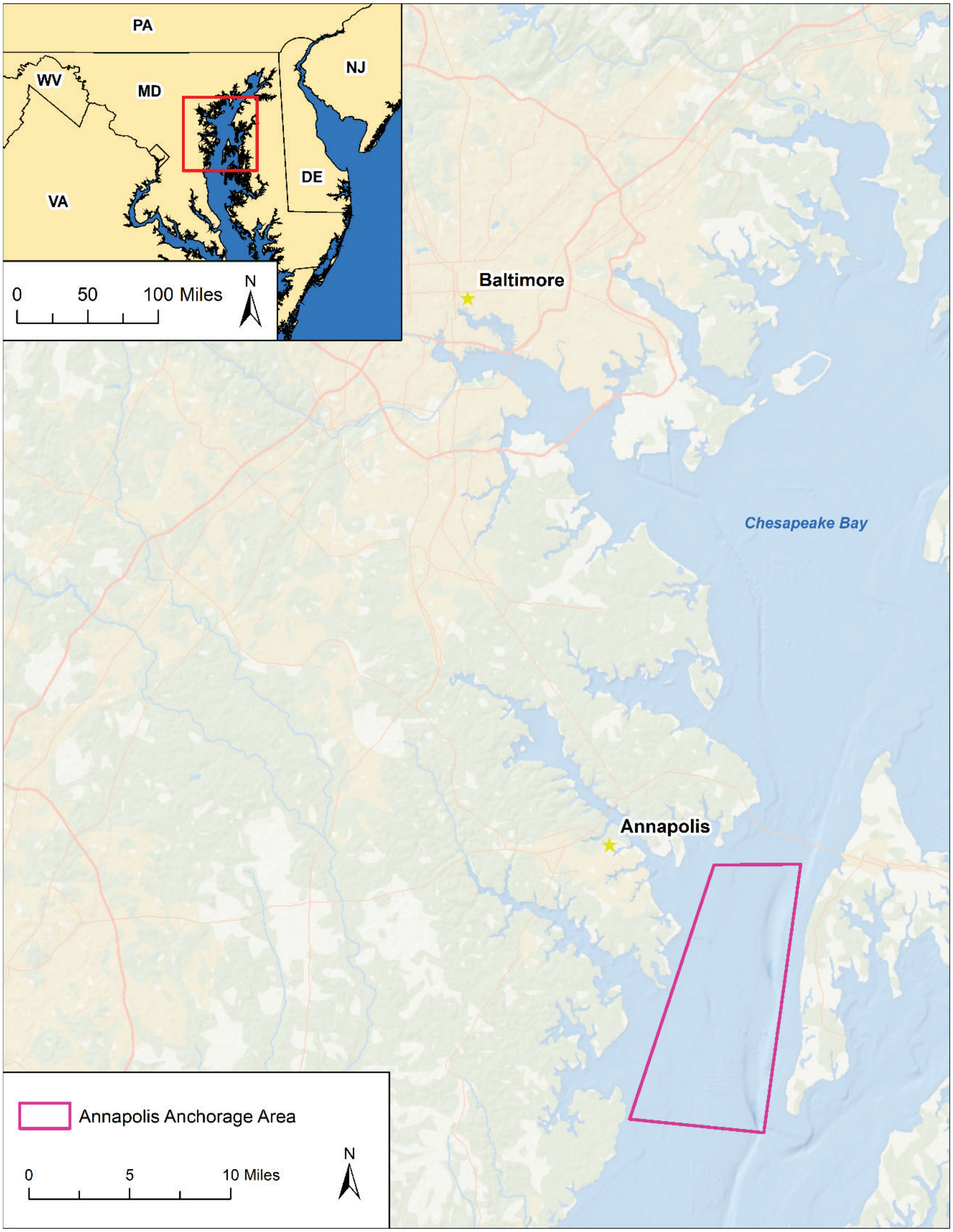

Figure 1: Location of Vessel Anchorage Area Near Annapolis, MD

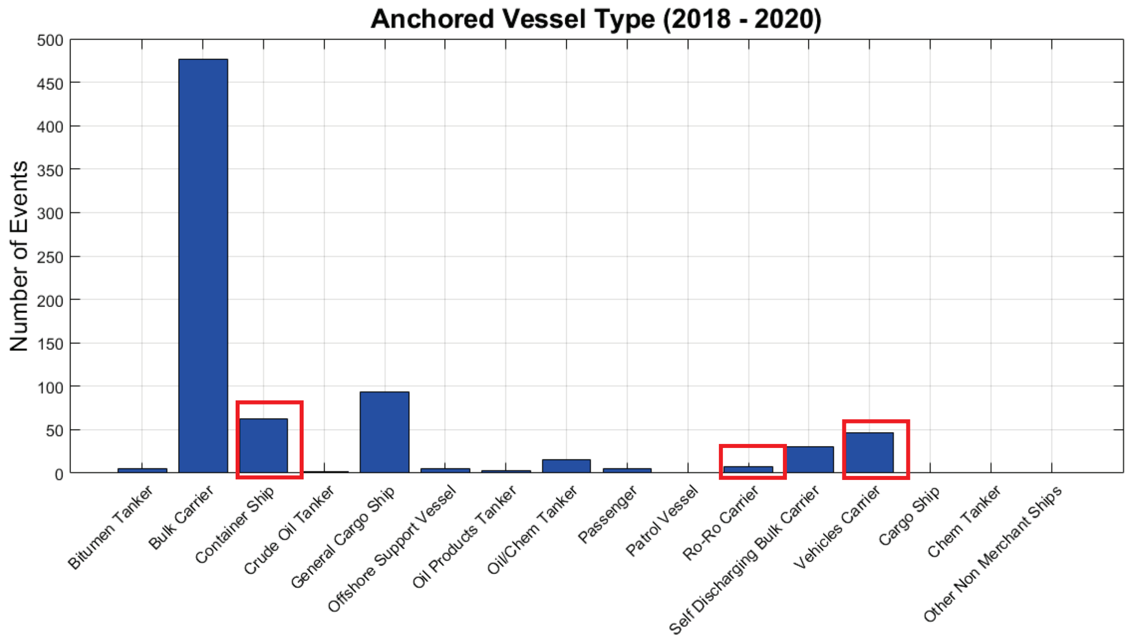

Figure 2: Distribution of Vessels Anchored Near Annapolis, MD (1/2018 – 6/2020).

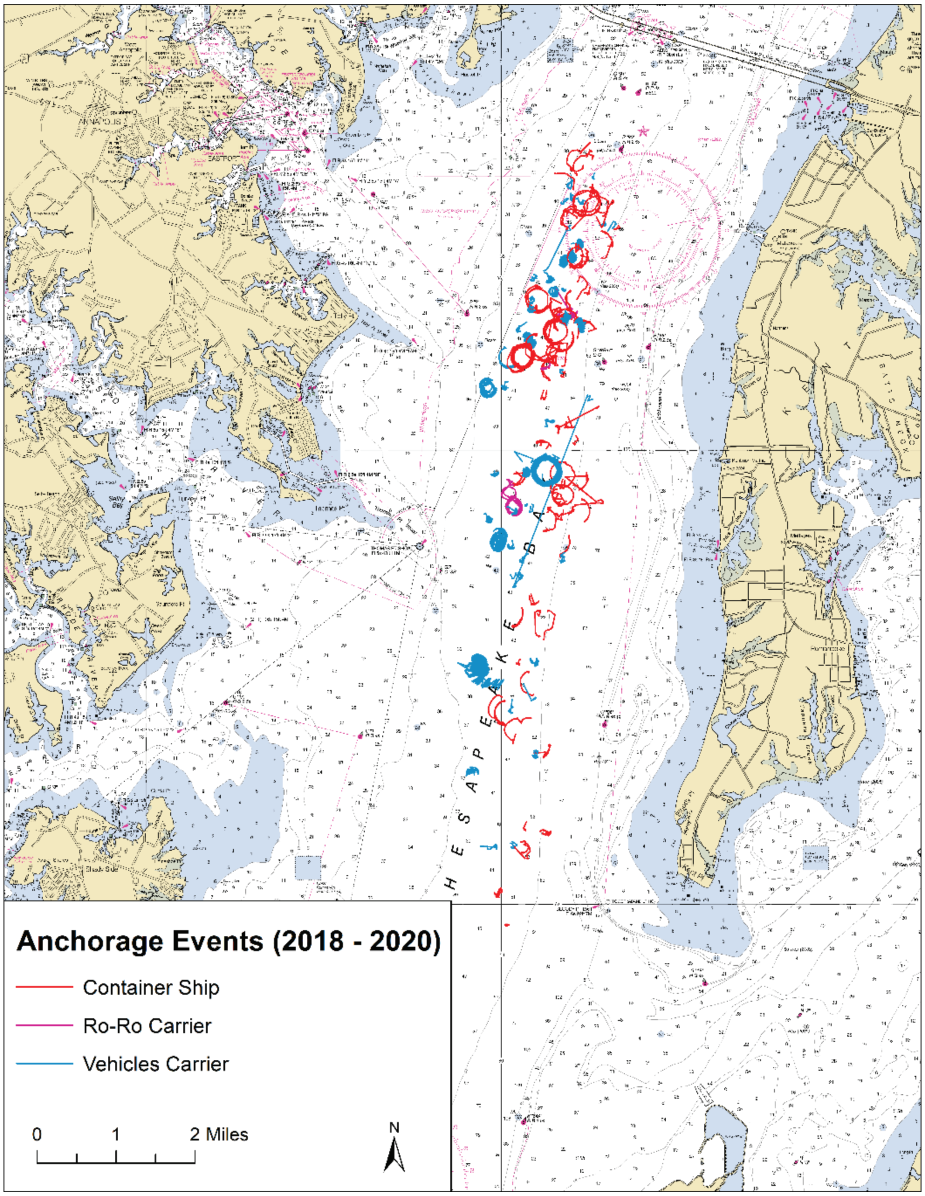

Figure 3: Spatial Distribution of Anchorage Events Near Annapolis for Container Ships, Ro-Ro Carriers, and Vehicle Carriers (1/2018 – 6/2020)

