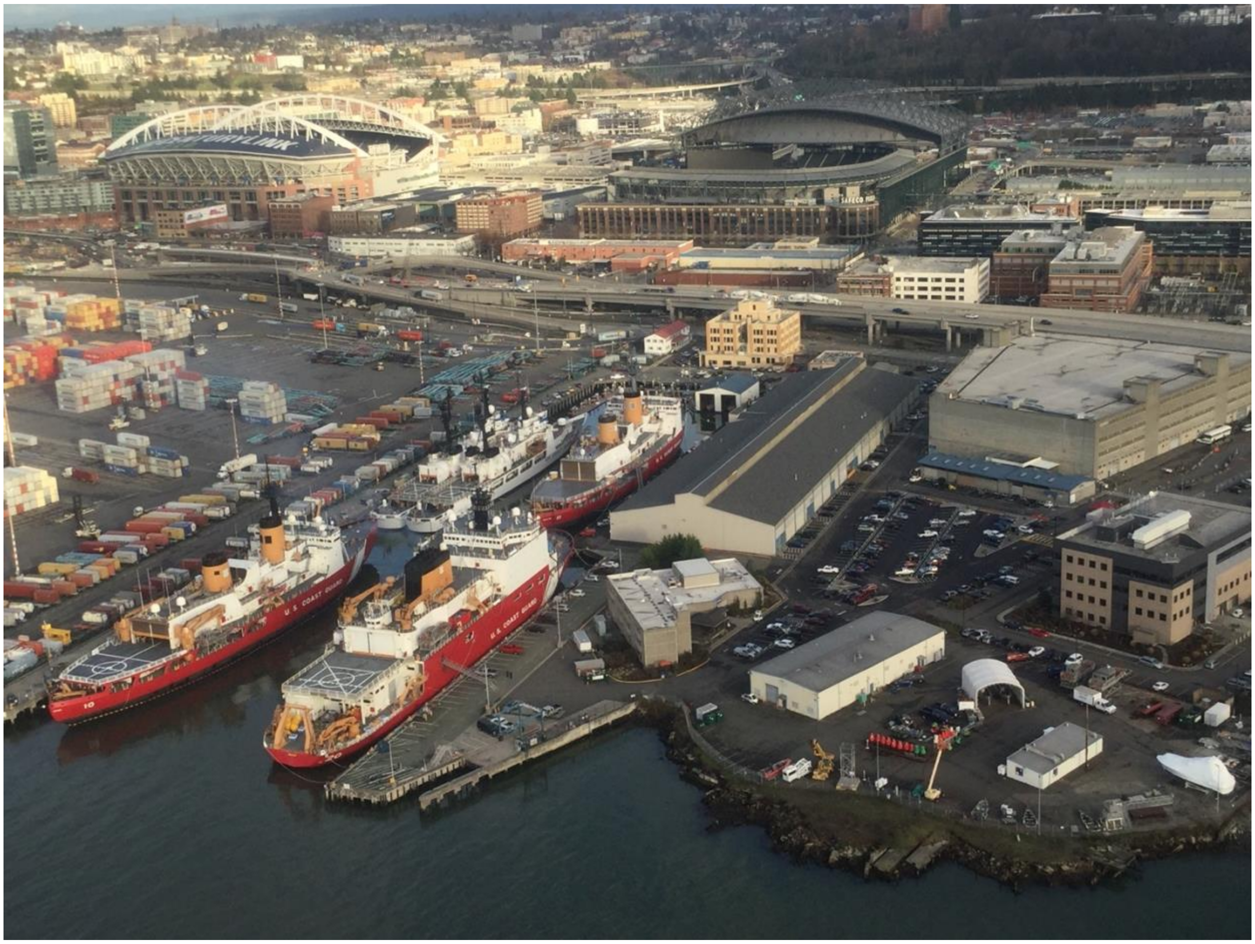

Recapitalizing and Expanding Coast Guard Base Seattle:

A Real Options Analysis

MIT Student 3
MIT IDS.330 Final Project

May 2021

Disclaimer: *This project analysis is currently being planned, budgeted, and prepared for construction based on a Coast Guard project. Cost estimates provided are adjusted to protect acquisition sensitive information. Furthermore, this report in no way represents the Coast Guard's actions or serves as a basis for evaluation or decisions. Details of the specific scenario are omitted on purpose as this report is only for educational purposes.*

Executive Summary

The U. S. Coast Guard (CG) identified Seattle, Washington, as a strategic location for both Arctic and Pacific operations. As such, it intends to homeport the new ocean-going icebreaking fleet and several Offshore Patrol Cutters at its current facility at Base Seattle. However, with limited property available, the CG must expand its footprint and recapitalize its deficient infrastructure to support the new assets. This assessment incorporates flexible design to identify and analyze project uncertainties, uses deterministic and stochastic analysis, and offers real options to decision-makers.

This analysis evaluates the options available using capital investment (CAPEX) and a performance metric defined as additional ships added per $100M investment. The primary uncertainties assessed are the cost of construction, environmental remediation and real estate, in addition to the actual cutter delivery dates or changes to homeport decisions. The CG's plan to acquire Seattle Port Authority owned property to the south and execute project elements following the land purchase precludes the organization from having flexible options.

Based on this analysis, the CG should reorder its project elements to delay the land acquisition and complete the environmental remediation elements. Furthermore, it should look at actual project element costs to inform subsequent project choices. Finally, it should understand the cost of delayed ship arrivals if construction is also delayed from both a financial and performance aspect. These flexible options help minimize capital investments while maximizing the mission capability.

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Project Background

The United States Coast Guard is in the midst of its largest fleet recapitalization in the history of the service. The Coast Guard (CG) will replace every major cutter class with Cutter in the Hamilton Class, USCGC MUNRO. Seattle is the preferred location for the new Polar Security Cutters (PSC) and several Offshore Patrol Cutters (OPC) currently major acquisitions engaged in constructing the classes' lead ships. Base Seattle is a strategic location for both Pacific and Arctic CG operations.

CG Base Seattle is an undersized property at 22 acres in the heart of Seattle's bustling maritime district. The restricted site does not enable expansion without land acquisition from Seattle's Port Authority and the Northwest Seaport Alliance. Furthermore, Seattle is a seismically active area, and the CG Base is built on fill material; therefore, vulnerable to liquefication and extensive damage. Significant recapitalization efforts are necessary to bring existing buildings up to code and to modernize the facilities. The CG plans have the new fleet of cutters arriving between 2024 and 2031. The first PSC is planned for 2024, with the second in 2026 and the third in 2027. The two heavy icebreakers currently residing at Base Seattle have exceeded their service lives and will decommission upon the arrival of their replacements. Furthermore, the OPCs will arrive in 2026, 2027, 2030 and 2031 based on current delivery plans.

In addition to the pier space to accommodate the new cutters and updates to existing code-deficient buildings, the CG has several objectives. First, the recapitalization project needs to provide additional mission support and unaccompanied personnel housing facilities, provide parking for all members, upgrade the aging utilities, meet security requirements, and build a childcare center. Additionally, the CG also hopes to vacate an existing lease two miles away and consolidate its District 13 offices at Base Seattle in the latter stages of the recapitalization.

