Submitted by:

THE PORT OF VIRGINIA®

In collaboration with

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Jacobs

AAPA 2021 Facilities Engineering Awards: "Pier Pressure" and "Berth-day Safety" Operational Technology Solutions

Title of Project: Port of Virginia Innovative Operational Technology Solutions

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1. Project Description

In partnership with the Port of Virginia (POV), Jacobs and Seaport OPX have developed and implemented a suite of online tools hosted in a digital dashboard to help POV quickly analyze and predict critical operational needs at the POV's three marine terminals in the Hampton Roads, Virginia area. This centralized dashboard houses the tools and at its foundation relies upon the Jacobs implemented comprehensive Geospatial Information System (GIS) database, the POV's "digital twin," to utilize data unique to POV and concepts applicable to any marine terminal. Integrating with the GIS database, NCOS ONLINE, developed by Seaport OPX, enables POV to call vessels safely and efficiently while reducing mooring risks through a robust physics-based port traffic management systems that utilize high performance, cloud-based computing environments to resolve vessel motions and forces.

FIGURE 1 – PROJECT LOCATION

2. Introduction

POV created a multidisciplinary team of internal departments and stakeholders, including Engineering, Operations, and Maintenance, as well as external consultants Jacobs Engineering Group (Jacobs) and Seaport OPX to develop and implement innovative technology-based tools to identify ways to work more efficiently, reduce operational delays, increase productivity and improve safety. By focusing on innovative solutions to problems, the team has developed and implemented five tools that assist POV in performing their work accommodating vessels at the POV's marine terminals. The following are highlights of the project:

- Developed a tool that evaluates berth suitability, including draft and stack height, for all the terminals based upon a specified vessel – the Vessel Berthing Decision Tree Tool.
- Developed a tool that checks the crane suitability for out of gauge (OOG) cargo at each of the berths and makes recommendations towards suggested accommodations (i.e. overheight bar, wires, side plugs, etc.) – the OOG Cargo Evaluation Tool.
- Developed a tool that can automatically plot vessel outlines at each terminal and berth to determine optimal position of ship and cranes for berth alignment by inputting a specific vessel – the Vessel Alignment Tool.
- Developed a tool that provides a real-time view of what is occurring at the different terminals including current environmental conditions, vessel positions and camera views – the Port Conditions at Berth Tool.
- Implemented a tool to automatically and dynamically calculate mooring configurations and identify potential issues 7-days in advance with the NCOS ONLINE Mooring Analysis (MA) module. The tool uses real-time and forecasted weather conditions to provide an early indication that action may be required to prevent breakaways and unexpected events.

3. Goals and Objectives

To facilitate interconnected relationships within engineering and other departments within the Port of Virginia organization, a series of discussions with the POV Operations Team led to the identification of common challenges that could be addressed with innovative engineering solutions. The issues identified related to daily operational and vessel planning practices as well as predicting dynamic heavy weather-related mooring decisions. The team creatively addressed these areas of concern to ultimately reduce unnecessary costs in terminal resources, delays in services, and time spent analyzing berthing and mooring abilities, and improve overall safety of operational activities for both the Port and the shipping lines.

4. Discussion

4.1 Background

POV has seen substantial growth in recent years in terms of cargo throughput, in part due to terminal expansion and capital investments. The vision that POV has to market itself as one of the premier container terminals on the East Coast has also included projects to accommodate Ultra Large Container Vessels (UCLVs) that are more frequently calling at East Coast container terminals. This increased demand of services and conditions has led to new challenges for terminal operators to perform as effectively and efficiently as they were previously able to.

POV's Engineering Department has taken measures to optimize its ability to track infrastructure and assets with the implementation of the GIS initiative to create a "digital twin" of its terminals. As the industry becomes more

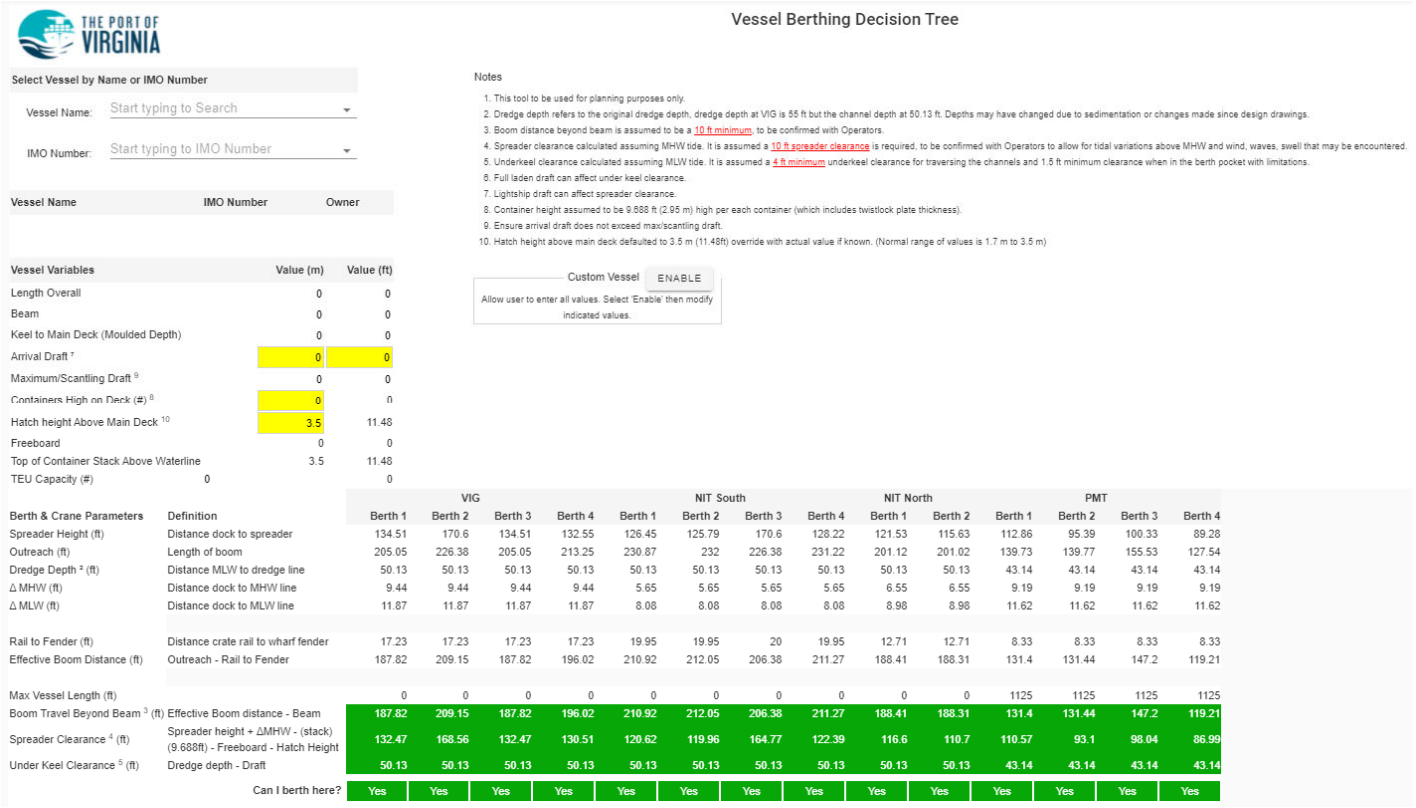
reliant on technology, a substantial GIS program has allowed for POV to take advantage of state-of-the-art advancements that will be standard for operational practice.