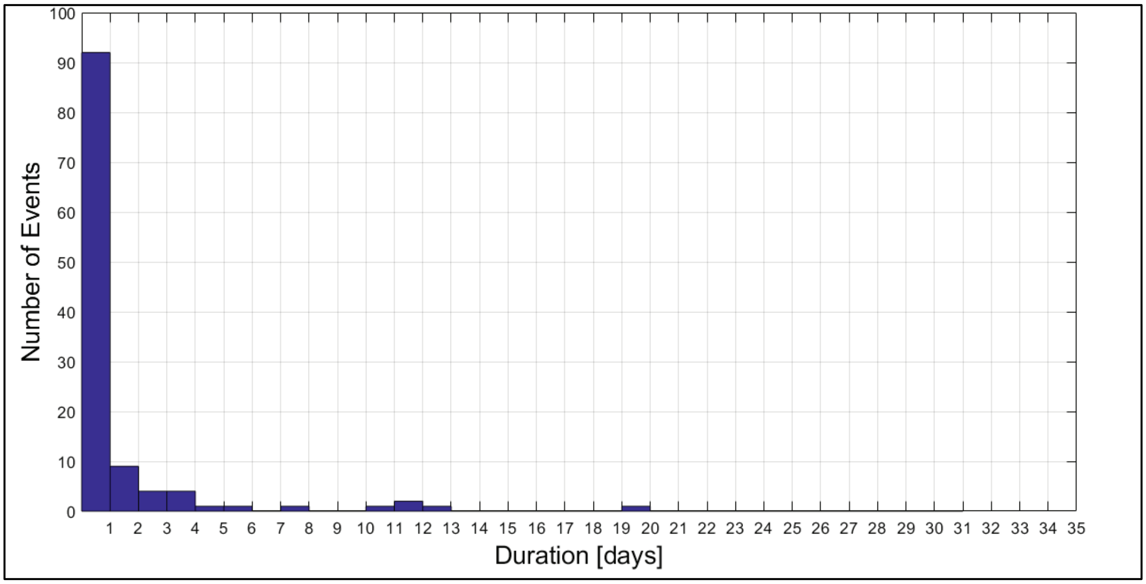

Figure 4: Histogram of Vessel Anchorage Durations for Container Ships, Ro-Ro Carriers, and Vehicle Carriers (1/2018 – 6/2020)

Table 1: Summary of Anchorage Events for Containerships, Ro-Ro Carriers, and Vehicle Carriers (1/2018 – 6/2020)

Vessel Type	No. of Anchorage Events	Average Anchorage Duration [hours]	Median Anchorage Duration [hours]
Container Ship	62	12	4
Ro-Ro Carrier	8	31	23
Vehicle Carrier	47	50	13

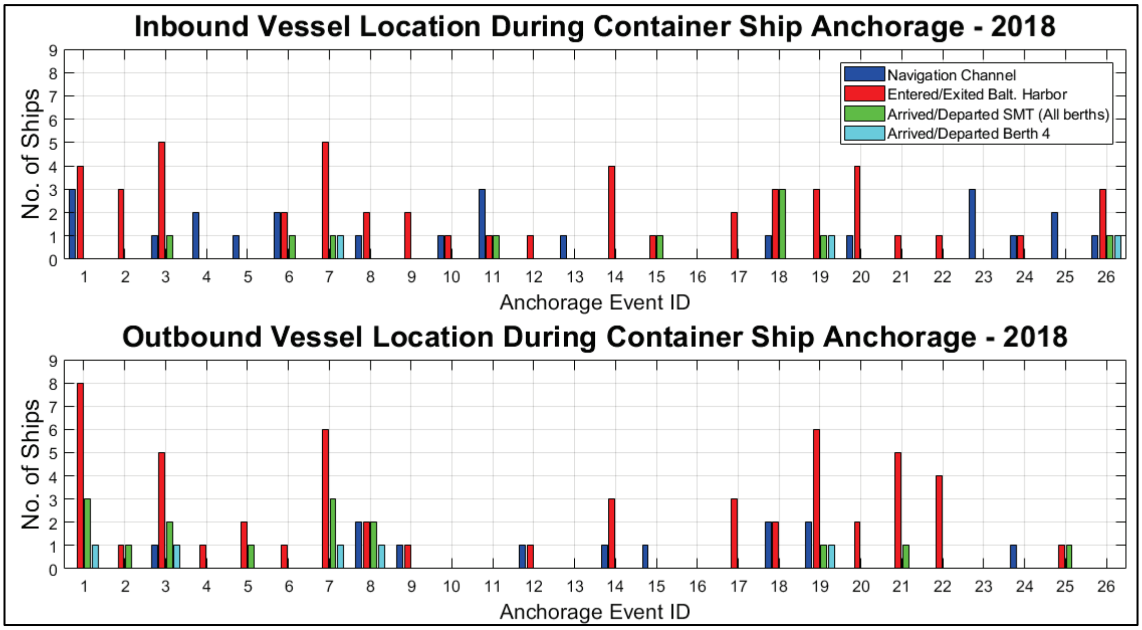

Figure 5: Vessel Locations During Containership Anchorages – 2018

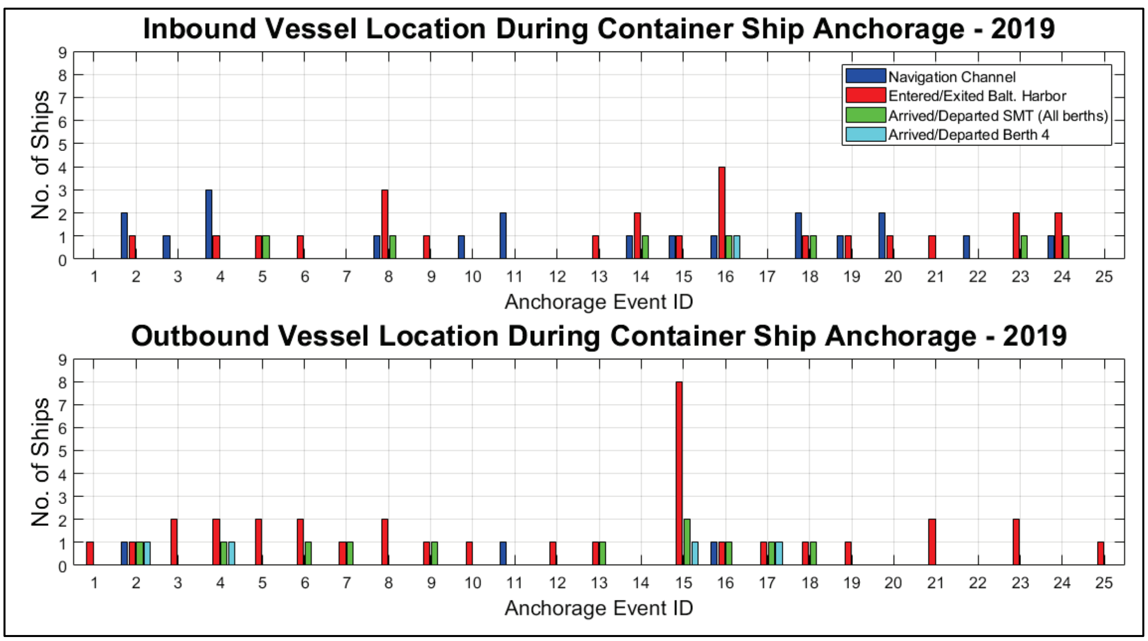

Figure 6: Vessel Locations During Containership Anchorages – 2019

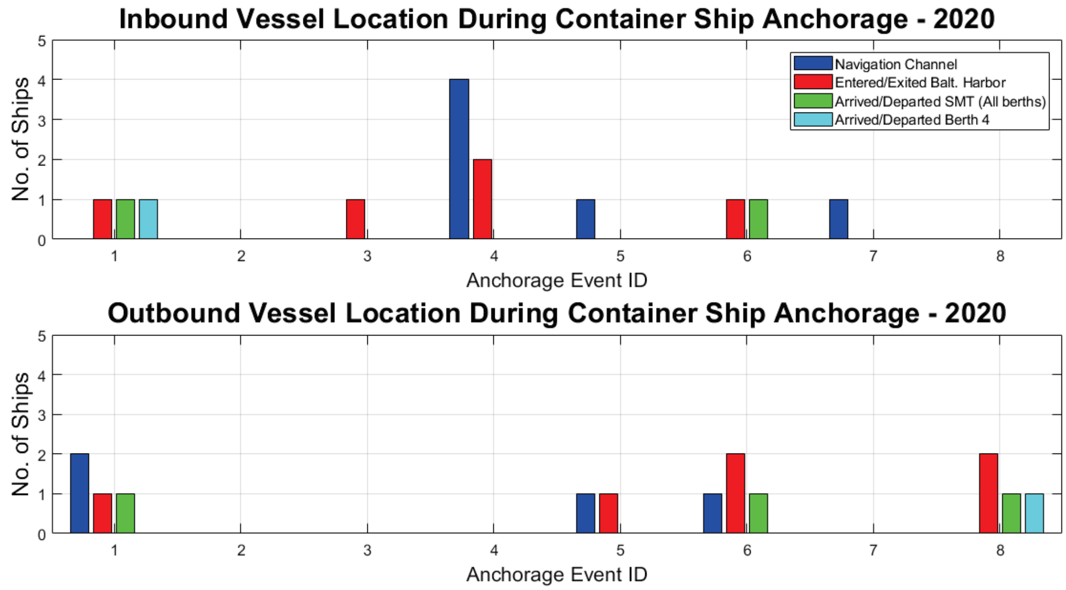

Figure 7: Vessel Locations During Containership Anchorages – 2020 (thru June)

Table 2: Yearly summary of vessel locations during anchorages near Annapolis

Year	Anchorage Events	Inbound Transits				Outbound Transits			
		Vessels in Navigation Channel*	Vessels Entering Balt. Harbor			Vessels in Navigation Channel*	Vessels Exiting Balt. Harbor		
			Total	Vessels Arriving at SMT (Berth 4)	Vessels Arriving at Anchorage 3		Total	Vessels Departing from SMT (Berth 4)	Vessels Anchored at Anchorage 3
2018	26	24	49	10 (3)	1	12	54	15 (5)	0
2019	25	20	24	7 (1)	0	3	34	11 (4)	0
2020**	8	6	5	2 (1)	1	4	6	3 (1)	0
Total	59	50	78	19 (5)	2	19	94	29 (10)	0

***Does not account for vessels entering/exiting Baltimore Harbor**
****Includes data through June 2020**

Seagirt Loop Channel

One measure of the efficiency of deepening the Seagirt Loop is to compare the departure times from Berth 3 and Berth 4 by either backing out or completing the loop. It is assumed that arrival maneuvers would continue to use the Dundalk West Channel exclusively.