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Figure 1. COA 2 - No land acquisition

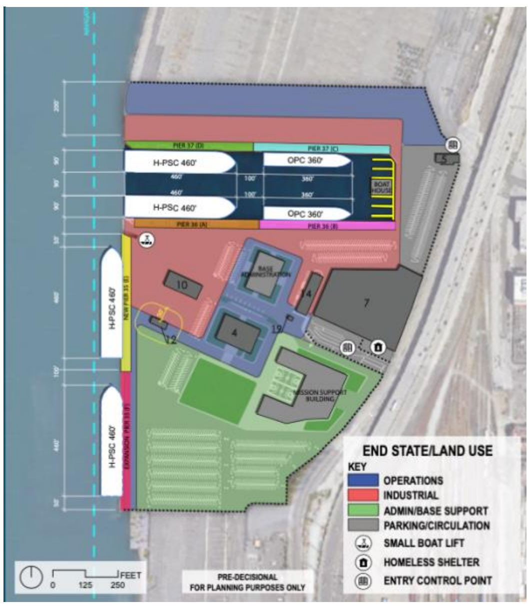

Figure 1. COA 3 - Expansion to Pier 35

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In conjunction with operational leaders, civil engineers, logistics leaders, and port partners, Coast Guard planners developed four potential courses of action to meet the requirements. Course of Action (COA) 2 uses the existing property footprint and does not acquire additional property (Figure). This COA is limited to a maximum of six (6) cutters in five (5) berths. It rebuilds a new pier (35) and addresses security deficiencies. In order to accommodate the additional personnel, a parking garage will be built. COA 3 seeks to acquire the land to the south, known as the T-30 property (Figure 2). This COA enables up to eight (8) cutters homeported at Base Seattle utilizing six (6) berths and addresses security deficiencies. The additional space permits expansion for more personnel and assets and is considered most viable regarding acquisition probability. COA 4 also allows homeporting eight (8) cutters at Base Seattle by acquiring land both to the north (terminal 46) and south (pier 35) for one cutter each (Figure 3). The last scenario, COA 5, achieves six berths by acquiring enough land to the north at terminal 46 to homeport eight cutters and other expansion needs but is considered less viable regarding the acquisition (Figure 3). The CG's leadership selected COA 3 as the recommended path forward and started to negotiate a land acquisition of neighboring properties.

There are advantages and disadvantages to each scenario, but the cost of capital investment (CAPEX) and the ability to meet mission requirements are the primary concerns. This analysis will use CAPEX to measure the capital investment in fiscal year 2021 (FY21) dollars. This analysis will use the ratio of additional ships (above the four currently located at Base Seattle) homeported in Seattle per cost, specifically additional ships per $100M invested, to address the project's contribution to mission capability.

Figure 2. COA 4 - Acquire land to the north and south (pier 35 and terminal 46)

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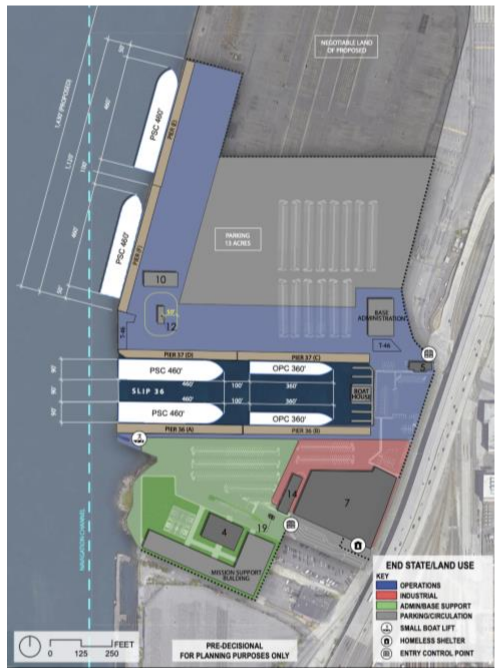

Figure 3. COA 5 - Expansion to the north (terminal 46)

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Deterministic Case

With COA 3 as the recommended path forward, the CG is engaging in negotiations with the Seattle Port Authority to acquire the land to the south of the existing Base property. Additionally, the project is expected to occur in phases as funding appropriations are approved and granted by Congress. Table 1 shows the plan for COA 3 implementation beginning with the land acquisition and subsequent project elements listed. Furthermore, the table serves as the deterministic system model with expected vessel arrivals, decommissionings, and accompanying personnel growth. Using the 7% discount rate published in OMB's 2020 Circular A-94, the net present value for the entirety of the project in FY21 dollars is $425M. COA 3 also yields 1.176 additional ships per $100M of capital cost performance metric. This means that approximately 1.18 ships are added to the facility per $100M of investment under COA 3. This deterministic analysis does not take any uncertainties or risks into account, nor does it offer design options other than those imposed by Congress's prerogative to accelerate, delay or cancel funding at any point in the project.

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2029	2030	2031	
Ship Assets	3	3	3	4	3	5	6	6	6	6	7	8	
Ship Changes	(-) WHEC			(+) PSC1	(-) WAGB1	(+) PSC2, (+) OPC1	(+) PSC3, (-) WAGB2, (+) OPC2				(+) OPC3	(+) OPC4	
Personnel	800	800	850	1000	1100	1400	1500	1500	1450	1450	1800	1900	
Project Elements	Land Acquisition		Slip 36 CERCLA Clean Up	Building 7 Seismic Retrofit and Modernization	Repair Portions of Terminal 46 Wharf	Pier 35 F CERCLA Clean Up	Demolish and Relocate ANT and Magazine	Utility Systems Upgrades & Replacement, New Mission Support Building, Security & perimeter system upgrades	New Operations Building, Replace haul routes & pavement	Construct Base Seattle Parking Garage			
													NPV
Capital Costs (FY21)	$43,572,000	$0	$113,547,035	$95,040,746	$15,257,904	$87,596,056	$0	$53,068,242	$17,127,946	$0	$0	$0	**$425,209,928**
Personnel/Cost($M)	0.000	0.000	0.318	0.793	1.122	1.690	1.972	1.715	1.529	1.529	2.352	2.587	**Personnel/Cost($M)**
Ships/Cost ($100M)	0.000	0.000	0.000	0.397	0.000	0.563	0.845	0.735	0.706	0.706	0.941	1.176	***Ships/Cost ($100M)***

Table 1. COA 3 - Base Case with deterministic Capital Cost estimates

Uncertainties and in Homeporting Major Cutters at Base Seattle

Several uncertainties exist impacting the project cost and performance, as quantified by capital expenditure per additional ship added to the Base. The five significant uncertainties identified and analyzed include:

a. Delivery and decommissioning of ships in an expected year
b. Land acquisition – impact on capabilities (Ships/$)
c. Environmental remediation costs
d. Real estate costs
e. Construction costs

As previously mentioned, the CG is currently building the lead ships for both the PSC and OPC classes. However, production rates of the new cutters can fluctuate based on several factors, including but not limited to shipbuilder contractual timelines and bonuses, long-lead-time components, successful sea trials, hurricanes and homeport location decision changes. Based on past major cutter production deliveries since 1990, production can exceed timelines by as much as 12 months and be delayed by as much as 24 months. Impacts on the schedule affect the cost of subsequent construction projects based on the time value of money to ensure the facility is ready to receive the new assets and personnel.