The foundation of the Port's GIS program has given POV the platform to create a supplemental set of tools aimed to provide terminal operators and engineers with the resources they need by creatively applying digital technology that was previously unavailable, to quickly and efficiently leverage their assets and infrastructure to evaluate and accommodate customers dynamically. The massive surge in import volumes and vessel calls seen in the US has resulted in shipping lines seeking out terminals that offer flexibility in berthing and crane deployments with greater tier heights. Due a lack of vessel schedule fluidity, bottlenecks have been occurring at many East Coast Ports and with the growing demand for dynamic customer accommodation, now with the assistance of these tools, POV has been able to increase market share by acquiring additional vessel calls and cargo volume from these other ports.

4.2 Objectives and Methodology

One of the new reoccurring challenges seen and expressed by terminal operators is that larger vessels call at the terminals with container tier heights of 6 to 8 high stacks on a regular basis. POV is capable of servicing vessels under these conditions, as they have been investing in larger cranes and terminal infrastructure aimed to accommodate these types of clients specifically, but restows were often necessary to put the vessel in proper condition to work the cargo. POV wanted a way to minimize costly and time-consuming restows and evaluate the suitability of their berths and cranes to accommodate the different vessels and their differing drafts and stack heights easily and rapidly. They wanted to be able to minimize restows and maximize the efficiency of cargo handling without delayed service time and missed opportunities for future clients.

This challenge formed the creation of the Vessel Berthing Decision Tree. Jacobs, along with POV Operations and Engineering, worked together collaboratively to detail the issue and the challenges and produce a tool that solved it. Collectively they were able to work together to form a solution to provide assurance that incoming vessels effectively utilized berth space. During the planning process, it was discovered that terminal planners are under high pressure to accommodate vessel operators and the current process was inefficient and difficult. There was no standardized method of evaluating the different vessels for suitability at the different berths at the POV. At the same time there were many variables to consider; the different vessel particulars, the different crane dimensions, tidal conditions, as well as the planned arrival draft and tier height of the vessel calling at the POV. Terminal planners would simply receive an email from the vessel operator of shipping line with a vessel name, it's arrival draft and tier height and would need to direct the vessel to the proper berth location and do so in a time sensitive manner. This tool was developed by creating a database of vessel particulars for all containerships globally and then combining that with Port of Virginia specific crane, berth and tidal data collected as part of the "digital twin" GIS effort to easily evaluate the suitability of all the different berths at the POV to accommodate the vessel. In today's workplace, after learning during COVID that work can take place outside the office and outside of traditional working hours, it was important the tool was hosted online, on a website where staff could access it wherever they might be and whenever they need it to perform their work. The tool was made to be user friendly, requiring POV only to select the vessel from a searchable drop down list and enter in the incoming draft and tier height, and instantly know the suitability of the different berths to accommodate that vessel. This approach allowed POV to optimize time spent planning for berth space and effectively communicate with shipping lines as to what will be needed days in advance, in addition to minimizing the reoccurring restow issue. The result ultimately provides a resource that is accessible, easy to use and repeatable.



Vessel Berthing Decision Tree

THE PORT OF VIRGINIA

Select Vessel by Name or IMO Number

Vessel Name: Start typing to Search

IMO Number: Start typing to IMO Number

Vessel Name	IMO Number	Owner

Notes

1. This tool to be used for planning purposes only.
2. Dredge depth refers to the original dredge depth, dredge depth at VIG is 55 ft but the channel depth at 50.13 ft. Depths may have changed due to sedimentation or changes made since design drawings.
3. Boom distance beyond beam is assumed to be a 10 ft minimum, to be confirmed with Operators.
4. Spreader clearance calculated assuming MHW tide. It is assumed a 10 ft spreader clearance is required, to be confirmed with Operators to allow for tidal variations above MHW and wind, waves, swell that may be encountered.
5. Underkeel clearance calculated assuming MLW tide. It is assumed a 4 ft minimum underkeel clearance for traversing the channels and 1.5 ft minimum clearance when in the berth pocket with limitations.
6. Full laden draft can affect under keel clearance.
7. Lightship draft can affect spreader clearance.
8. Container height assumed to be 9.688 ft (2.95 m) high per each container (which includes twistlock plate thickness).
9. Ensure arrival draft does not exceed max/scantling draft.
10. Hatch height above main deck defaulted to 3.5 m (11.48ft) override with actual value if known. (Normal range of values is 1.7 m to 3.5 m)

Custom Vessel ENABLE

Allow user to enter all values. Select 'Enable' then modify indicated values.

Vessel Variables	Value (m)	Value (ft)
Length Overall	0	0
Beam	0	0
Keel to Main Deck (Moulded Depth)	0	0
Arrival Draft [7]	0	0
Maximum/Scantling Draft [9]	0	0
Containers High on Deck (#) [8]	0	0
Hatch height Above Main Deck [10]	3.5	11.48
Freeboard	0	0
Top of Container Stack Above Waterline	3.5	11.48
TEU Capacity (#)	0	0