Departures from Berth 4

The AIS data was analyzed to evaluate typical vessel maneuvering at SMT Berth 4. Two vessel maneuvers were examined where one involves a departing vessel completing the Seagirt Loop and the other involves the departing vessel to back-out of Berth 4 using the turning basin between SMT and DMT and the Dundalk West Channel. An example of both departure maneuvers from Berth 4 is shown in Figure 8 along with the reference point at which the maneuver durations were evaluated. It was discovered that the vessel draft reported in the AIS data was not updated reliably and therefore was not able to be used further in this analysis.

The frequency and average duration of the maneuvers from Berth 4 for vessels with a length overall greater than or equal to 985 ft (300 m) from 2018 – 2020 is given in Table 3 while the distribution of maneuver durations is shown in Figure 9. The average duration of departures utilizing the Seagirt Loop were found to be similar to back-out maneuvers (3 minutes faster). However, there was more variability in the recorded duration for the back-out maneuver compared to the complete loop maneuver. This variability can be seen in Figure 9 where the maneuver durations range from 27 to 109 minutes and 32 to 68 minutes for the back-out and complete loop maneuvers, respectively. Maximum durations for the back-out maneuver exceeded 70 minutes and occurred for 2.5% of vessel departures from Berth 4 from 2018 – 2020, whereas the duration for maneuvers using the loop channel exceeded 60 minutes once from 2018 – 2020. Regardless of maneuver, vessel departures from Berth 4 were clustered between 30 to 60 minutes.

Departures from Berth 3

Berth 3 is currently under construction to accommodate ultra large container vessels, therefore AIS analysis of arrivals and departures of these vessels is not included. However, departure maneuvers from the deepened SMT Berth 3 (post-construction) were previously simulated at MITAGS to demonstrate the feasibility of deepening the Loop Channel. The simulations included both back-out and departures through the Seagirt West Channel but ended prior to the common reference point used for the AIS analysis. The maneuver durations from the simulations were extrapolated using an average vessel speed of 6.5 knots from the end of the simulation track to the common reference point (Figure 8). Table 3 includes the extrapolated times for vessels departing Berth 3 to reach the reference. The average simulated time differential for departures from Berth 3 were 7 minutes faster to complete the loop rather than backing out.

The potential impacts to vessel movement after SMT Berth 3 has resumed operation (expected to be the end of 2021) would most likely occur when a vessel departs Berth 3 and attempts to perform the back-out maneuver while another vessel is present at Berth 4. This would require the departing vessel and associated tugs to avoid the vessel berthed at Berth 4 which could increase departure times and decrease navigational safety, particularly during high wind events.

Tug Use

Input from the Association of Maryland Pilots suggested that two to three tugs are required for each maneuver due to size of the vessels and environmental conditions, but that the number of tugs would not change due to deepening the Seagirt Loop.

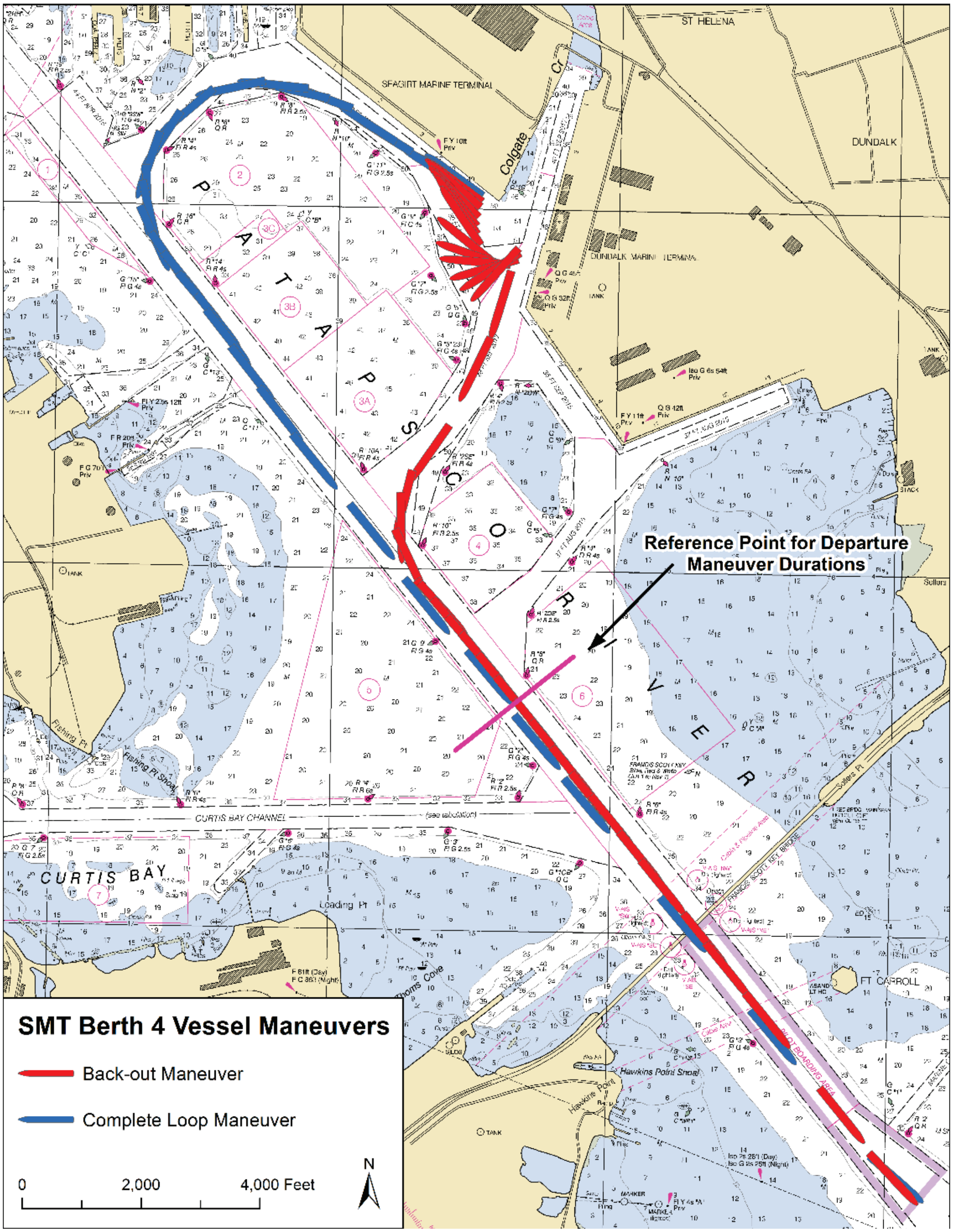

Figure 8: Typical Vessel Departure Maneuvers from SMT Berth 4 (ref. AIS Data Records)

Table 3: Summary of Vessel Maneuvers at SMT Berth 4 (LOA ≥ 985 ft) and SMT Berth 3 (MITAGS simulations)

Maneuver	SMT Berth 4 (AIS Data 1/2018-6/2019)		SMT Berth 3 (MITAGS)
	No. of Occurrences	Average Maneuver Duration [mins]	Simulated Maneuver Duration* [mins]
Complete Loop	86	43	45
Back-out	203	46	52

*** Maneuver duration was extrapolated to common reference point**

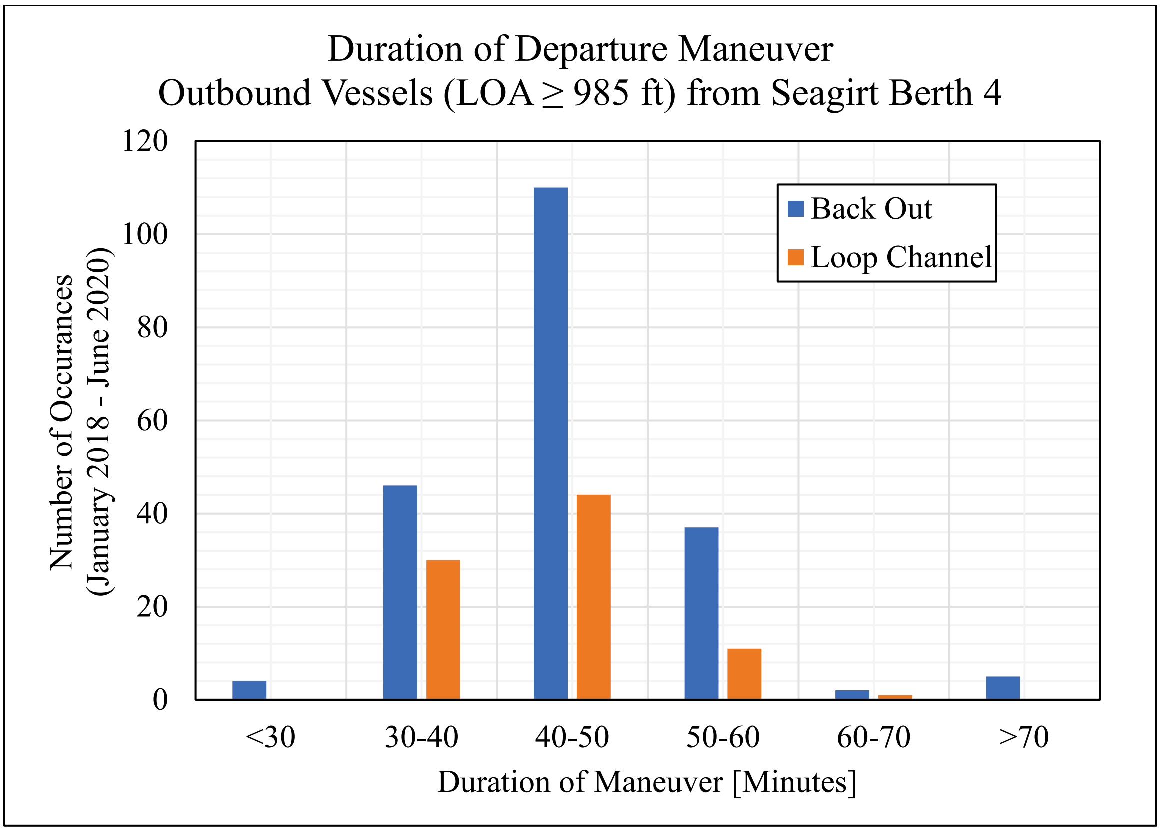

Figure 9: Distribution of Vessel Maneuver Durations

Dundalk Marine Terminal (DMT)

The duration of vessel departures from DMT to the reference line used above (Figure 8) was evaluated from the AIS data. The distribution of the vessel departure durations from DMT for 2018 - 2020 is shown in Figure 10. A summary of the DMT vessel departures is given in Table 4 where the average vessel departure time showed to be less than what was found for SMT Berth 4 departures.