In order to meet performance objectives and maximize the number of cutters homeported at Seattle, land acquisition from the Seattle Port Authority is necessary. Based on preliminary conversations, the land to the south of pier 35 has greater viability than that to the north, terminal 46. However, there is uncertainty regarding the CG's ability to purchase either land parcel. In the past, the Port Authority has not been willing to sell or lease the land to the Coast Guard, but in recent years, due to a reduced amount of use and political pressure, the Port Authority has agreed to open negotiations to help meet the Coast CG's need for space. If unable to purchase the additional land from the Port Authority, the CG must pursue COA 2 and fully utilize the existing berths at piers 36 and 37. However, this scenario only enables six ships to be homeported in Seattle. This uncertainty substantially affects the performance capability and mission execution.

The costs associated with real estate, environmental remediation and construction are always unpredictable, especially on the waterfront. The real estate costs for the parcels to the south and north vary slightly (~ 10%) from one another but fluctuate with the market. As a federal organization, the CG must pay an independently appraised value for the property. These prices typically fluctuate within 15% of the original appraisal. Environmental remediation has extremely high uncertainty in normal conditions due to the unpredictable nature of not knowing what one will find until the dredging starts. However, there is less risk of these environmental costs because the CG tested the soil and pre-arranged for dredge disposal sites. Therefore, the reduced uncertainty range for environmental costs lies between -20% and 40% of the estimated costs. Construction costs predicted up to ten (10) years in the future based on 10% conceptual designs have significant uncertainty associated with them. The CG anticipates high uncertainty in construction costs, especially for major repairs, retrofits and upgrades to existing buildings. Furthermore, there is a high likelihood that the CG would change the scope as the plans evolve. Finally, waterfront construction has a higher degree of uncertainty associated with it due to the limited number of contractors in the market with this unique capability and the prevalence of unforeseen conditions in the maritime environment. The current parametric cost estimates follow AACP's class 5 guidance, where the confidence ranges between -30% and 50% (AACE International, 2020).

Sensitivity Analysis

In order to focus the analysis on the most important uncertainties or those that most significantly impact the value of the options, a sensitivity analysis is a helpful tool. Using the worst- and best-case deterministic values for each of the five uncertainties identified in the previous section, the range of possible effects to the metrics of interest were calculated. Table 2 captures the maximum and minimum CAPEX and additional ships per $100M investment for the five most prominent uncertainties. Derived from these values, tornado diagrams help illustrate which uncertainties impact the metrics the most (Figure 4 and Figure 5).

Uncertainty	Increase Ships/Cost	Decrease Ships/Cost	Ships/ Cost Min	Ships/ Cost Max	Financial range	Performance range	CAPEX Minimum	CAPEX Maximum	CAPEX Minimum	CAPEX Maximum
Construction costs	0.17	-0.21	1.35	0.97	$144,395,870	-0.38	-$54.1	$90.2	$371,061,477	$515,457,347
Environmental Redmediation Costs	0.14	-0.19	1.31	0.99	$125,065,657	-0.32	-$44.6	$80.5	$380,601,507	$505,667,165
Land Acquisition	0.00	-0.31	0.87	1.18	$78,483,041	0.31	-$78.5	$0.0	$346,726,887	$425,209,928
Delivery of ship in expected year	0.06	-0.54	1.23	0.63	$69,333,345	-0.60	-$19.1	$50.3	$406,157,789	$475,491,134
Real Estate costs	0.02	-0.02	1.19	1.16	$13,071,600	-0.04	-$6.5	$6.5	$418,674,128	$431,745,728

Table 2. Uncertainty variables influence on NPV and additional Ships/$100M investment

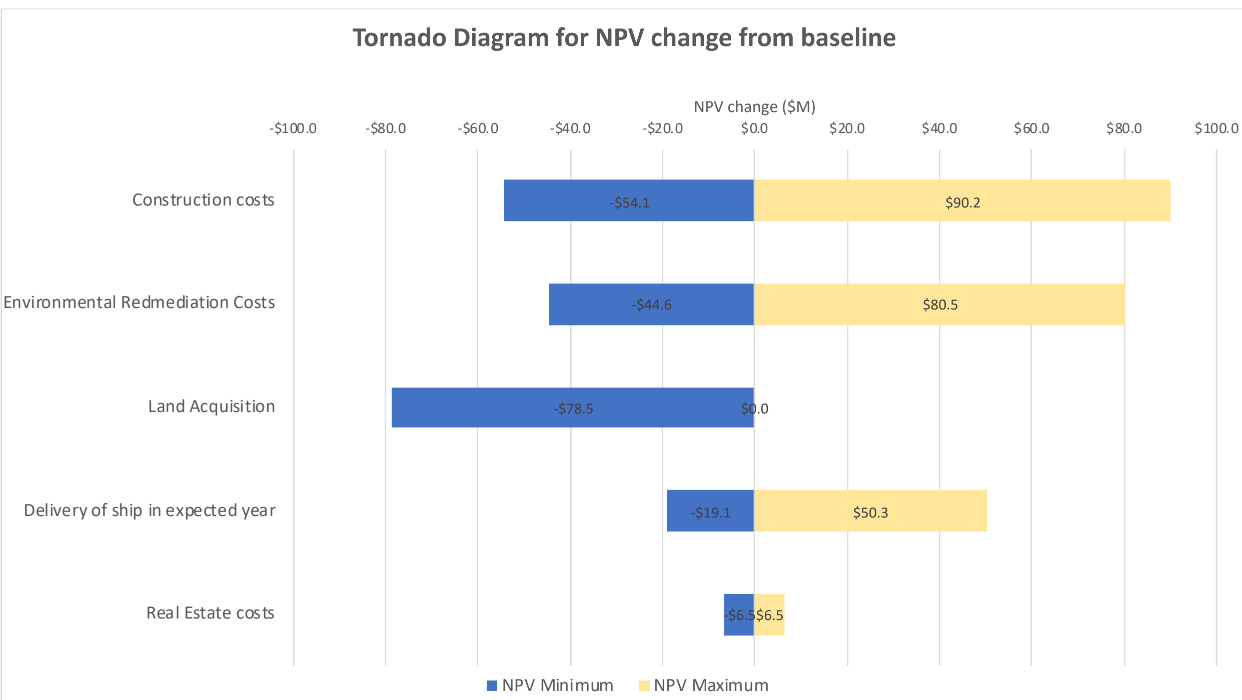

Figure 4. Tornado Diagram for NPV change from baseline COA 3

From the Deterministic Case Section, COA 3 expands the Base to the south at an estimated $425M. Figure 4 shows the sensitivity of these uncertainty variables to this metric, ranking them from the most impactful to least impactful. Because the construction and environmental remediation costs account for over 90% of the project costs, it is not surprising to see these uncertainties having the most significant impact on the project's CAPEX. Nor is it surprising to see the asymmetry in the diagram toward the increased cost for each of these significant cost components as the price typically goes up over time as the scope is better defined. The land acquisition's uncertainty is binary. It can either be purchased, or it cannot, and there is no lease option available. The land acquisition's uncertainty barely edges out the delivery of the ships on their expected schedule uncertainty. However, the impact of work delayed two years or accelerated one-year impacts the dollar's value toward construction, especially over ten years, as observed in Figure 4. Finally, this figure shows the relatively small impact real estate costs has on the project as a whole.