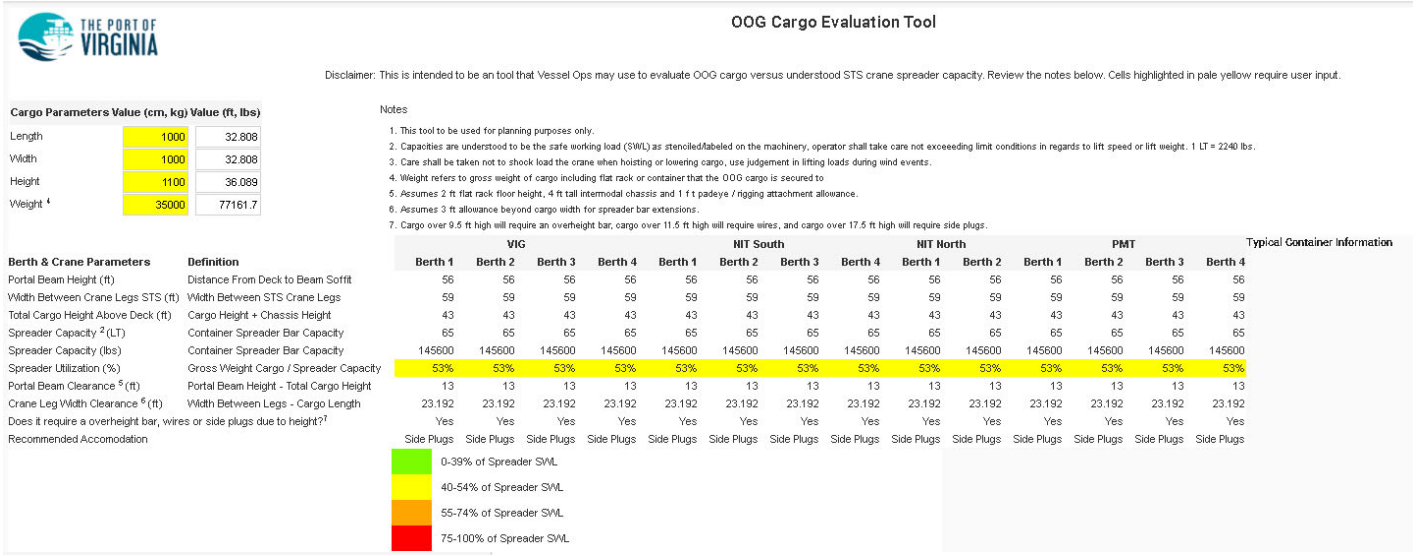
		VIG				NIT South				NIT North		PMT			
Berth & Crane Parameters	Definition	Berth 1	Berth 2	Berth 3	Berth 4	Berth 1	Berth 2	Berth 3	Berth 4	Berth 1	Berth 2	Berth 1	Berth 2	Berth 3	Berth 4
Spreader Height (ft)	Distance dock to spreader	134.51	170.6	134.51	132.55	126.45	125.79	170.6	128.22	121.53	115.63	112.86	95.39	100.33	89.28
Outreach (ft)	Length of boom	205.05	226.38	205.05	213.25	230.87	232	226.38	231.22	201.12	201.02	139.73	139.77	155.53	127.54
Dredge Depth [2] (ft)	Distance MLW to dredge line	50.13	50.13	50.13	50.13	50.13	50.13	50.13	50.13	50.13	50.13	43.14	43.14	43.14	43.14
Δ MHW (ft)	Distance dock to MHW line	9.44	9.44	9.44	9.44	5.65	5.65	5.65	5.65	6.55	6.55	9.19	9.19	9.19	9.19
Δ MLW (ft)	Distance dock to MLW line	11.87	11.87	11.87	11.87	8.08	8.08	8.08	8.08	8.98	8.98	11.62	11.62	11.62	11.62
Rail to Fender (ft)	Distance crate rail to wharf fender	17.23	17.23	17.23	17.23	19.95	19.95	20	19.95	12.71	12.71	8.33	8.33	8.33	8.33
Effective Boom Distance (ft)	Outreach - Rail to Fender	187.82	209.15	187.82	196.02	210.92	212.05	206.38	211.27	188.41	188.31	131.4	131.44	147.2	119.21
Max Vessel Length (ft)		0	0	0	0	0	0	0	0	0	0	1125	1125	1125	1125
Boom Travel Beyond Beam [3] (ft)	Effective Boom distance - Beam	187.82	209.15	187.82	196.02	210.92	212.05	206.38	211.27	188.41	188.31	131.4	131.44	147.2	119.21
Spreader Clearance [4] (ft)	Spreader height + ΔMHW - (stack) (9.688ft) - Freeboard - Hatch Height	132.47	168.56	132.47	130.51	120.62	119.96	164.77	122.39	116.6	110.7	110.57	93.1	98.04	86.99
Under Keel Clearance [5] (ft)	Dredge depth - Draft	50.13	50.13	50.13	50.13	50.13	50.13	50.13	50.13	50.13	50.13	43.14	43.14	43.14	43.14
	Can I berth here?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

FIGURE 2 – VESSEL BERTHING DECISION TREE

The success of this tool led to the request for additional tools that would help POV maximize their abilities in addressing other challenges that they frequently experience. By building upon the past success in collaboration, POV Engineering, Operations and Jacobs were able work together to create other tools that solved reoccurring challenges and this effort produced the subsequent Out of Gage (OOG) Cargo Evaluation Tool, the Vessel Alignment Tool, and the Port Conditions at Berth Tool. OOG cargo is considered anything that cannot be loaded into a six-sided shipping container or exceeds a 40-foot high cube container's dimensions. Examples of the OOG cargo include very large vehicles, trailers, aircraft parts, wind turbine parts, large machinery, or construction equipment.

It has traditionally been very logistically difficult to plan for OOG cargo in advance, and to evaluate what needs to be done to accommodate it. When OOG cargo comes through a terminal, there are a series of questions that need to answered and parameters that need to be analyzed in a way that is similar to the Vessel Decision Tree. To successfully work OOG cargo, certain preparations must be put in place ahead of time so that there is not a delay in service and that charges to the shipping line can be accurately expressed in advance. Cargo that exceeds the safe working load of the specified ship-to-shore (STS) crane entails that additional measures are required including hiring an outside floating crane to work the cargo, which will in-turn entail additional associated costs.

POV's new OOG Cargo Evaluation Tool takes into account the cargo dimensions, such as length, width, and height; the OOG cargo's weight, and the crane's spreader capacity to make recommendations for accommodating the OOG cargo, such as utilizing over-height bars, wires, and side plugs.



OOG Cargo Evaluation Tool

Disclaimer: This is intended to be an tool that Vessel Ops may use to evaluate OOG cargo versus understood STS crane spreader capacity. Review the notes below. Cells highlighted in pale yellow require user input.

Cargo Parameters	Value (cm, kg)	Value (ft, lbs)
Length	1000	32.808
Width	1000	32.808
Height	1100	36.089
Weight [4]	35000	77161.7

Notes

1. This tool to be used for planning purposes only.
2. Capacities are understood to be the safe working load (SWL) as stenciled/labeled on the machinery, operator shall take care not exceeeding limit conditions in regards to lift speed or lift weight. 1 LT = 2240 lbs.
3. Care shall be taken not to shock load the crane when hoisting or lowering cargo, use judgement in lifting loads during wind events.
4. Weight refers to gross weight of cargo including flat rack or container that the OOG cargo is secured to
5. Assumes 2 ft flat rack floor height, 4 ft tall intermodal chassis and 1 f t padeye / rigging attachment allowance.
6. Assumes 3 ft allowance beyond cargo width for spreader bar extensions.
7. Cargo over 9.5 ft high will require an overheight bar, cargo over 11.5 ft high will require wires, and cargo over 17.5 ft high will require side plugs.