The impact of back-out vessel maneuvers from SMT on DMT operations and efficiency was not able to be quantified from the AIS data. However, input from the Association of Maryland Pilots suggests that back-out maneuvers from SMT do not significantly impact DMT operations under present day conditions. Nonetheless, potential impacts on DMT vessel operations after Berth 3 upgrade is complete and additional vessels must turn in the basin (without project) should be evaluated in the harbor simulation portion of the economics study.

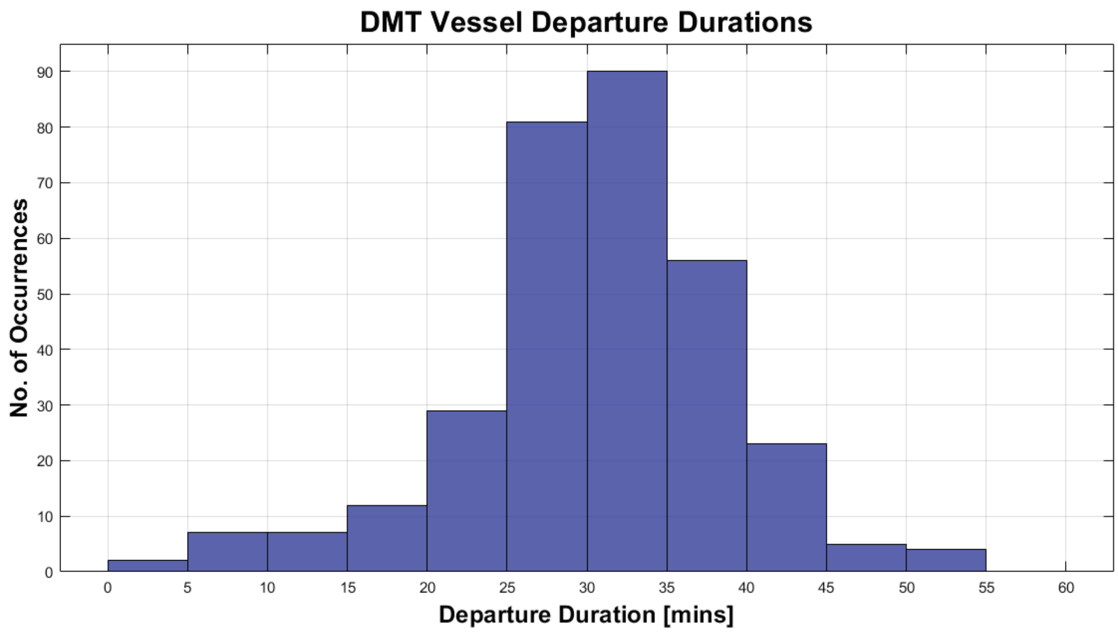

Figure 10: Distribution of DMT vessel departure durations for 1/2018 – 6/2020

Table 4: Summary of DMT vessel departure durations by year

Year	No. of Occurrences	Average DMT Departure Time [mins]
2018	128	32
2019	135	35
2020*	59	29

*Includes data through June 2020

Conclusions and Discussion

The following is a summary of the review and processing of AIS data on existing use of the Baltimore Harbor Channels and Anchorages. It should be noted that the AIS data represents Harbor movements with SMT Berth 4 in operation, but does not include ultra large container vessels calling at SMT Berth 3 as the upgrades to that berth are currently underway. For the purposes of the economics study, SMT Berth 3 upgrades will be part of the "existing" condition and therefore must be taken into account by modeling to determine the influence on the vessel traffic and maneuvering.

- AIS data for harbor activity was processed for the time period Jan 2018 through Jun 2020, 30 months.
- Containership anchorages south of the Chesapeake Bay Bridge occur on average about twice a month.
- Duration of containership anchorage events is typically short, with median duration of 4 hours. The majority of these events coincide with other vessel movement in the Harbor channels or at SMT and DMT, indicating the vessels are waiting for channels or for berths to vacate before making the passage north.
- Currently, containerships longer than 985 feet (300 m) back out of SMT Berth 4 using Dundalk West Channel an average of 81 times per year. With the deepening and upgrade of SMT Berth 3, this is expected to increase without the concomitant deepening of the loop channel.
- The vessel draft at which vessels back out rather than completing the loop could not be discerned from the AIS data (due to uncertainty in reporting). However, pilots reported vessels which exceed underkeel clearance requirements in the loop channel currently back out and use the 50 ft turning basin for departure.
- Under existing conditions, vessels greater than 985 feet (300 m) LOA departing SMT Berth 4 save on average 3 minutes completing the loop rather than backing out. However, backing out has more variability and can take more than 30 minutes longer than average for extreme cases.
- The preliminary simulations of design vessel departures from the upgraded SMT Berth 3 showed that vessels could save approximately 7 minutes completing the loop rather than backing out.

The data and simulations to date show a relatively small average time benefit for ships departing SMT through the loop channel. However, other considerations should also be considered in weighing the benefits of the project including navigation safety and reliability of the using the loop channel versus backing out and turning the ships adjacent to Berth 4 and DMT.

Additional factors that may influence vessel traffic in the Seagirt Loop channel and are not reflected in the present-day vessel traffic analyzed in this memorandum include:

- Future deepening of Seagirt Berths 1 and 2.

- Completion of the Howard Street rail tunnel to allow double stacking of rail cars and influence on container throughput at the Seagirt Terminal.

Attachment 3: BHAC Seagirt Loop Feasibility Study – Economic Benefits [DRAFT], dated September 30, 2021

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moffatt & nichol

MEMORANDUM

To: BHAC Seagirt Loop Feasibility Economic Team
From: Eric Smith, Moffatt & Nichol on behalf of MDOT MPA
Date: 09/30/2021
Subject: BHAC Seagirt Loop Feasibility Study – Economic Benefits [DRAFT]
Moffatt & Nichol Job No.: 10848-07

INTRODUCTION

The purpose of this memorandum is to provide rationale for national benefits derived from deepening of the Seagirt Loop channel servicing the Port of Baltimore (POB) in accordance with the National Economic Development (NED) manual for deep draft navigation. Benefits are assessed for the with-project and without-project scenarios and can be grouped into to two categories of potential transport cost benefits: (1) water side related to the improved movement of vessels in the harbor and (2) reduction in land-based transport costs:

1. Water Side
    - Transportation Costs Savings
        - Switch to larger vessels
        - Passing for ultra large container vessels and delay reduction
        - Improved safety and reduced accident incidence
2. Land-side
    - Other NED / NER Benefits
        - Reduced landside transportation costs

The approach and rationale for establishing the respective NED benefits are described below and initial quantification of these benefits is estimated based on historical trends and the project fleet forecast. The data summarized herein is intended to provide input to the HarborSym model and USACE economic analysis, which will in turn quantify the extent of improvements to the Baltimore harbor cargo transportation system and refine the initial benefit estimates.

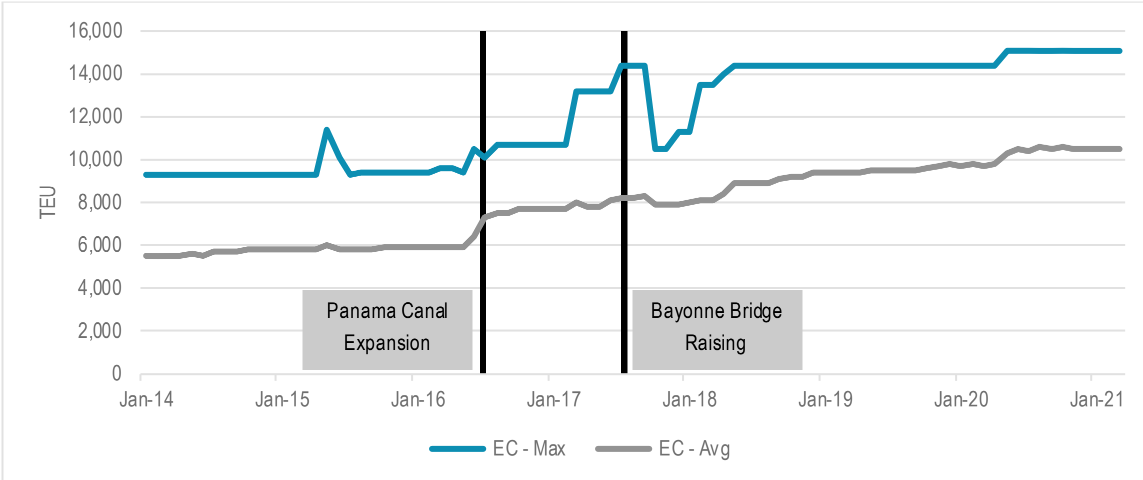
THE SWITCH TO LARGER VESSELS

As per the NED guidance: Section 14.3, A Transportation Costs Savings – Switch to larger vessels.