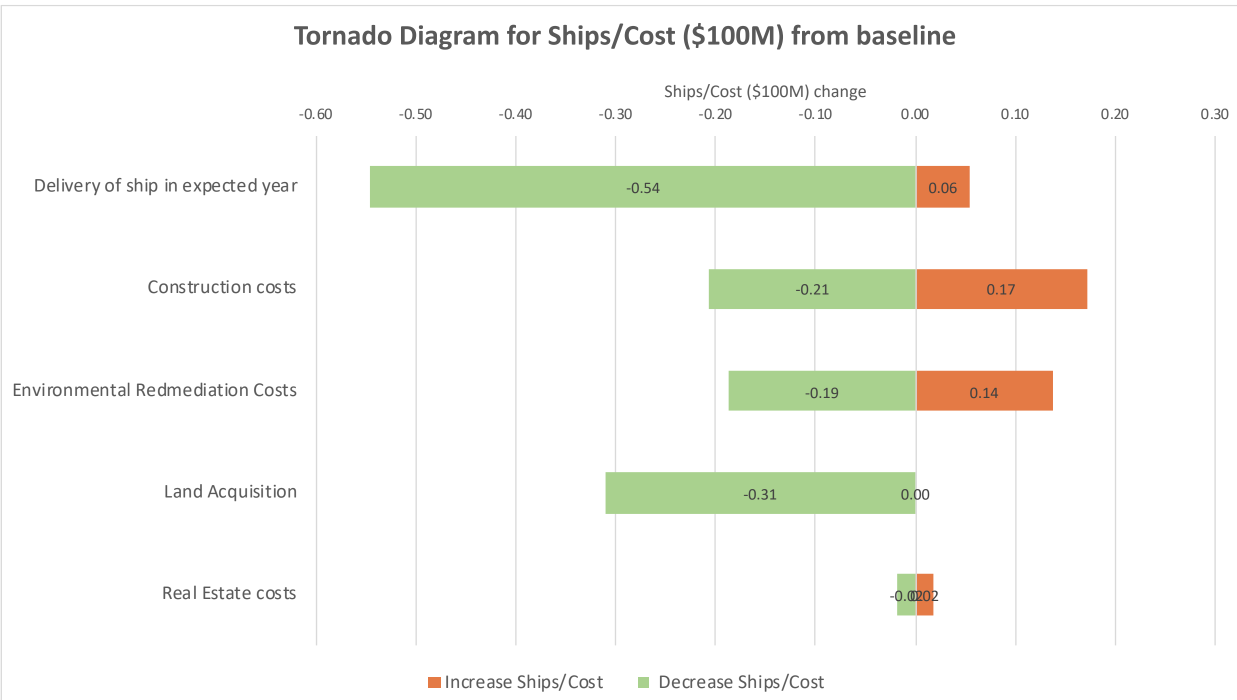

Figure 5. Tornado Diagram for additional ships per $100M capital investment from baseline

The baseline used in Figure 5 is five additional ships (8 total) at $425M or 1.17 ships/$100M. The land acquisition uncertainty limits a negative downside where only three new vessels could be homeported at Base Seattle if additional land is unavailable for purchase. There is no upside to this uncertainty because the baseline case represents this scenario where the land is available, and the capital investment is $425M. However, the most sensitive variable to the performance metric differs from the financial metric in that the delivery of the ships in the expected years has the most pronounced impact. Because neither of the lead ships for the PSC or OPC classes has been delivered to the CG yet, there is significant uncertainty associated with the arrival dates for these vessels. Like the financial metric, construction and environmental remediation cost uncertainty has a sizable influence on the performance metric despite only impacting the denominator in the ratio. Interestingly, there is more downside (green) in the performance metric than upside (red). There are no plans to exceed eight ships at Base Seattle, so the upside is capped, but the downside falls well below the baseline, especially if cutters are delayed in production.

This sensitivity analysis resulted in the need to continue exploring options to reduce the downside and maximize the upside for all of the identified uncertainties except the real estate costs. The real estate costs, although important, do not warrant further analysis based on their relatively minor contribution to the objectives of the project.

Spreadsheet Model incorporating uncertainty and flexibility

The standard valuation model discussed in the Deterministic Case serves as the foundation for the Monte Carlo simulation incorporating uncertainty into the project. Probability distribution functions are matched to the uncertainty variables based on the parameters previously mentioned in the Uncertainty section. An asymmetric triangular distribution best represents the cost uncertainty with construction and environmental remediation. For construction, the best case is 70% of the estimated cost, and the worst case is 150% of the estimated cost. For environmental remediations, the best case is 80% of the estimated cost, and the worst case is 140% of the estimated cost. A simple normal distribution centered on the mean best fits the real estate cost uncertainty. The standard deviation is 15% of the mean.

The ship's delivery, or arrival in an expected year, is best represented by a uniform distribution where a ship can arrive as early as one year in advance or two years late. Because congressional appropriations are fiscal year specific, funding is not accelerated in reality. However, if a ship's delivery is delayed, the associated construction with that delivery can be delayed incurring a cost associated with the discount rate from one year to the next. Although the costs will increase with delayed construction, considerable flexibility is gained if the CG changes its mind on the homeporting location, vessel class and size, or cancels the acquisition for an unknown reason. In this case, the CG can abandon later construction project elements, reducing its total Capital Investment and increasing its additional ships/$100M capital investment ratio.

The spreadsheet model also defers linked project elements. For example, if the environmental remediation of slip 36 is more expensive than initially envisioned, the CG could defer the remediation of pier 35 and consider purchasing additional land if the purchase price of land was cheaper than the expected remediation costs.