Berth & Crane Parameters	Definition	VIG				NIT South				NIT North				PMT				Typical Container Information
		Berth 1	Berth 2	Berth 3	Berth 4	Berth 1	Berth 2	Berth 3	Berth 4	Berth 1	Berth 2	Berth 1	Berth 1	Berth 2	Berth 3	Berth 4		
Portal Beam Height (ft)	Distance From Deck to Beam Soffit	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56		
Width Between Crane Legs STS (ft)	Width Between STS Crane Legs	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59		
Total Cargo Height Above Deck (ft)	Cargo Height + Chassis Height	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43		
Spreader Capacity [2] (LT)	Container Spreader Bar Capacity	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65		
Spreader Capacity (lbs)	Container Spreader Bar Capacity	145600	145600	145600	145600	145600	145600	145600	145600	145600	145600	145600	145600	145600	145600	145600		
Spreader Utilization (%)	Gross Weight Cargo / Spreader Capacity	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%		
Portal Beam Clearance [5] (ft)	Portal Beam Height - Total Cargo Height	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13		
Crane Leg Width Clearance [6] (ft)	Width Between Legs - Cargo Length	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192	23.192		
Does it require a overheight bar, wires or side plugs due to height?[7]		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		
Recommended Accomodation		Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs	Side Plugs		

0-39% of Spreader SWL
40-54% of Spreader SWL
55-74% of Spreader SWL
75-100% of Spreader SWL

FIGURE 3 – OUT OF GAUGE (OOG) CARGO EVALUATION TOOL

To address the ability to berth a vessel accurately and safely, POV and Jacobs developed the Vessel Alignment Tool. Reports around the world show how catastrophic it can be when cranes are not pre-staged properly or pilots are not accurately informed about the berthing of their vessel to align with cargo operations. Having a vessel in the wrong position means delays, tugs need to reposition the vessel and potentially it affects adjacent berths with a cascading effect as well as the possibility of collision with STS cranes due to flare of vessel bow of overhang of stern. Additionally, there was no easy way to rapidly model where future vessels should align at the different berths at POV. Cranes prepositioned to optimally unload containers fore and aft of the bridge increases the efficiency of operations and reduces delays. This tool applies data collected regarding bridge location, and builds upon the previously compiled vast dataset of the vessel particulars along with berth information from the GIS "digital twin" to be able to rapidly plan for any vessel at any terminal at POV.

Similar to the Vessel Berthing Decision Tool, POV Operations and Engineering, and Jacobs collaboratively worked together to define the problem and produce a user-friendly solution. With the tool produced, POV was now able to pre-plan for any scheduled or theoretical vessels, selecting any container vessel in the world from a searchable, drop down menu and the ship is drawn, precisely, to-scale, including the bridge position, at any of the terminals at POV. Workers on the ground can find a specified footmark based on the results outputted by the tool to understand exactly where cranes need to be and where the vessel needs to be as well, the light truck gives the POV Pilots the confidence that they are aligned optimally at berth. The vessel alignment can be carefully and readily planned and the optimal position of the vessel at the berth can be determined remotely with just a few clicks of the mouse. This tool allows POV to plan for the upcoming vessels and position light-trucks at the target alignment along the berth, minimizing any repositioning by costly tugs, and ensuring the cranes are correctly prepositioned, safely outside the clearance areas for berthing, and will be ready to work the cargo right away, without delay when the vessel berths at POV.

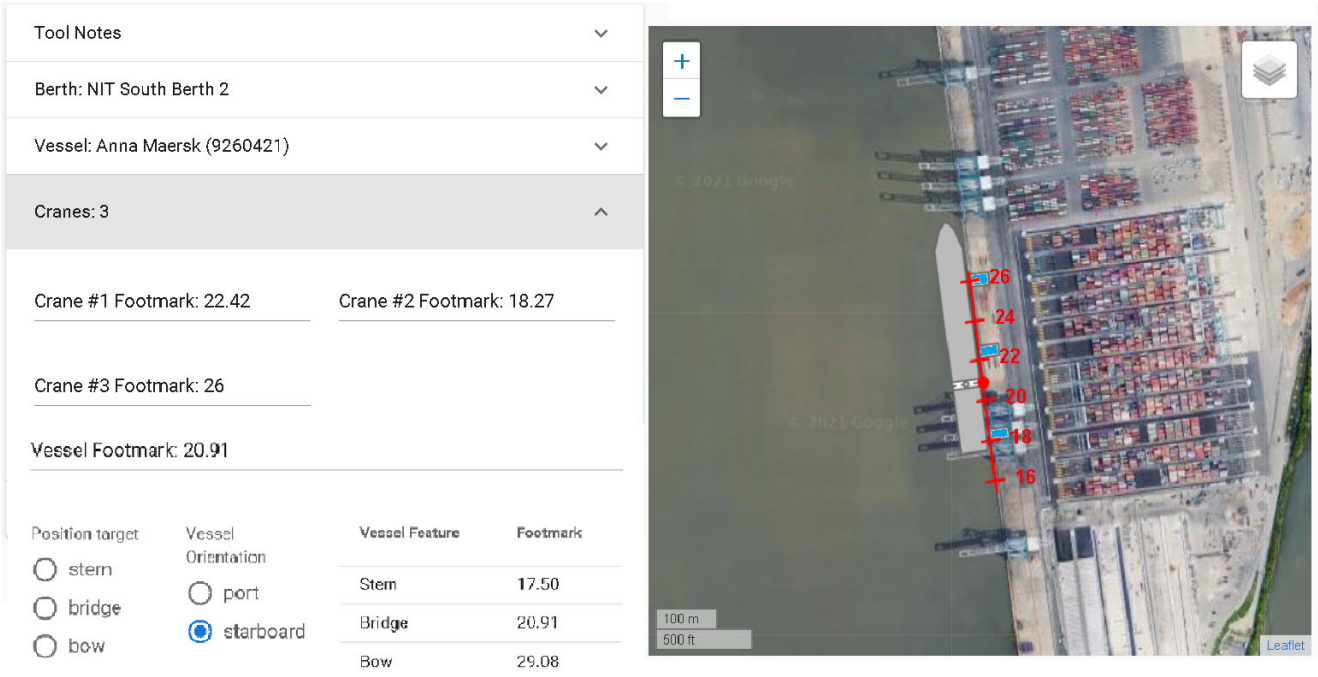


FIGURE 4 – VESSEL ALIGNMENT TOOL

The final tool, currently in-process of development, allows for a real-time look at what is happening at different berths around POV. While the previous three tools all allow for POV to plan for what will happen, this tool give POV a snapshot of what is currently happening now. Similar to the previous tools, this tool is built upon the GIS "digital twin" foundation and provides POV with a multi-facetted, heads-up display that takes vessel location information shows it on a map of real-time activity that is on-going at the POV. Users can see where the different vessels are at berth, as well as tugs and incoming and departing vessels relying upon automatic identification system (AIS) vessel tracking. This information is combined with real-time environmental information, tides, current, wind, temperature, etc. as well as camera views showing visually what is occurring. POV can use this tool to allow them to check what is going on, another tool to remotely monitor and check on the operations at the POV terminals.