> *"Depending on the characteristics of the proposed project, carriers may have an incentive to use larger vessels, possibly draft constrained, with a resulting increase in average load per vessel (and a corresponding cost reduction per ton of cargo carried). This will be reflected as a shift in the fleet forecast between the without-project and with-project alternative fleets. Larger vessels at the same draft as smaller vessels can carry larger loads. It is often more cost-effective to transport goods on larger vessels, even if not fully loaded to maximum DWT capacity."*

There is the potential for the Project to allow, and induce, the introduction of larger vessels to services which call not just the POB, but also the entire US East Coast (EC). There is historical precedent that the removal / alleviation of infrastructure constraints on the US East Coast has resulted in larger vessels being deployed to call the EC ports. The two most recent and significant events include completion of the Panama Canal expansion project (2H2016) and the raising of the Bayonne Bridge(2H2017). Both of these events allowed for larger vessels to call the EC, and indeed the carriers responded by doing so, as illustrated in Figure 1. In May of 2021 CMA CGM added the Marco Polo (16,022 TEU) to the Columbus Jax services making it the largest vessel to call the EC (not reflected in the graph).

Figure 1: Average and Max Vessel Size on Asian Services



Source: BlueWater; Moffatt & Nichol

Any improvements to the EC infrastructure offering will allow the carriers to take advantages of the economies of scale offered by larger vessels and introduce these ships to the EC services when possible. Improvements to the Seagirt Loop should allow the POB a greater service offering to these larger ships, through the reduction of queuing / congestion and increased maneuverability. Such improvements should allow the carriers / services to continue to call the POB, and the broader EC, with larger ships as has been demonstrated historically.

Currently there are 11 regularly scheduled container services calling at the POB as shown in Table 1 below. Of these services there are four dedicated to the Asia and / or South Asia trade routes, three to the Europe / Med region, three to the Americas and two to Africa. The largest vessels currently calling are on the OCEAN AUE service and the 2M TP12 service (both approaching the 14,000 TEU vessel class). Moffatt & Nichol estimates that in order meet growing demand on the routes that three of these services will likely see future upgrades to the average and max vessel sizes, including 16,000s, these are namely:

(1) OCEAN AUE Service (East Asia via Panama Canal); **(2)** 2M TP 12 service (rtw); and **(3)** MSC Indus 2 service (South Asia, Middle East and Med)

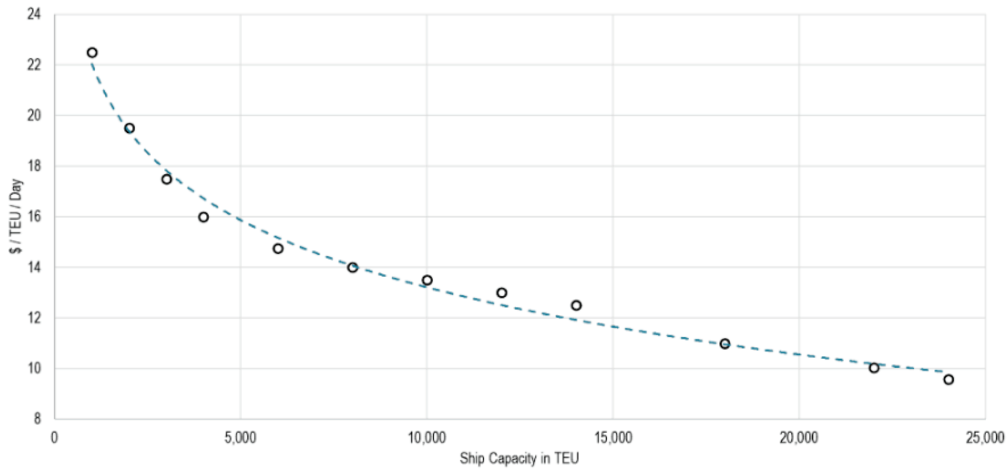
Table 1: Port of Baltimore Service Profile & Vessel Size (TEU Capacity)

Service Area	Service Name	Frequency	Avg	Min	Max
Asia	OCEAN Alliance -- ANL - Taiwan Strait-TWS/AUE	7 days	12,022	8,508	13,900
Asia	Maersk - Asia - USEC-TP20 rtw	7 days	4,471	4,250	5,100
Asia	2M Alliance -- Alianca/Hamburg Sud/ZIM - TP12/Empire	7 days	11,036	9,038	13,630
Africa	Grimaldi Lines - North America/West Africa	10 days	932	612	1,318
Africa /Carib	MSC/Maersk Line - America Express-AMEX	7 days	2,644	1,798	3,674
Carib / South America	MSC -- ZIM - USA/SAEC String 1	7 days	6,152	5,248	6,969
South & Cent America	Maersk Line/Hapag-Lloyd -- APL/CMA CGM/Hamburg Sud/SeaLand - NAE2/USW	7 days	4,137	3,752	4,544
Europe	2M Alliance -- Alianca/Hamburg Sud - TA2/NEUATL2	7 days	7,762	6,478	8,241
Europe	ACL -- Hapag-Lloyd - A Service	7 days	3,809	3,809	3,809
South Asia, Mid E, Med	MSC - Indus 2	7 days	7,444	6,402	9,200
Europe / Med	2M Alliance/Hamburg Sud - MEDUSEC/TA5	7 days	8,573	8,034	9,200

Source; BlueWater

The operating costs per TEU / Day decreases as vessel capacity increases. A 12,000 TEU vessel has a cost of rough $13.00 per TEU / Day, compared to roughly $11.00 for a 16,000 TEU vessel as presented in *Figure 2*. These lower operating costs allow carriers to improve operating margins and therefore where and when possible, the carriers seek to deploy larger vessels (in line with demand).

Figure 2: Operating costs per TEU / Day by Vessel Size



Source: TransportGeography.org; Alphaliner[1]

For the purpose of the analysis – until additional modeling is undertaken, it is assumed that:

Table 2: With-Project & Without-Project Assumptions

With-Project Scenario	Without-Project Scenario
• Seagirt Loop improvements allow for a higher frequency of larger vessels (14,000+ TEU) to call the POB • All three of the identified services continue to operate on a weekly basis, utilizing vessels of 14,000 TEU+ (2030 and beyond) • The use of larger vessels leads to reduced per unit (TEU) operating cost to the freight	• Seagirt Loop is not improved resulting in the need to back out large vessels (14,000 TEU+), and restricted one-way passing in the approach channel • While two of the three services may upgrade to a larger vessel profile (utilizing all 16,000 TEU vessels); the third will only partially upgrade (using half 16,000 TEU ships) due to risk of delays and calls Baltimore every other week with a 12,000 TEU vessel. • The need to carry cargo on smaller vessels leads to higher per unit (TEU) operating costs for that volume of cargo (a portion of the total)

Source: Moffatt & Nichol

- **Volume Assumptions**:
  - 10% of a 16,000 TEU vessel is exchanged on a weekly basis at Baltimore – which leads to a total exchange of 3,200 TEU per week (1,600 TEU offloaded and 1,600 TEU loaded)
  - Under the without-project scenario 26-weeks of the volume is carried on 16,000 TEU vessels, and the remaining 26-weeks is carried on 12,000 TEU vessels. This translates into a total 83,200 TEU per year carried by 16,000 TEU and 12,000 TEU vessels respectively throughout the course of a year.

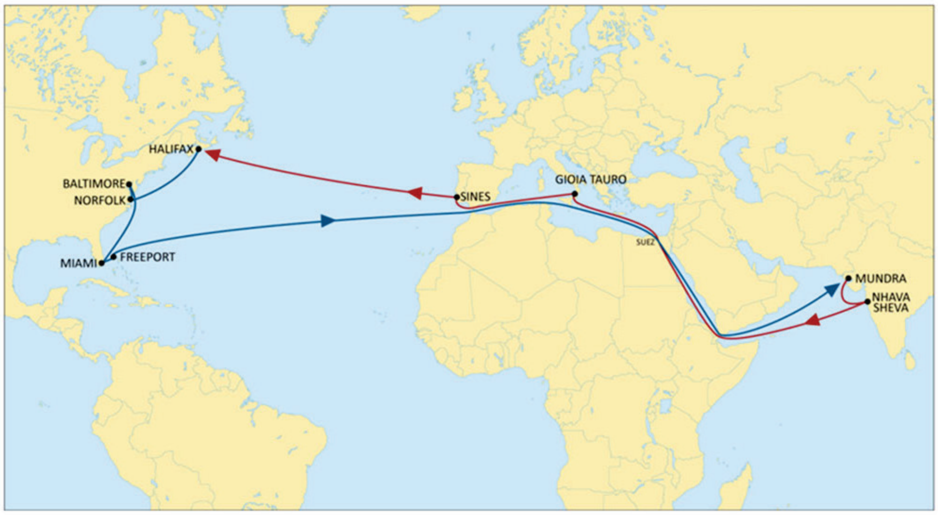
- **Operating Cost Assumptions**
  - The operating cost of a 12,000 TEU vessel is $13.00 per TEU / Day

[1] Moffatt & Nichol is working to independently validate these assumptions, however, based on the review to date these values appear consistent with in-house estimates

- The operating cost of a 16,000 TEU vessel is $11.00 per TEU / Day

- **Service Assumption**
  - Assume a 50-day rotation which is similar to the MSC – Indus 2 service which serves the South Asia (India) and Med trade routes, as presented in Figure 3.

Figure 3: MSC Indus 2 Service Map



Source: MSC

Determination of Potential Benefits

Using the assumptions described above, the following can be deduced:

1) TEU-Days = 83,200 TEU X 50 days = 4,160,000 TEU days per year

2) Operating costs of 16,000 TEU vessel = 4,160,000 TEU-days X $13 per TEU / day = $54,080,000

3) Operating costs of 12,000 TEU vessel = 4,160,000 TEU-days X $11 per TEU / day = $45,760,000

4) Annual Savings = $54,080,000 - $45,760,000 = $8,320,000

5) Future Value (FV) of Savings = $8,320,000 per year 2030 – 2079 = $416,000,000

6) **Present Value (PV) of Savings = $62,455,674**[2]

Note): If the above analysis was used on the assumption of a TransAtlantic voyage (20 days round-trip) the PV of the benefits would equate to $24,982,270, though the likelihood of seeing vessels this large (16,000 TEU) is not as great when compared to the Asian (North and South) routes.