Results

There are several actions the Coast Guard could take to offer itself options that mitigate potential losses and take advantage of opportunities. First, the CG could reorder several of the activities and phases to allow land negotiations to occur parallel with actual construction or remediation. Table 3 exhibits the reordered project elements to optimize flexibility and options analysis. For example, the CG could immediately start the CERCLA environmental clean-up projects at pier 35 in 2022 instead of 2023, and the CERCLA environmental clean-up of pier 36 in 2023 instead of in 2026 (denoted in green). They could reorder tasks to build out the Base's current land and configuration to improve the probability of success in negotiations with the Seattle Port Authority for the land and still be ready to receive new ships as they arrive from production. The construction project elements are colored orange, and the real property elements are brown.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2029	2030	2031	
Ship Assets (planned)	4	3	3	3	4	3	5	6	6	6	6	7	8	
Ship Changes	(-) WHEC	(-) WHEC			(+) PSC1	(-) WAGB1	(+) PSC2, (+) OPC1	(+) PSC3, (-) WAGB2, (+) OPC2				(+) OPC3	(+) OPC4	
Personnel	1000	800	800	850	1000	1100	1400	1500	1500	1450	1450	1800	1900	
Project Elements			Slip 36 CERCLA Clean Up	Pier 35 F CERCLA Clean Up	Building 7 Seismic Retrofit and Modernization	Repair Portions of Terminal 46 Wharf	Demolish and Relocate ANT and Magazine	Land Acquisition	Utility Systems Upgrades & Replacement, New Mission Support Building, Security & perimeter system upgrades	New Operations Building, Replace haul routes & pavement	Construct Base Seattle Parking Garage			$425,209,928
Capital Costs (FY21)		$0	$113,547,035	$87,596,056	$95,040,746	$15,257,904	$0	$43,572,000	$53,068,242	$17,127,946	$0	$0	$0	$425,209,928
With Uncertainty		$0	$119,687,069	$92,332,796	$100,117,110	$16,072,867	$0	$36,977,373	$55,902,750	$18,042,792	$0	$0	$0	$439,132,757
Personnel/Cost($M)		0.000	0.000	0.249	0.675	0.963	1.927	1.972	1.715	1.529	1.529	2.352	2.587	**Personnel/Cost($M)**
Ships/Cost ($100M)		0.000	0.000	0.000	0.338	0.000	0.642	0.845	0.735	0.706	0.706	0.941	1.176	***Ships/Cost ($100M)***

Table 3. Optimized COA with reordered project elements

The project element reordering does not change the deterministic capital cost from $425M with COA 3. However, when incorporating uncertainty using the PDFs described in the model section of this report, the slight P50 reduction in NPV is not apparent in the CDF (Figure 6) but discernable in tabular form (Table 4). For the most part, the reordering of environmental remediation tasks before the land acquisition has a slightly positive effect on the CAPEX, but its real benefit is that it enables real options throughout the project's timeline.

By reordering the remediations ahead of the land acquisition, the CG can assess the actual costs of remediating slip 36 and decide if it would be cost advantageous to purchase additional land as an alternative to accommodate the new cutters. The grey line in the CDF (Figure 6) illustrates the effect of this option. It reduces the downside (high NPV) if the environmental remediation costs exceed the land acquisition cost alternative. Figure 7 displays the probabilities for the different scenarios explored thus far.

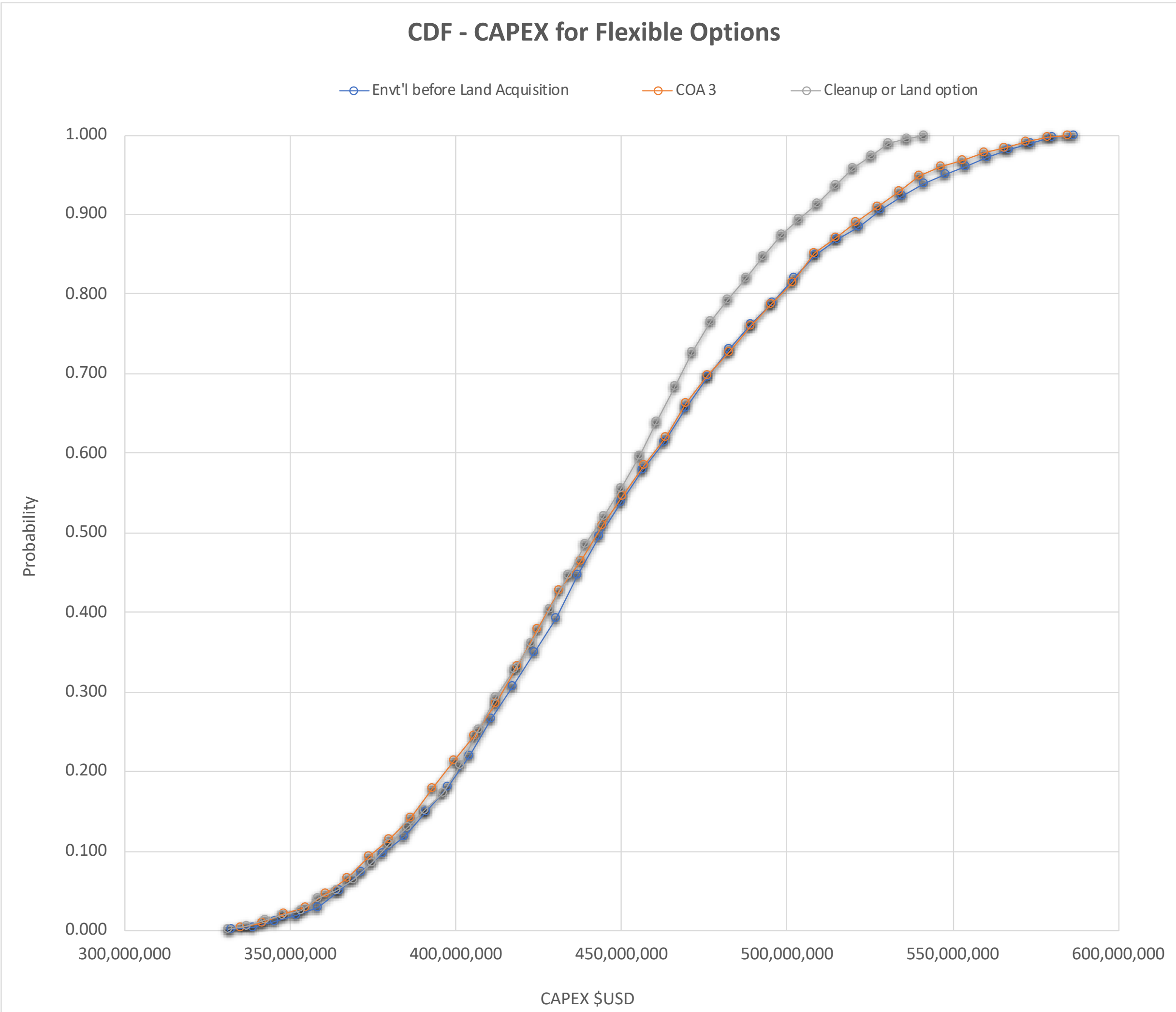

Figure 6. Cumulative Distribution Function for Base Seattle Homeporting project with options