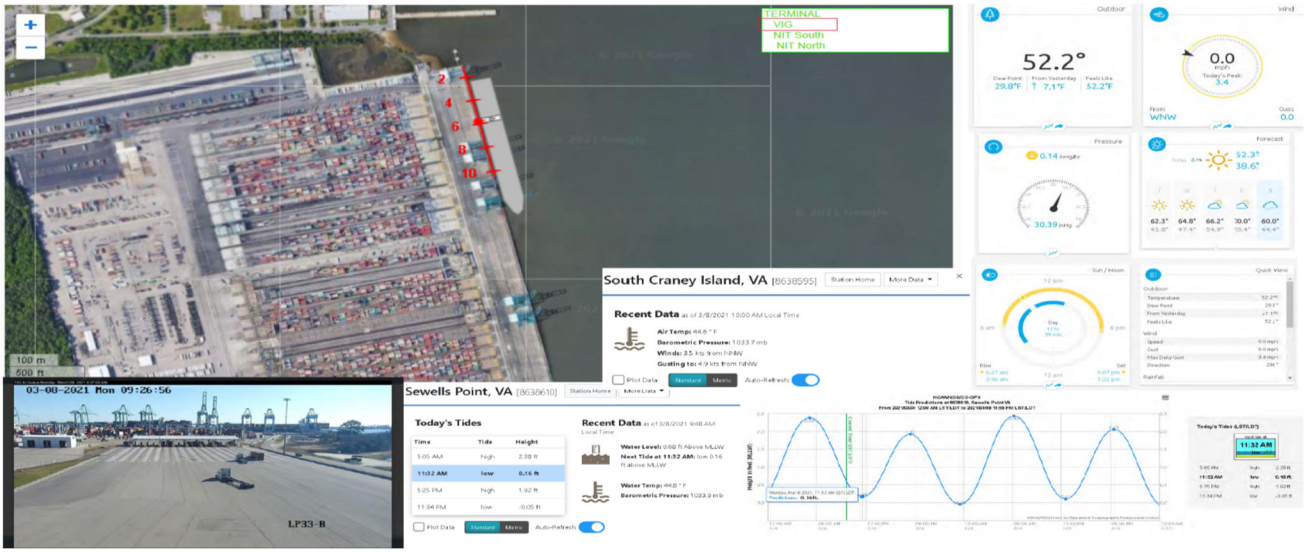


FIGURE 5 – PORT CONDITIONS AT BERTH TOOL

Similar to the other tools this tool is also hosted online from an easily accessible Ops Dashboard website, so that POV can go to a single unified site to perform their evaluation and planning of upcoming vessel arrivals. They have one place to check and plan their work. The Ops Dashboard hosts all these tools and addresses the POV needs in a user-friendly way to assist them in their daily routines. Alongside these aforementioned tools, the NCOS ONLINE Mooring Analysis tool developed by Seaport OPX is also accessible on this same Ops Dashboard.

During adverse weather conditions like high winds and storm events, the Operations team relays heavily on the Engineering Department to assist with evaluating the safety of the ships at berth. These evaluations were often time consuming, based on static conditions, and did not provide the level of accuracy to assure safe berthing conditions. As a result, POV was spending hundreds of thousands of dollars on tug resources to hold a ship at berth or transiting ships to anchorage to wait out the storm.

To improve support activities for Operations, Engineering implemented the NCOS ONLINE Mooring Analysis (MA) module. Using NCOS ONLINE, Engineering is able to screen mooring risks days in advance and monitor risks in real time as weather forecasts update. NCOS ONLINE runs complex and accurate mooring assessments in minutes enabling Engineering to provide their support to Operations on a day-to-day basis in addition to during storm events.

NCOS ONLINE represents a complete "digital twin" of POV's physical assets and environmental conditions relevant to the mooring analysis at Norfolk International Terminal (NIT)and Virginia International Gateway Terminal (VIG), namely quay details, bollards, and fenders as well as winds, waves, currents, and water levels. The system integrates directly with POV's GIS data to ensure the correct information is utilized for mooring assessments. This mooring information and geospatial data are hosted in a secure, cloud based NCOS ONLINE portal enabling access from the office and the terminal.