Note): The benefits calculated above represent the savings generated on the cargo calling just Baltimore. The overall savings should be calculated for total volume of cargo (to all US ports) ports to properly assess the national impact. The improvement to the Loop is part of the broader infrastructure offering of the EC. The fewer limitations to service / deployment options the greater the likelihood of carriers introducing larger vessels to the coast.

[2] FV savings discounted by 7% - FV of benefits must be discounted to $-today in order to make the comparison to construction cost estimates

PASSING FOR ULTRA LARGE CONTAINER VESSELS AND DELAY REDUCTION

As per the NED guidance: Section 14.3, A Transportation Costs Savings – Enhanced Maneuverability and Delay Reduction:

> *"For deep draft projects, it can be expected that changes in the physical characteristics of the existing project (such as widening, anchorages and passing lanes) may alter vessel maneuverability and result in decreased transit time. Some or all of the large vessels using tides to transit a channel may no longer be tide dependent. Benefits attributed to enhanced vessel maneuverability or delay reduction are usually computed as time savings multiplied by some per-unit cost applicable to vessel underway operations or idling at port. In other instances, accessorial related vessel costs (such as tug requirements or time for harbor maneuvers) may change."*

Currently, the transit of Ultra Post-Panamax and larger container vessels constrains the approach channels north of the Chesapeake Bay Bridge (Bay Bridge) to one-way traffic, based on Maryland Association of Pilots (Pilots) channel operating rules due to the channel width. If the assigned Seagirt Marine Terminal (SMT) berth is occupied, incoming vessels must wait south of the Bay Bridge until a departing containership clears the channels and bridge. The Pilots have stated that the deepening of the Seagirt Loop channel will allow the incoming containerships to proceed north in anticipation of the departure of the outgoing ships and pass on opposite sides of the Seagirt Loop. This will alleviate potential queueing as berth utilization increases. The Pilots have stated that the channel will no longer be characterized as a "one-way" channel which may make carriers more likely to dedicate larger vessels to call at the port. Potential time saving for incoming vessels is on the order of 3 hours. The increases in efficiency versus without-project should be calculated in HarborSym with introduction of rules to allow passing at the Seagirt Loop.

Increases in harbor efficiency for container vessels would apply to Ultra Post-Panamax and New Post-Panamax fleets. Using the assumptions above, the following can be derived:

1) The operating cost of a 12,000 TEU vessel is $13.00 per TEU / Day or $6500/hour.
2) A delay of 3 hours south of the bridge would equate to $19,500 per vessel.
3) Presently, 6% of vessels are delayed south of the bridge. This may increase in the future and should be modeled by HarborSym to determine the future waiting percentage.
4) According to USACE fleet forecast, Ultra and New Post-Panamax vessel calls in 2030 will be 117, increasing to 33 in 2050.
5) Conservatively, using 6% of calls, this equates to an annual delay cost of $136,890 in 2030 and $354,510 in 2050.
6) **Present Value (PV) of Annual Savings = $2,050,937**

IMPROVED SAFETY AND REDUCED ACCIDENT INCIDENCE

As per the NED guidance: Section 14.3, A Transportation Costs Savings:

> *"Cost reduction benefits result from a decrease in the cost of shipping commodities that reflect the same origin-destination pattern and harbor in all project conditions. Cost reduction benefits generally take one of three forms…Other: reduced cargo handling costs, reduction of tug assistance,* ***reduction in accident rate and cost of damage****, lower cost switch from land transportation, advanced maintenance, reduced insurance, interest and storage costs."*

The proposed deepening of the Seagirt Loop will improve navigation safety in and around SMT and Dundalk Marine Terminal (DMT) for vessels departing the terminal. Currently, vessels docking at SMT approach the terminal through the Dundalk West Channel and dock with the starboard side of the vessel.to the dock. Vessels with draft greater than 40 feet dock at SMT Berth 4 and must utilize the turning basin to back, turn and depart through Dundalk West Channel. Vessels with draft less than 40 feet depart forward through the Seagirt Loop.

Upon completion of SMT Berth 3 deepening that is nearing completion and is expected to be online in January 2022, vessels with drafts between 40 feet and 47.5 feet will dock at either SMT Berth 3 or Berth 4 and will utilize the turning basin for departure. MDOT MPA and the private POB partners, plan to improve SMT Berth 2 into a third 50-foot berth if the Seagirt Loop improved.

In discussions with the Pilots, the use of the turning basin for departure has been successful but carries some inherent risk to the adjacent berths at SMT and DMT as well as to the departing vessel. These inherent risks include:

- Starting and stopping main engine between backing and forward propulsion during turning maneuvers, as detailed below,
- Close proximity to other vessels and terminal structures – particularly during high winds. The proximity will increase with improvements to SMT Berths 2, and 3 wherein deep draft vessels will back past one or two other vessels to utilize the turning basin.

Below is an historic example of a situation substantiating the risks of backing a vessel and utilizing the turning basin which resulted in additional costs and delays.

Turning Basin Backing Incident

On February 15, 2017 at 23:26 hours, the MSC Lisbon, a 1105-ft-long 9200 TEU Containership, departing SMT Berth 4 lost main engine power while completing a maneuver in the turning basin. The pilot in command of the vessels was able to dock the vessel under tug power at DMT Berths 5 and 6 but the vessel remained in the turning basin under tug control for more than 30 minutes. The incident occurred during a period of elevated winds above 20 knots, with gusts above 30 knots. The vessel was held at berth until 09:32 hours on February 17, when main engine power was restored and winds had abated. *Figure 4* shows the AIS track of the MSC Lisbon during the emergency maneuver and departure from Dundalk.

The loss of power occurred when the MSC Lisbon stopped engine to change from astern propulsion to forward propulsion. Marine diesel engines are susceptible to such mechanical incidents when the engine is cold and it is started and stopped. In the opinion of the pilots, this incident would likely have been avoided if the engine was kept running, which would have been the case if the Seagirt Loop were deep enough for the vessel to proceeded forward out the loop.

Thankfully, the February 15th incident did not result in damage to any vessels or port infrastructure, but in other circumstances, this would have been possible. If DMT Berths 5/6 had been occupied, there would not have been available safe landing area as these are the only 50 ft berths at DMT. The MSC Lisbon departure to NY was ultimately delayed by 34 hours due to the incident.

The costs for allision during an emergency may vary, but past incidents that have resulted in allisions with terminal structures and concomitant damage to the wharves and vessel can be used as a benchmark. For example, the Busan Trader made contact with Seagirt wharf face in 2018 resulting in $200,000 in damage to the facility (according to USCG) and unknown cost to the bow of the vessel.

Reduction in Operational Windows

Based on experience with the MSC Lisbon from the February 15th incident, the Pilots have indicated they would likely hold ultra large container vessels during periods of elevated winds rather than back past occupied berths to the turning basin. In the without-project condition, vessels at SMT Berth 3 that back past SMT Berth 4, would operate under reduced departure operational winds. While the wind conditions for departure are at the discretion of the pilot, currently vessels will typically depart and transit the harbor up to a nominal wind speed of 30 knots. Annual wind frequency at Francis Scott Key Bridge is presented in *Figure 6*. A reduction in operational winds imposes limitations and delays to the departure of vessels through the turning basin.

Calculation of Safety Benefits

Incidents such as the MSC Lisbon and changes to operational wind limits have potential additional costs to include ship demurrage, cargo delays, and repair costs. The following are suggestions for calculation of these benefits.

1. Frequency. Calculate number of vessels with draft greater than 40 feet calling at Seagirt to calculate a number/call incident rate. Based on historical calls, 419 vessels have called at Seagirt between 2014 and 2020 with draft greater than 40 ft and used the turning basin to depart. Of these vessel calls, there has been one incident in the turning basin.

This yields an empirical rate of 1 per 419 calls or .2%. In 2020, all Ultra Post-Panamax and 50% of the Super Post-Panamax vessel exceeded a draft of 40 feet. Maintaining this same ratio, in 2030 there would be 200 vessels utilizing the turning basin according to the fleet forecast. At an incident rate of 0.2%, there would be one incident every 2 years in 2030, increasing to one per year in 2050.

2. Incident Costs. Cost associated with a turning basin incident will be developed to include cargo/vessel delays, potential structural damage, and vessel damage. Extrapolate these costs with frequency over 50-year project life and compare to potential costs which are not incurred in with-project scenario. Below is an estimate of per incident repair or delay costs:

    a. According to USCG Incident Investigation Reports, there have been 10 allision incidents of damage to vessel or berth at DMT and SMT since 2002. Damage costs vary, but average repair cost over the 10 incidents is $280,000 per event.

    b. Delay of a 10,000 TEU vessel for 34 hours at $14/TEU/day = $198,000 (est. based on MSC Lisbon).