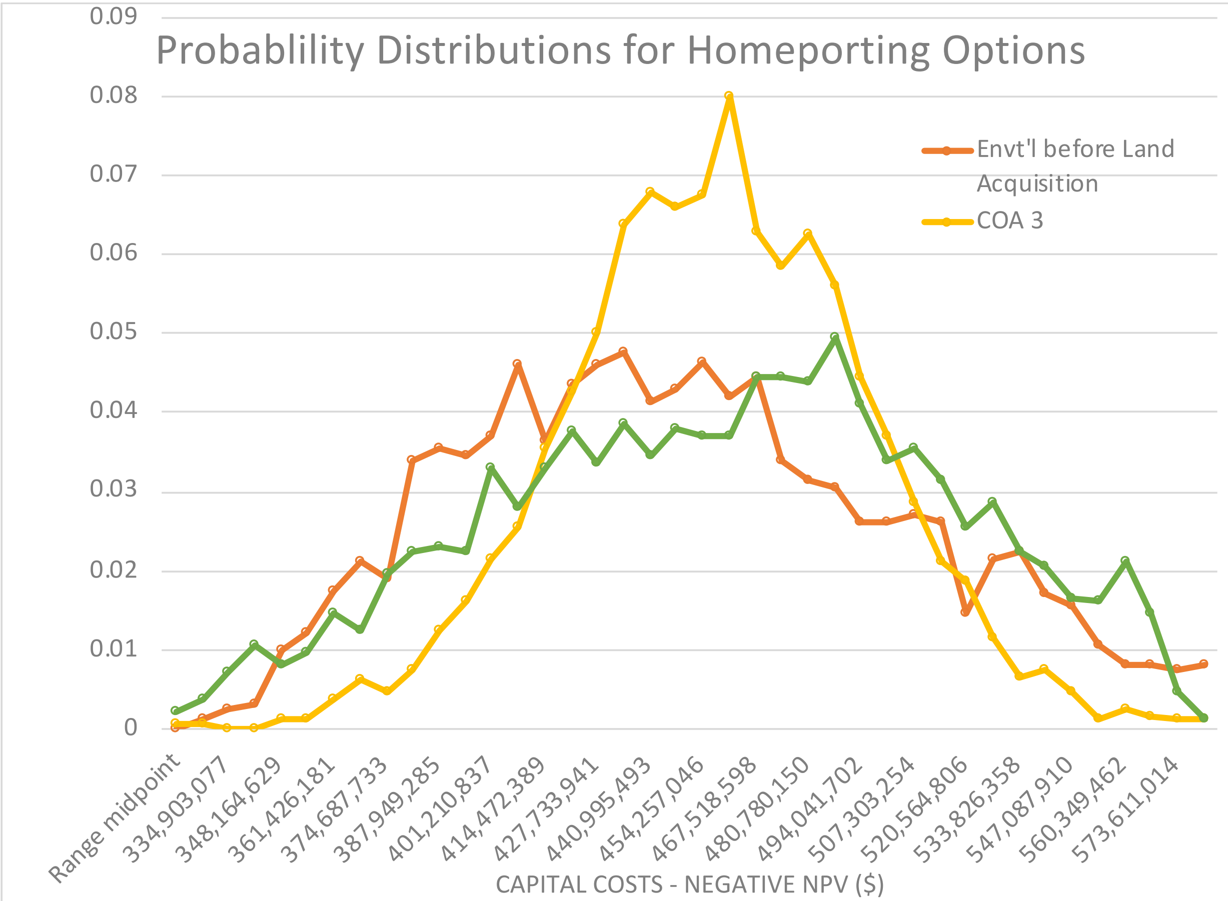

Figure 7. Probability Distributions for Base Seattle Homeporting Options

Another option at the CG's disposal is the ability to defer construction projects as late as possible to react to either delivery delays or cancellations. The seventh and eighth major cutter deliveries do not occur until 2030 and 2031. If the CG decides to homeport those cutters elsewhere or the acquisition of the vessels is cancelled for some unknown reason, the CG may want to understand the costs involved with curtailing construction to accommodate fewer vessels than planned. Figure 8 exhibits the difference between the optimized ordering of project elements, where the environmental remediation projects precede the land acquisition and the delayed delivery of CG cutters. The difference between the two curves in the CDF represents the additional cost of having ships delayed and subsequently delaying construction elements to coincide with the delayed ship's actual arrival. Because ships have twice as much chance of being delayed versus delivered early, and even if the ships are delivered early, the construction cannot occur earlier; the effects on NPV can only be worse.

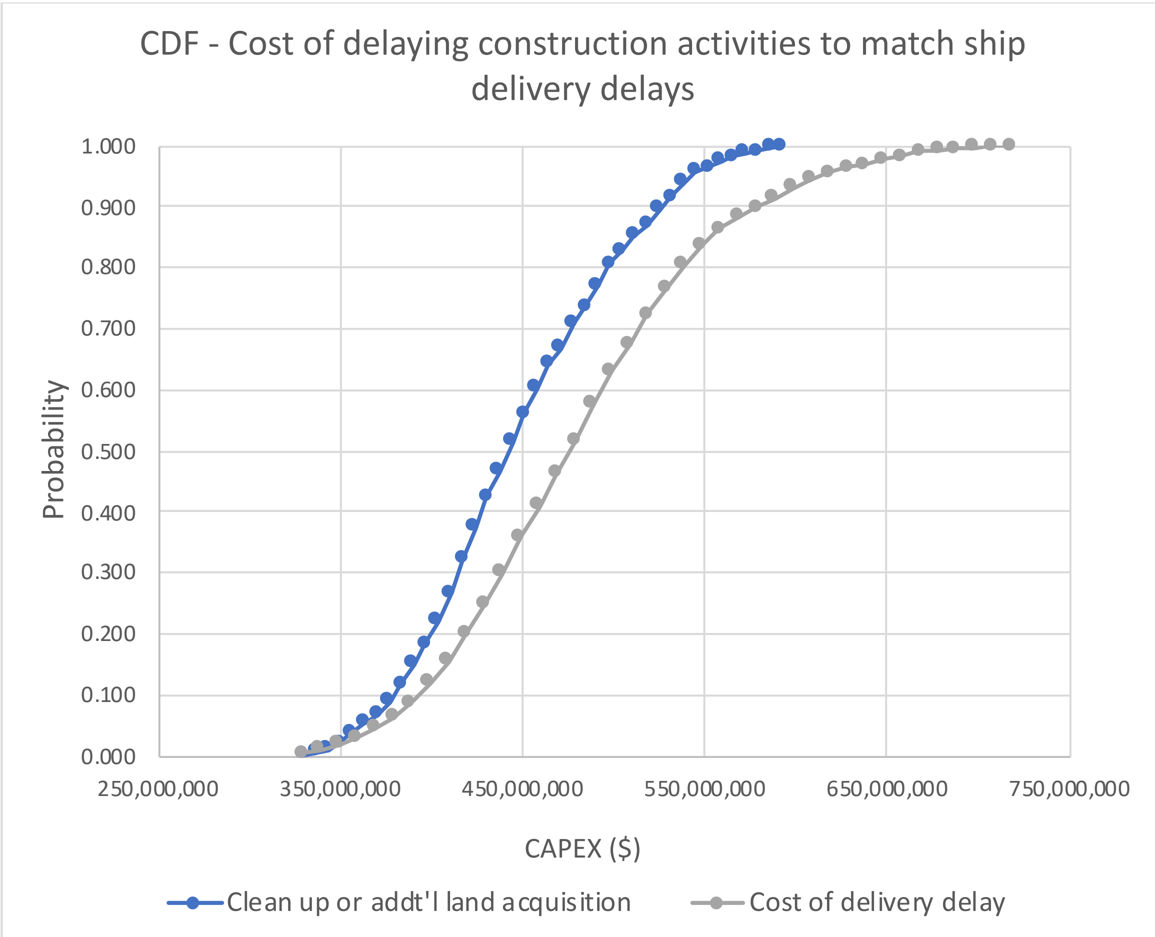

Figure 8. CDF Comparison between optimized reordering of project elements and delayed cutter delivery