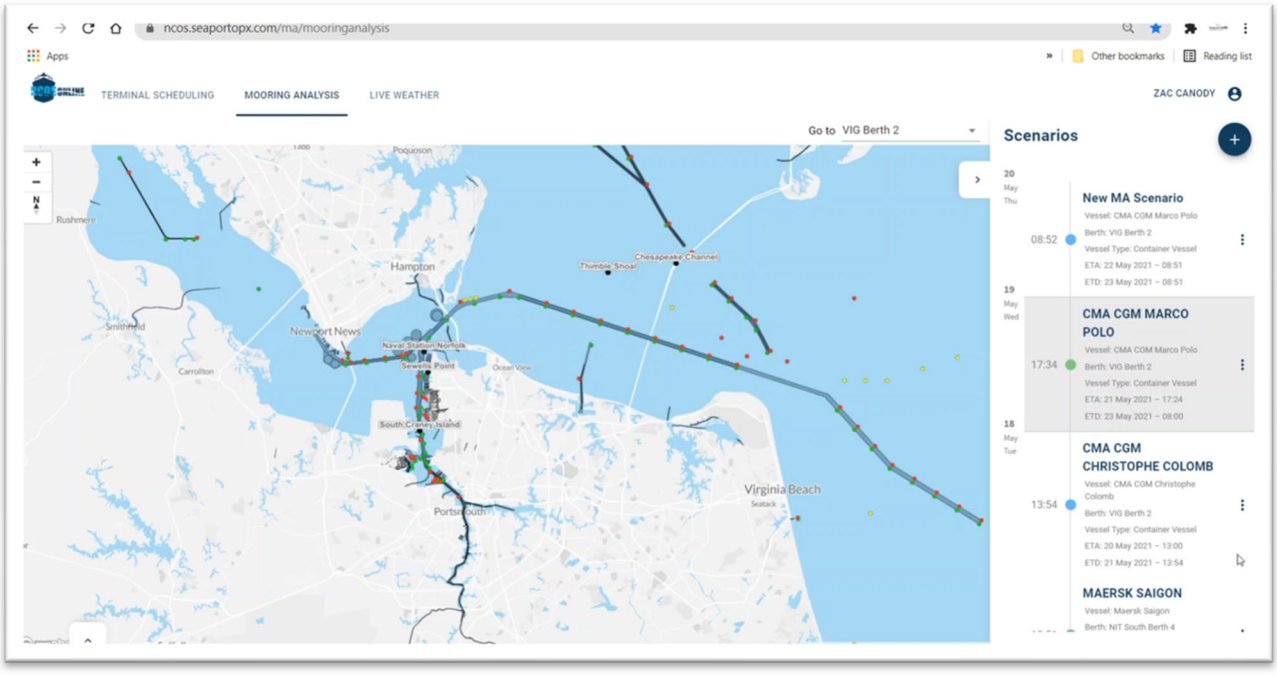


FIGURE 6 – NCOS ONLINE INTERFACE

Through POV's NCOS ONLINE portal, Engineering users enter a moored vessel using the 'autofill' feature that allows the user to select a vessel from Seaport OPX's Fleet Manager and POV's vessel databases. Upon vessel selection, this feature automatically pre-fills in vessel particulars such as Length Overall (LOA), Length between perpendiculars (LPP), Beam, and Deadweight Tonnage (DWT). Dynamic vessel particulars such as Metacentric Height (GM) and Draft are entered manually as these vary on a call-by-call basis.

New vessels can be manually assigned a terminal and berth or dragged and dropped onto the target berth. The assigning of a terminal and berth takes into account POV's existing berth planning logic and tools developed by Jacobs. This includes berth configuration optimization accounts for relevant POV port guidelines such as the maximum allowable number of lines per bollard and minimum vessel spacing.

Using a list of predefined mooring arrangements and vessel configurations, line configurations are specified for each mooring scenario. The system also supports manual edits of line configurations of targeted mooring configurations.

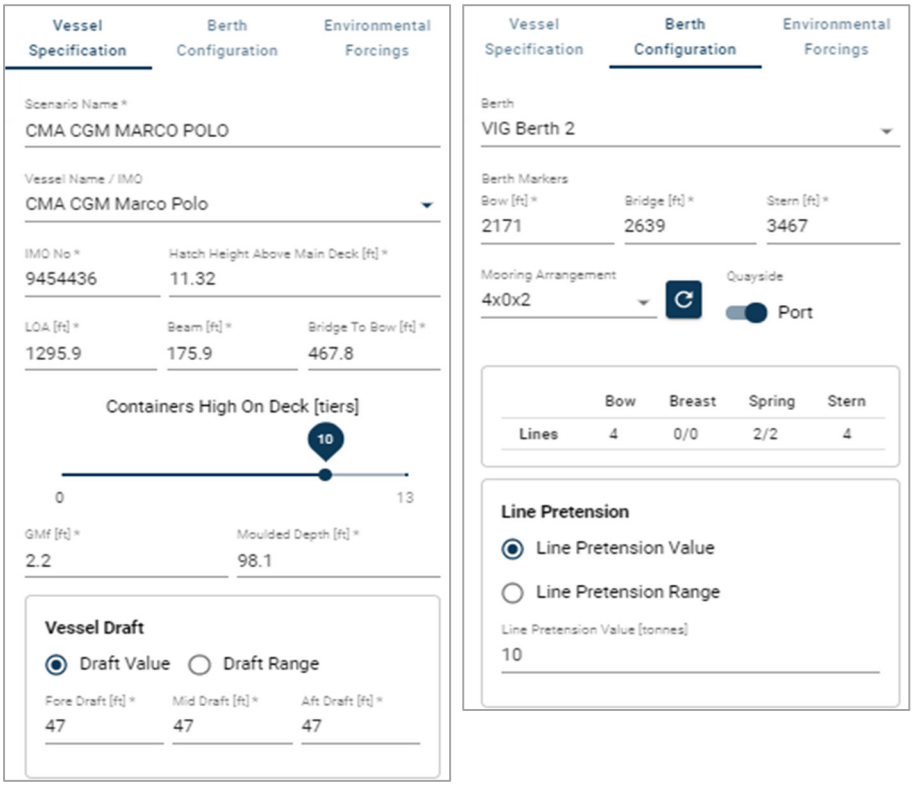


FIGURE 7 – NCOS ONLINE SCENARIO BUILDER - VESSEL AND BERTH SELECTION

The environmental conditions are determined based on detailed 7-day forecasts covering the period which each vessel is scheduled to be at berth. Based on forecasted conditions, an auto-generated recommendation on how to most effectively and safely moor each vessel depending on the weather and terminal occupancy is generated. This report includes bollard, fender and line loads as well as maximum vessel motion for the specified vessel under the specified environmental conditions with the specified mooring arrangement

Once a moored vessel is entered into the system, NCOS automatically monitors the forecasted moored vessel performance and issues warnings and recommendations if the weather forecast starts to change adversely. Alerts are issued through email and SMS and are effectively monitored in Map View using a traffic light colored alert system to indicate the status of each moored vessel.

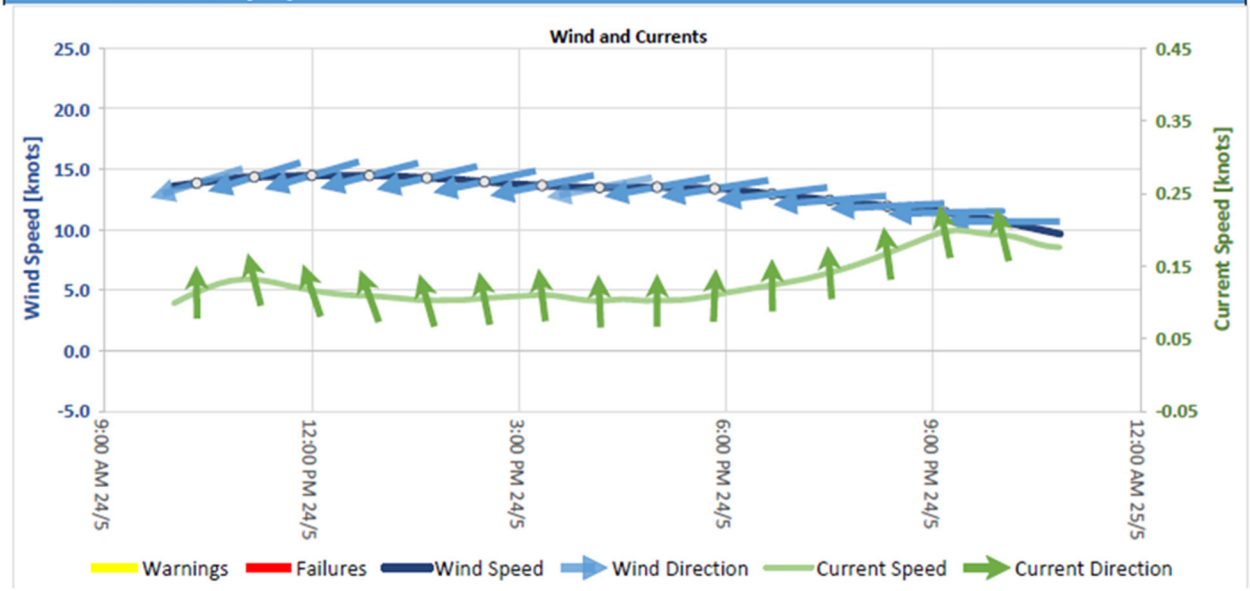
NCOS ONLINE Mooring Report
Vessel: CMA CGM Marco Polo (9454436)
Dynamic Berth Forecast
Issued 11:14 AM 24 May 2021