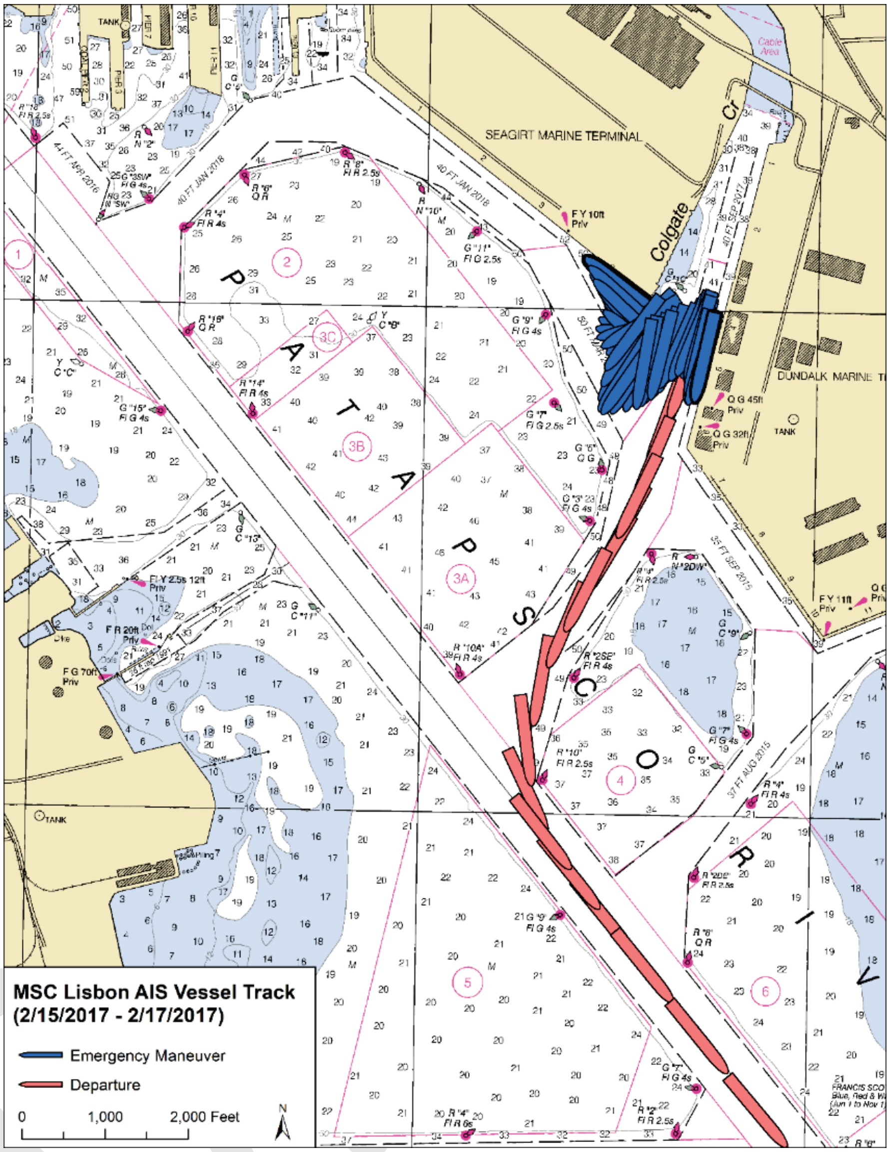
    c. Overall per incident potential cost is estimated at $500,000.

    d. Assuming a 0.2% incident rate, PV of incidents between 2030-2079 = $2.4 million.

3. Operational Costs. For vessels in Ultra Post-Panamax or New Post Panamax categories, assume the departure wind is limited to 20 knots for SMT Berths 1, 2, 3 in without-project conditions due to backing maneuvers as outlined above based on feedback from the Pilots. This departure wind is raised to 30 knots in the with-project scenario. On an annual basis, winds exceed 20 knots about 4% of the time versus less than 0.5% for 30 knots. Therefore, potential delays for Berths 1, 2, and 3 will be reduced in with-project condition, which should be further quantified in HarborSym to calculate the benefits of the increased operability.

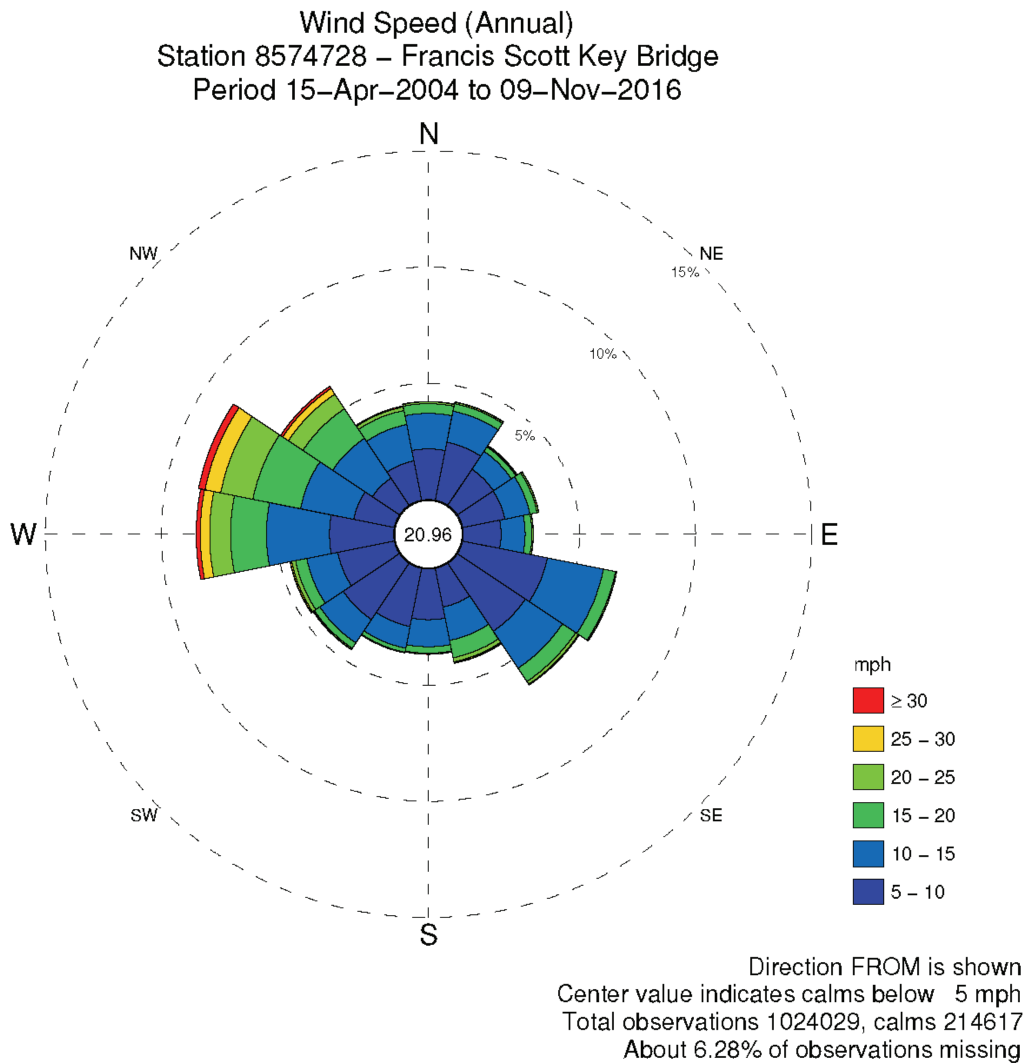
Calculated navigational safety benefits apply to any vessel with draft greater than 40 feet that would utilize the deepened Seagirt Loop rather than the turning basin upon departure. This includes a portion of the Super Post-Panamax vessels and all Ultra Post-Panamax and New Post-Panamax vessels. Deepening of the Seagirt Loop will simplify departure, decrease the time in proximity to other vessels and structures, and remove the engine start/stop required during turning maneuvers.

Figure 4: AIS Track During MSC Lisbon Emergency Maneuver



Source: M&N AIS Vessel Movement Database, 2017

Figure 5. Wind Rose for Francis Scott Key Bridge



Percentage of Occurrence

Wind Speed, mph	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total	4.21	4.31	3.10	3.34	3.02	6.77	6.30	4.16	3.67	3.71	4.48	4.58	8.50	8.59	6.16	4.13	79.04
30+													0.17	0.28	0.11		0.65
25–30													0.41	0.68	0.29		1.65
20–25							0.14	0.18				0.16	0.90	1.42	0.75	0.15	4.20
15–20	0.42	0.33	0.23	0.32	0.29	0.52	0.68	0.76	0.28	0.17	0.28	0.50	1.54	2.09	1.54	0.62	10.58
10–15	1.53	1.36	0.93	1.10	1.04	2.46	1.92	1.47	1.17	0.95	1.21	1.35	2.71	2.34	2.06	1.60	25.19
5–10	2.17	2.54	1.87	1.85	1.62	3.71	3.52	1.69	2.18	2.55	2.91	2.49	2.76	1.78	1.41	1.72	36.77

Source: NOAA Meteorlogical Station 8574729 Francis Scott Key Bridge N.E. Tower, MD https://tidesandcurrents.noaa.gov/stationhome.html?id=8574729

DIVERSION OF CARGO – REDUCED LANDSIDE TRANSPORTATION COSTS

As per the NED guidance: Section 14.3, C Other NED/NER Benefits – Reduced landside transportation costs.

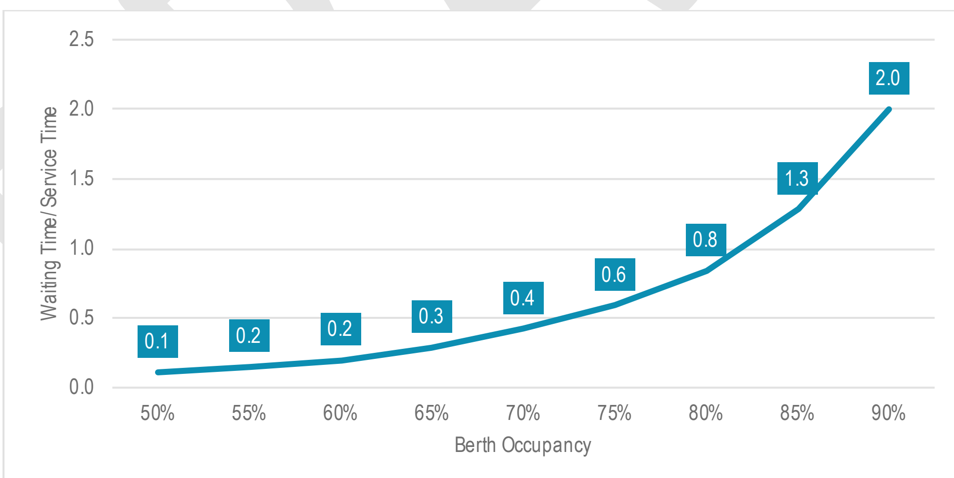
> *"Reduced landside transportation costs (if it can be demonstrated that cost reductions will occur because of the project and would not occur without it) [55]"… [55] " The basis for claiming such benefits is the P&G requirement to consider all transportation costs from origin to destination. Since the P&G does not specifically recognize landside transportation benefits, an obligation to claim such benefits and show associated costs does not apply. The acceptability and amount of such benefits will depend on how good a case can be made that the project is the proximate cause of the cost reductions, how well the cost reductions can be documented as part of the origin-destination transportation costs, and whether all associated costs have been identified. Generally, this will limit benefits to the reduced cost of cargo handling or reduced inland transportation costs attributable to specific improvements in the immediate port area."*

Acknowledging that demonstration benefits through the reduction of landside transportation costs may be challenging to link directly to the Seagirt Loop Project, there is a strong argument and historical precedent suggesting that without the planned improvement to the Seagirt Loop the risk of cargo being diverted to other EC Ports (NYNJ) is a distinct possibility. This is particularly true at Baltimore where there is a single dedicated container terminal, and no potential to divert cargo to another (second) terminal within the POB should congestion issues arise. The value of the additional cost of transporting the diverted from NYNJ back to Baltimore which would be incurred should be considered a benefit of the Seagirt Loop Project.