Cost is a key metric, but it is also essential to analyze the system's performance metric. In this analysis, the performance metric is the number of additional ships added to Seattle per $100M of investment. It is an indicator of success because homeporting new cutters improves mission capability. By looking at the same parameters as that for the CAPEX assessment, a comparison is available for decision-makers who value cost and performance differently. The CDF in Figure 9 values curves further to the right compared to that of the CAPEX assessment. This illustration highlights the negative aspects of ships being delayed while still incurring the costs to support eight new cutters (yellow line). Also, the original COA 3, optimal reordering of the project elements, and the option to complete the environmental clean-up or purchase additional land have minimal effect on the performance metric. Figure 10 displays the triangular PDFs for the three main options. The P50 value for all three options is approximately 1.1 additional ships per $100M capital investment. The biggest take away from the performance analysis is that the delay of ships significantly impacts the system's performance unless project elements are cancelled due to the changes or delays.

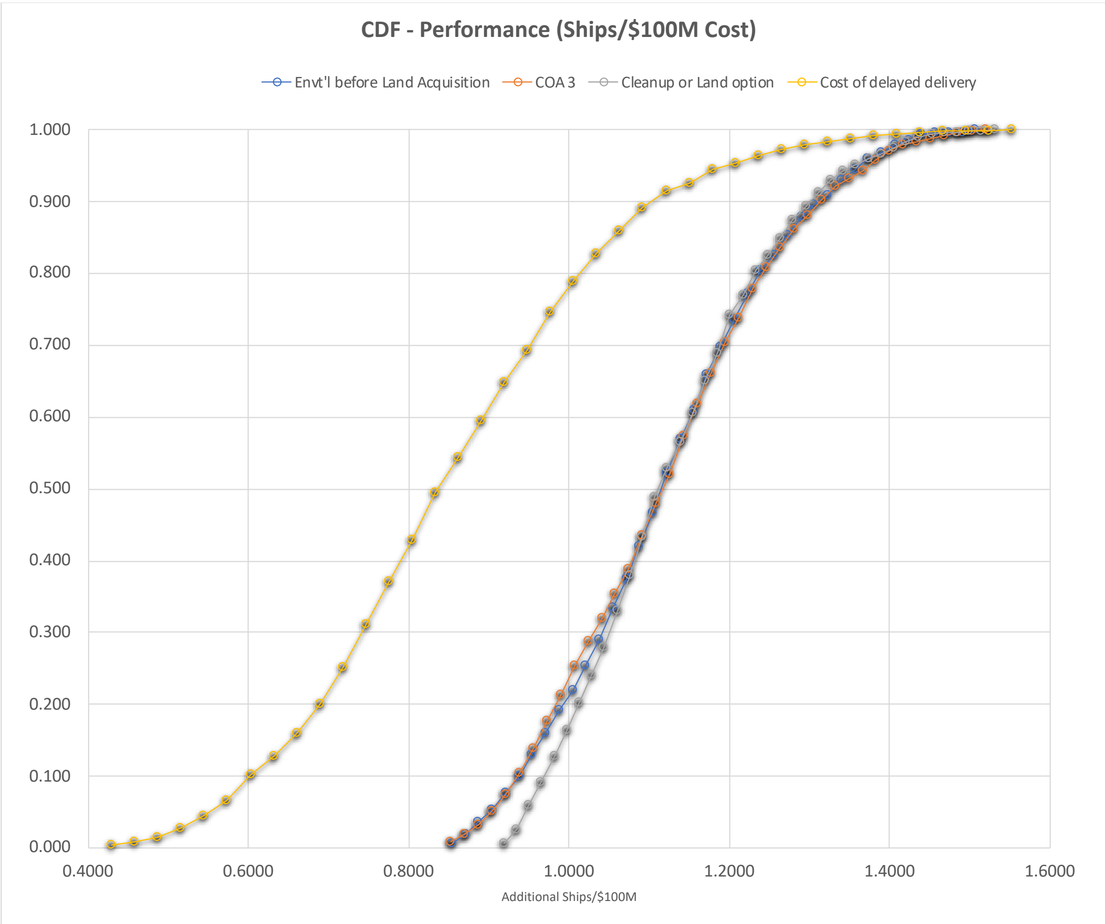

Figure 9. Cumulative Distribution Function for system performance (Additional ships/$100M cost)

Figure 10 displays the PDF for the performance metric. The PDF for COA 3 looks like a symmetric triangle for this simulation. However, the Remediation or land acquisition option and the reordering of the project elements appears to have an asymmetrical triangular distribution skewed toward a lower additional ships/$100M capital investment ratio. Finally, Table 4 offers a tabular view for decision-makers to see the advantages and disadvantages of each scenario. The green highlighted boxes indicate the best comparable values for the associated metric. Although standard deviation can indicate a system's robustness or flexibility, it is difficult to say which is better in this context.