DRAFT

Vessel Specification			
Class	Container Vessel	DWT	186470 t
IMO No	9454436	Beam	175.9 ft
LOA	1295.9 ft	Bridge to Bow	467.8 ft
Moulded Depth	98.1 ft	Tiers on Deck	10
Hatch Height	11.32 ft	Total Height Above WL	161.2 ft
BABLI File Input	NO	Windage (L)	221437 ft²
Displacement	185915 t	Windage (T)	32801 ft²
GMf	2.2 ft	Draft	45 ft
Vessel TEU	16020		

Berth Configuration			
Terminal	VIG	Berth	VIG Berth 2
Bridge Marker	2868 ft	Berth Pocket Length	938 ft
Wharf Height	11.9 ft	Dredged Depth (MLLW)	50.13 ft
Min Water Depth	50.9 ft	Max Water Depth	54.1 ft
Lines Drawn	16	Line Pretension	10 t
Deck above Wharf	42.6 ft-42.6 ft	Outreach beyond Beam	33.3 ft
Spreader Clearance	21.3 ft-21.3 ft	UKC	5.1 ft-5.1 ft

Berth Plan Forecast Synopsis



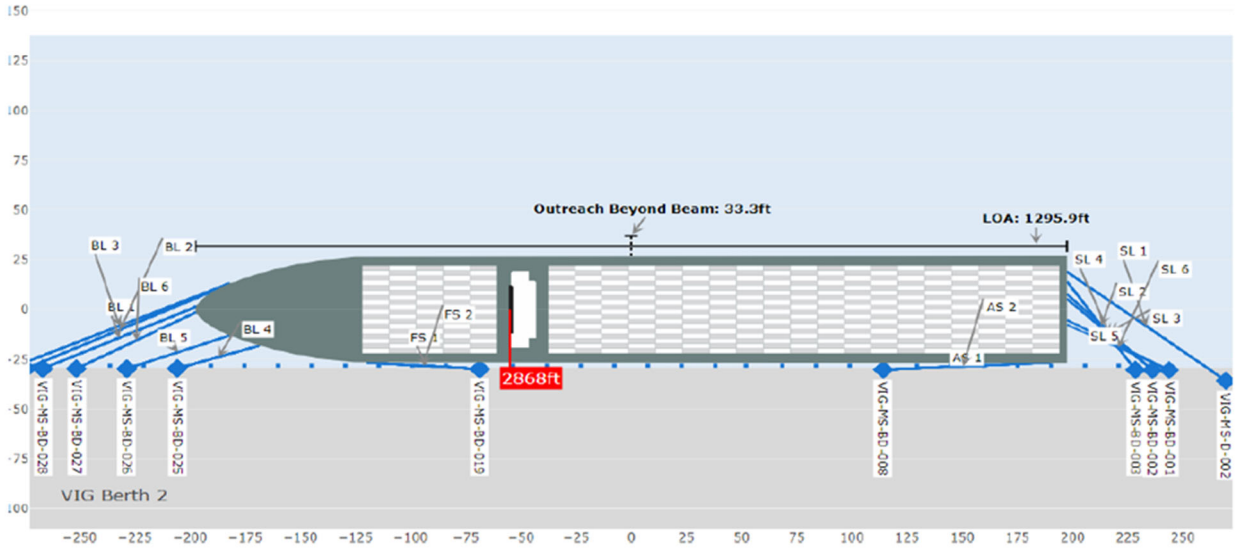


FIGURE 8 – NCOS ONLINE MOORING REPORT DYNAMIC BERTH FORECAST

Both the mooring report and alerts are made available to the Ops team. With this information, Operations are able to engagement with ships' agents, captains and pilots regarding to how to most effectively and safely moor their vessel prior to calling.

NCOS ONLINE also offers POV Engineering the option to run scenarios based on pre-defined environmental conditions to support planning efforts. Engineering is able to select the range of environmental forcing to be analyzed consisting of a user-specified matrix of wind, wave, current and water level scenarios. The subsequent mooring analysis will consider each selected mooring arrangement under the selected environmental conditions. This enables Engineering to evaluate whether larger vessels are safe to berth at POV terminals.

Seaport OPX has worked closely with POV through a series of workshops to insure the NCOS ONLINE system is both fit for purpose and use. These workshops enabled POV to provide feedback on additional functionalities and limitations specific to their operating standards and procedures.

Seaport OPX delivers long-term, sustainable change management through operational support that engenders trust at every level of the organization. Organizational change is always difficult, but well-structured change management plans with the flexibility to adapt to individual needs and learning approaches has enabled Seaport OPX to successfully manage NCOS's implementation at POV. Seaport has thoroughly planned the NCOS implementation, and all user training and engagement has been staged and individualized based on users' technical competency and system use needs.

Seaport OPX understands that POV works 24/7 to ensure the safety of its ships, the security of its working terminals and the protection of its marine environment. To support this, Seaport OPX includes an ISO-certified 24/7 support line under the license fee. The 24/7 Support technical team is always on standby to address any user questions.

4.3 Hardware and Software Used

Developed by Seaport OPX, NCOS ONLINE provides an integrated web-based platform for supporting a wide range of critical port workflows covering both strategic planning and 24/7 operational support services. In recognition that no two ports have the same needs, NCOS ONLINE was designed to be modular, which means you only pay for the services you need, when you need them.

NCOS ONLINE represents a physics-based digital model of port assets, empowering defensible, optimized strategic and operational decision-making. This sets the system apart from pure logistics-type port management systems, as NCOS is capable of providing accurate optimization support based on the dynamic hidden capacity potential and constraints provided by the physical port environment. Access to this technology stack takes place through a series of intuitive online Ops Dashboard which is tied to the POV "digital twin" GIS system.