Berth Utilization

As the projected number of vessels calling the POB increases (405 in 2020 increasing to 472, 596, 761 in 2030, 2040 and 2050 respectively); and the larger number of these calls come on larger vessels (12,000 TEU – 16,000 TEU) where the exchanges are higher, berth occupancy at SMT will become highly utilized.[3] As the utilization of the facility increases, so does the average wait time (queuing time) for the vessel to be serviced as shown in Figure 6.

Figure 6: Berth Utilization and Impact on Wait Times (3-Berth Facility)



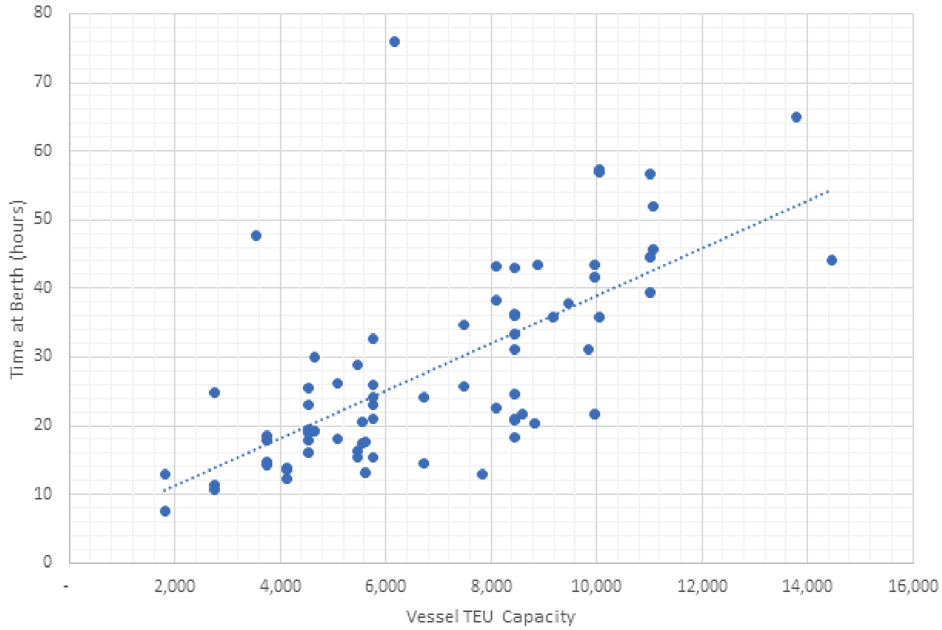
Source: UNCTAD: Table 2 Random Arrivals; Erlang 2-diistributed service time [4]

Berth utilization of a terminal is in part determined by the mixture of vessels calling the facility. In general, as vessels become larger (in terms of TEU capacity) they tend to spend more time at berth, as illustrated in *Figure 7*, which presents the time at berth by vessel size at Seagirt in 2020. This is primarily a function of the number of containers being exchanged, the number of cranes assigned to the vessels and the productivity of those cranes. 6,000 TEU vessels tended average 24-hours at berth, whereas the 10,000s closer to 40-hours and the 14,000s over 50-hours.

[3] Berth utilization will be one of the outputs from the HarborSym analysis

[4] Wait times will improve with regular scheduling

Figure 7: Time at Berth by Vessel TEU Capacity (Seagirt 2020)



Source: Baltimore Maritime Exchange

Using the existing set of vessel call forecasts provided by the USACE in the "econ forecast TMN 28JUL2021 v2" pptx; and the average days at berth observed at Seagirt, a rudimentary estimate of berth utilization can be worked out. By 2030 berth utilization at Seagirt could reach 71% before increasing to 91% in 2040 as presented in *Table 3*. It is in these ranges of utilization that wait / queuing issues become problematic for terminal operators and carriers alike. It should be noted that the vessel call forecasts do not include any assumed visits from a New Post Panamax vessel (16,000 TEU), which generally require more time at berth than their smaller counterparts, and any inclusion of these vessels into the forecast will push the utilization estimates even higher.

Table 3: Implied Berth Utilization

	Calls 2030	Calls per Week	Days @ Berth	Days @ Berth per Week	2040 Calls	Days @ Berth per Week
Sub Panamax	-	1	0.8	0.6	-	-
Panamax	73	1	1.0	1.4	109	2.1
Post-Panamax	119	2	1.3	3.1	91	2.3
Super Post-Panamax	163	3	1.6	5.0	158	4.8
Ultra Post-Panamax	117	2	2.2	4.9	237	9.9
New Post-Panamax	-	-	2.5	-	-	-
Total	**472**	**9**		**14.9**	**595**	**19.1**
Total Available Berth Days per Week (3 Berths X 7 Days)				**21**		**21**
Implied Berth Utilization				**71%**		**91%**

Source: USACE; Moffatt & Nichol

Schedule reliability has and will continue to be of the utmost importance (particularly for retail importers) and carriers have been known to alter their rotations (either through skipping calls outright or shipping to other terminals / ports) in order to make sure that the overall integrity of the schedule remains intact.

When congestion has become problematic in the past, there have been observed instances when the carriers divert cargo. Perhaps the most widespread example of this can be observed on the US West Coast today (2021) where port congestion has reached unprecedented levels, and the instances of skipped sailings, altered service rotations and redirected cargo is quite significant. Services have been altered such that not only have they sought to find less congested gateways on the West Coast, but also have pushed into the Gulf and East Coast ports. NYNJ and Savannah are now experiencing similar conditions (albeit not as extreme) to LALB and Oakland where the number of ships at anchor waiting for a berth are now approaching the low-to-mid 20s.

Historical Precedent:

2013 – Maher Terminal NAVIS-related Service Disruption – Hapag-Lloyd encourages shippers to use Halifax, Baltimore and Norfolk

2015 – US West Coast Congestion – cargo diverted to Canadian and Mexico ports - Statement of Commissioner Richard A. Lidinsky, Jr. Commissioner – Federal Maritime Commissioner

2021 – US West Coast Congestion – Multiple instances

- LALB services redirected to Oakland / NWSA
- Zim reroutes Oakland service through LA
    - Hapag-Lloyd and CMA CGM also have announced skipped sailings at Oakland[5]
- Skipped Sailings at Oakland reduce exports

As addressed in the "The Switch to Larger Vessel" discussion, the daily operating rates for these larger vessels can approach $200,000 / day e.g. 16,000 TEU @ $11 per TEU per Day implies daily operating costs $176,000 / day. The carriers have to calculate their ability to generate revenue by offering calls (frequency and exchange) at certain ports vs. the cost of additional time (and vessels) needed to extend service rotations while maintaining weekly calls.

- **Volume Assumptions**:
    - Assuming the 10% of the 16,000 TEU vessel service is offloaded on a weekly basis – or 1,600 TEUs per week
    - Assume that because of congestion this service cancels offloading in Baltimore for 5-weeks out of the year (Hapag-Lloyd used a 7-week hiatus in Oakland); and drops off these boxes in NYNJ instead
    - This results in 8,000 TEU per year being offloaded in NYNJ and truck back into the Baltimore market

- **Trip Assumptions**:
    - # of TEU per Truck = 2.5 TEU / Truck
    - # of Trips = 8,000 TEU / 2.5 TEU / Truck = 3,200 Truck Trips
    - Distance from NYNJ to Baltimore = 175 Miles
    - Total Miles = 3,200 Trips X 175 Miles = 560,000 Miles / Year

- **Trip Costs**:
    - Truck Operating Costs = $2.03 / Mile (includes truck operating costs [labor, fuel, parts] + highway wear + CO2 emissions + safety)
        - Assumes operating cost escalates 1% per year
    - Trucking Costs = 560,000 Miles X $2.03[6]

[5] https://www.joc.com/node/3677261; https://splash247.com/hapag-lloyd-cuts-oakland-for-several-weeks-due-to-congestion/
[6] $2019

Determination of Potential Benefits

Using the assumptions described above, the following can be deduced:

1) 8,000 TEU of diverted cargo per year

2) Yields 3,200 truck trips per year

3) Total Miles = 3,200 Trips X 175 Miles = 560,000 Miles / Year

4) Trucking Costs = 560,000 Miles X $2.03[7]

5) FV of Truck Costs 2030 – 2079 = $81,758,124

6) **PV of Annual Truck Costs (Annual Savings) = $10,855,839**[8]

NOTE): The assumed 8,000 TEU of diverted cargo per year represents on average 0.3% of the Port's total volume 2030 – 2079. This volume could potentially increase significantly (along with the calculated benefits) should it be determined that a full service call is dropped.

CONTINUING EFFORTS

This memo contains initial estimates of NED benefits to date, the following efforts are continuing to support the economic analysis:

1) Confirm vessel forecast (timeline and vessel class) for 2030 – 2050 and discuss / establish approach for 2050 - 2079

2) Refine berth utilization / occupancy (includes assumptions around vessel turn-times)

3) Refine all analysis presented in this document – including vessel sizing / cargo diversion arguments

4) Continued weekly coordination with USACE economics team

SUMMARY

This memorandum has identified and provided initial quantification of additional benefits consistent with NED guidance that will be derived from the BHAC Seagirt Loop Deepening project. The data summarized herein is intended to provide input to the HarborSym model and USACE economic analysis, which will in turn quantify the extent of improvements to the Baltimore harbor cargo transportation system and refine the initial benefit estimates. The assumptions utilized above may be subject to refinement as the BHAC Seagirt Loop Feasibility Study progresses.

[7] $2019

[8] FV savings discounted by 7%

REFERENCES

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