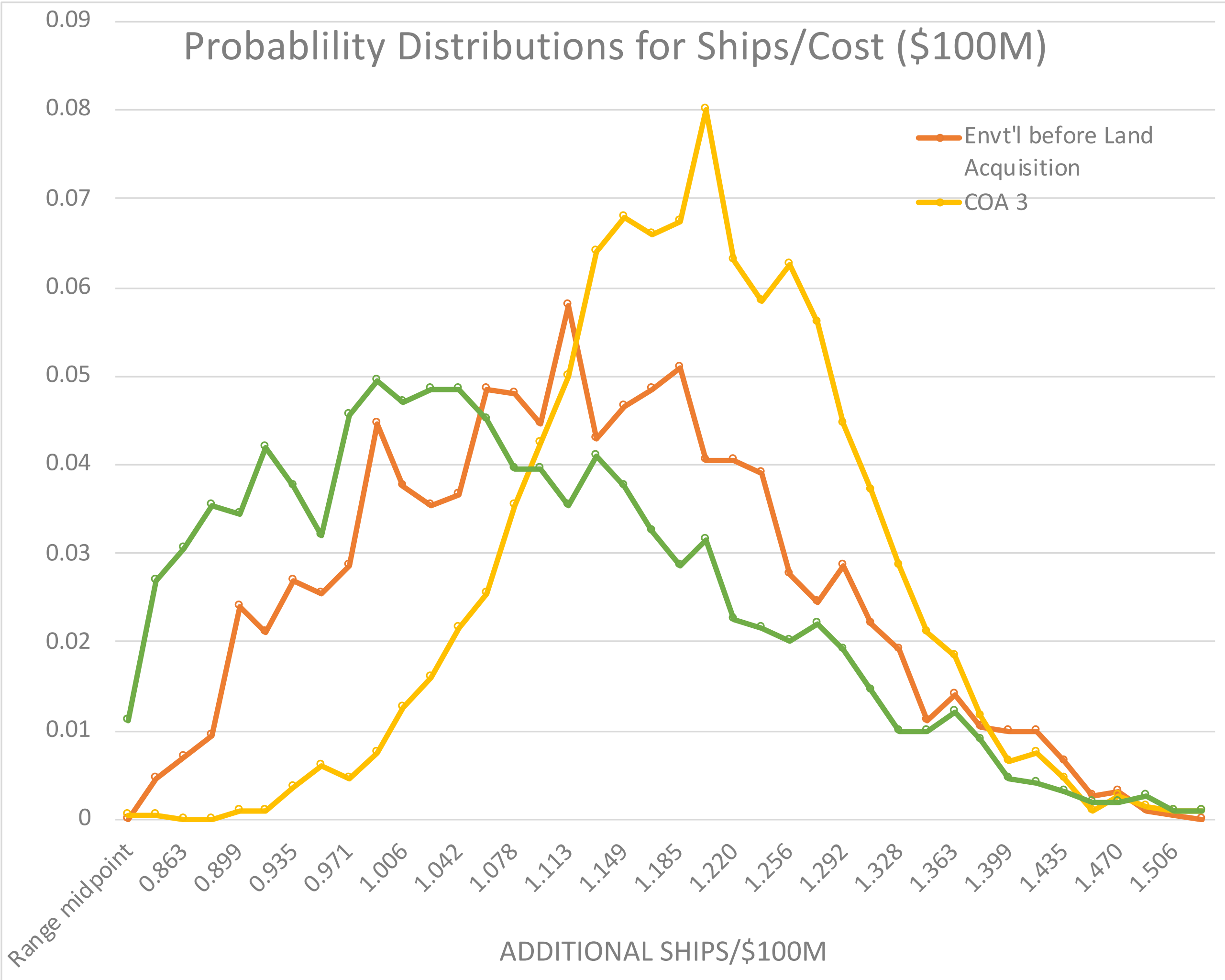

Figure 10. Performance Metric PDF

	COA 3	Re-ordered Elements Envt'l Remediation before Land Acquisition	Remediate Pier 35 or Acquire more land	Delayed cutter deliveries
E(CAPEX)	$ 451,217,993	$ 450,995,388	$ 442,461,755	$ 485,796,139
Std Dev (CAPEX)	12.27%	12.17%	10.59%	14.77%
Maximum CAPEX	$ 600,051,512	$ 595,704,480	$ 546,833,830	$ 722,722,587
Minimum CAPEX	$ 330,432,913	$ 326,442,045	$ 325,040,135	$ 324,435,019
Fixed cost, pay year 1	$ 43,572,000	$ 113,547,035	$ 113,547,035	$ 113,547,035
Flexibility Value (CAPEX)	$ -	$ (222,606)	$ (8,756,238)	$ 34,578,146
E(Addt'l ships/$100M)	1.122	1.332	1.140	0.858
Std Dev (ships/$100M)	12.51%	10.64%	10.81%	22.17%
Maximum ships/$100M	1.537	1.332	1.491	1.499
Minimum ships/$100M	0.834	0.837	0.917	0.423
Flexibility Value (Ships/$100M)	0.000	0.210	0.018	-0.264

Table 4. The tabular form of both financial and performance metrics

Options and Recommendations

Based on the analysis conducted, the CG should reorder its project elements for the Base Seattle expansion. By conducting the environmental remediation upfront and delaying the acquisition of additional land, the CG provides itself with flexibility and other options to reduce the capital investment into the project. Although reordering the elements does not reduce the capital investment necessary if everything proceeds as planned, it offers flexibility in execution, especially regarding its most significant uncertainty, timely ship deliveries. Additionally, this reordering does not harm the performance metric as ships are delivered.

Because ship deliveries and homeport decisions are uncertain, structuring the construction elements that offer the CG more flexibility allows the organization to minimize its losses and maximize the opportunities. This analysis did not account for the cancellation of a homeporting action; but rather only assessed a delay. If a homeport decision is changed and fewer ships are homeported, the CG could cancel or reduce the scope and associated cost of construction projects intended to help support those additional assets. Reduction of scope would have a positive impact on both the financial and performance analysis. However, if a shipbuilder delays a delivery, the CG should not delay construction project elements as this adversely affects CAPEX and performance metrics.

The reordering of the projects created natural groupings of like construction activities such as environmental remediation for slip 36 and pier 35 as well as construction elements such as the retrofit of Building 7 and Wharf repairs, for example. Using actual costs from previous construction elements to inform future decisions helps reduce the downside of higher-than-expected construction or remediation costs. For example, if the Slip 36 remediation has an exorbitant cost, the CG has retained the option to forgo remediating pier 35 at a similar cost a year later. Instead, the CG could exercise the option to purchase additional land at a lower overall cost.

Because the existing land at CG Base Seattle is suitable to support six cutters, delaying the land acquisition keeps all of the COAs presented in the project background available. If the Seattle Port Authority’s preferences change and the land to the north is easier for them to sell, the CG remains poised to adjust its construction plans accordingly. This flexibility not only helps keep costs down and maximizes the number of ships homeported in Seattle, but it also gives the city of Seattle options and builds political capital in a region of immense influence to the CG.

Final Reflection

A flexible approach to design is an alternative way of thinking that in many ways contrasts with a standard engineering principle reinforcing economy of scale. This course and assignment taught me that flexibility provides options in an uncertain world. In my experience, engineers and decision-makers do not like to think about the uncertainty in any given problem. Because it is tough to quantify and understand what we don't know, many tend to ignore it or make assumptions that support an initial plan or way of addressing the problem at hand. Flexible design looks at uncertainty differently. It enables delayed action or decisions that can minimize losses and maximize positive opportunities.

Some of the tools I've learned in this course have helped me focus my attention on the uncertain factors that matter the most. It is easy to get lost in the details because most projects have a myriad of uncertain variables. However, first thinking about metrics that best help define a successful project sets up the problem space effectively. Then, using sensitivity analysis to identify which uncertainty factors most influence a project's success helps focus efforts. Finally, using stochastic analysis techniques helps engineers effectively communicate probabilities that more accurately depict the situation. Simulations create distributions that help decision-makers easily see the advantages of flexible design and the options it enables. (de Neufville & Scholtes, 2011)

Finally, as I continue to ascend in the Coast Guard organization to decision maker levels, I find it valuable to think about the costs and opportunities involved with delayed decisions. This analysis helped me see the impact of delayed homeporting decisions both negatively and positively. The utility of this method makes the effort required to unveil these opportunities well worth it. I can't foresee looking at construction or acquisition projects the same way. I will apply the learnings from this course to develop and review future business cases and planning efforts. I would like to thank Professor Richard de Neufville and Indrayud Biswas Mandal for their help, patience and tutelage.

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