The unique combination of cutting-edge vessel response engine and the state-of-the-art, high-resolution metocean models provides clear benefits with regards to improved accuracy and versatility for correctly calculating vessel response for modern larger and wider vessels.

NCOS ONLINE incorporates DHI's state-of-the-art dynamic mooring analysis software, MIKE 21 Mooring Analysis (MA), to inform the response of each moored vessel under a range of environmental criteria. MA is a 3D time domain (dynamic) deterministic mooring analysis tool which solves the 6 Degrees of Freedom (DOF) motions and forces of the vessel and mooring respectively. The solver specifically addresses dynamic and non-linear mooring line, bollards and fender reaction forces, and depth-dependent hydrodynamic interaction between the vessel and quay. In many cases, complex environmental conditions such as wind gust frequency or passing vessel response are critical to moored vessel response due to a specific vessel's natural resonance frequency. MIKE 21 MA accounts for these impacts with an unparalleled accuracy but without compromising the need for computational speed and timely on-demand results.

NCOS (MIKE 21) MA adopts a highly sophisticated approach to computationally resolving ship hydrodynamics, first calculating the frequency-dependent response of the vessel represented by a 3D panelized grid, replicating

the ship's hull form exactly. The diffraction forces are then calculated based on the incident forcing acting on every single panel along the vessel hull. As a result, the vessel response can be evaluated for any given non-uniform hydrodynamic loading acting across the hull boundary.

Seaport OPX's metocean forecasting is also powered by DHI's MIKE suite of modelling software. The POV NCOS ONLINE portal includes 2D flexible mesh model to cover the VIG and NIT terminals to simulate waves, currents, winds and sea levels (tide plus residuals). The spectral wave model (SW) simulates wave transformation within the Port area while the hydrodynamic (HD) model simulates water levels and currents within the Port area.

The HD model also simulates tidal signals in combination with local wind shear stresses and bathymetric pressure to provide a forecast of general circulation and sea levels within the port domain. The SW model will approximate the transformation of ocean swell within the port domain as well as the generation of local wind waves.

Additionally, NCOS ONLINE extracts high resolution 7-day global wind forecasts from NOAA every 6 hours through secure FTP. NCOS ONLINE access live instrument readings such as from wind sensors, wave buoys and tide gauges every 1 minute.

These datasets, in combination, form the basis of the NCOS calculations. NCOS's web-based visual interface, inbuilt functionality for stakeholder data access, and inbuilt quality-checking and real-time alerts positions the system as an ideal single source of truth for all operational marine related data and predictions, further streamlining marine operations. User benefits include:

- On-Demand optimized management of moored vessel configuration, improving berth operability and safety
- Unlimited access to virtual port environment including automated dynamic forecasted environmental conditions for the entire port asset
- Instantaneous automatic multi-tier alert system when safety thresholds are exceeded
- Dynamic optimization of optimal mooring conditions to fit individual vessel configuration, berth utilization, and dynamic weather events
- Automated forecasting of mooring and fender loads based on accurate 7-day predictions
- Automated alerts and optimization support when predicted Mooring and Fender loads exceed target levels due to weather changes
- Effective stakeholder user-group management of information sharing and operational execution of on-demand tasks
- A flexible access point to a multitude of powerful add-on modules

All NCOS system and service components are monitored 24/7 to confirm their status, health, and responsiveness. All critical system components, including web servers, web APIs, databases and GeoServer, are monitored on live status dashboards, with automated alerts and notifications to the POV team configured in the event of downtime or system degradation events.

4.4 Project Cost

Development of these tools took several years and were based on multiple POV initiatives, such as the multi-year program to develop a GIS "digital twin". Further, there are no construction costs, as it is a technology tool to improve operational efficiency. Therefore, project costs associated largely include manhours for developments of concepts, engineering of logic and connection to GIS data to run calculations, and quality control of results and transcription to IT platforms. An initial budget of $60,000 was established for external consultants to set the foundations of the tools in the Ops Dashboard. An additional $60,000 to develop the tools into an interactive dashboard is expected to complete the next phase with migration of host network to POV network. These costs do not include POV's software or hardware costs, in-house labor costs, or other efforts such as the GIS tool/program, which were required for the effort but budgeted for separately.

To date, POV has invested just under $200,000 in the implementation and annual license fees for the NCOS ONLINE system beginning in 2019. Included in this fee, Seaport OPX has provided POV with workshops, tailored training programs and 24/7 Support Services. Additional investigations have also been conducted to evaluate vessel transits through the dynamic calculation of under keel clearance and maneuverability.

4.5 Performance Measures

The important takeaways for measuring the performance of these tools are how it supports the return on investment for newly constructed capital infrastructure and the Operations team that is using it. POV terminals have been experiencing record breaking traffic. In May 2021, NIT recognized 158,000 container lifts, topping a terminal best. Reports of last-minute service requests, diverting business to Virginia, has become common place, with Maersk spending an additional $150,000 in this manner over the month of May 2021. There are other factors that play a role in this success but is also a testament to the effectiveness that terminal berth space is being utilized.

Additional benefits have been realized through the use of dynamic mooring analyses during storm events. POV is able to proactively make informed decisions sooner resulting in significant cost savings. These decisions included rescheduling ship calls earlier and enabling the Port to make decisions to allow vessels to stay at berth when they could safely do so based on mooring analyses produced by NCOS. POV has also minimized their weather downtime at both container terminals using the NCOS forecasts to schedule terminal openings for when conditions became favorable. During one storm event, POV avoided $500,000 in operational costs and improved labor and resource planning in advance of the storm event.

4.6 How the Project Fulfills the Award Criteria

The approach taken to address challenges currently being faced by POV and supports their initiative to become an organization that utilizes state-of-the-art practices, offers a level a creativity to these solutions that are applicable to any operating marine port. These programs that have been developed and implemented can utilize any unique set of terminal data to conform to the analytical digital concepts establish herein. The easy to use, repeatable and accessible nature of these tools shows the effectiveness it has to offer considering the benefits seen and relatively low cost to develop.

5. Conclusion

The development of these innovative tools is a success story of what is possible when collaboration between terminal operators, port staff, consulting engineers and software developers can achieve when they work together on identifying challenges and coming up with solutions. By embracing technology and preparing for the future, POV first with their investment in their GIS "digital twin" and now with the creation and implementation of their online tools has taken great strides to use data to increase efficiency and reduce operating costs. POV's online tools have allowed POV to quickly analyze and predict critical operational needs by providing an evolving platform for identifying areas of improvement and producing solutions to address them. POV is working to create a port that is modern, capable of handling an increased volume of goods and doing so safely and more efficiently by leveraging their technological investments as they plan for the future.