DOI: 10.36163/aon-2022-0001

MODELLING OF TEMPORARY NAVAL SHIPS BERTHS ON A FLOATING PIER – PORT OF KOPER CASE STUDY

Andrej Androjna
University of Ljubljana
Faculty of Maritime Studies and Transport
Pot pomorščakov 4,6320 Portorož, Slovenia
e-mail: Andrej.Androjna@fpp.uni-lj.si

Marko Perkovič
University of Ljubljana
Faculty of Maritime Studies and Transport
Pot pomorščakov 4,6320 Portorož, Slovenia
e-mail: Marko.Perkovic@fpp.uni-lj.si

Peter Vidmar
University of Ljubljana
Faculty of Maritime Studies and Transport
Pot pomorščakov 4,6320 Portorož, Slovenia
e-mail: Peter.Vidmar@fpp.uni-lj.si

ABSTRACT

The paper presents an analysis of the modelling of temporary naval ships berths on a floating pier in the port of Koper. For this case study, traffic flow, weather conditions, navigation channel and a proposed floating pier were investigated. Energy calculations for berthing were performed using the deterministic method and dynamic simulation, supported by manoeuvring simulations on the Transas/Wartsila NTPro 5000 simulator of two current and two proposed naval vessels under all weather conditions. The results will be used in practise to determine the design, safety of navigation and manoeuvring in a waterway towards a non-existing floating pier in the port of Koper. The establishment of the temporary naval ships berths is intended to improve and alleviate the lack of ship berths for the Slovenian Navy.

Keywords – temporary naval ships berths, a floating pier, deterministic method, dynamic simulation, port of Koper

1. INDRUCTION

The Slovenian Navy is facing a shortage of space for its ships. As part of the development of Slovenia's only port, new berths are planned on the north side of the Ro-Ro 4 berth in the third basin of the Port of Koper. The third basin of the Port of Koper is the least used. It is primarily intended to accommodate vessels for the transport of bulk cargo, which can be very large. Therefore, this channel is deepened to 18 meters and more. Ro-Ro vessels also occasionally berth on the Iron Ore and Coal Terminals (TRT). Here, too, there are two special piers, namely the multi-purpose terminal (VNT) and the Ro-Ro 4. Generally, naval vessels do not interfere with commercial activities and the entry and exit of naval vessels takes place outside the navigation channel. The only possible interaction is between the Ro-Ro vessel during the manoeuvre and the vessels moored at the designated site, as a more intense manoeuvre during the Ro-Ro vessel's departure could indirectly affect the warships (propeller wash).

2. METHODOLOGY

2.1. METHODOLOGY USED

The methods presented here are related to the case study of traffic flow, weather conditions, navigation channel and a proposed floating pier, for which energy berthing calculations were carried out using the deterministic method and dynamic simulation. Manoeuvring simulations were carried out on the Transas / Wartsila NTPro 5000 simulator of two current and two proposed naval vessels under all weather conditions. The study was prepared in accordance with the Project Conditions of the Maritime Administration of the Republic of Slovenia No. 351-5 / 2021-2 dated 31. May 2021, which included an inspection of navigation in the basin III, an overview of meteorological and oceanographic conditions, an overview of water depths in the basin III, a real-time nautical simulation with crew with simulation report and GIS annex, a dynamic analysis of the berth of a larger naval vessel, the selection of bollards and fenders and the impact of Ro-Ro vessels leaving and entering the basin on the safety of naval vessel berths (interaction). Berthing energy calculations were carried out using the deterministic method and dynamic simulation, supported by manoeuvre simulations on the Transas / Wartsila NTPro 5000 simulator [PIANC, 2013-2016]. The simulations were carried out with typical vessels of the Slovenian Navy and also with sample models of a possible offshore patrol vessel (OPV) that the Slovenian Ministry of Defence might order in the medium term.

2.2. ANALYSED AREA

A detailed survey of vessel traffic in the Koper harbour basin III was carried out. Table 1 contains berthing statistics for the last four years, with vessels classified according to basic types, dimensions, widths, GT and payloads. There are several berths in harbour basin three, mainly for bulk carriers (TRT berths 1 to 3). The basin is also well utilised with car carriers moored at the new dedicated Ro-Ro Terminal 4 (built in 2020), as well as at the multi-purpose terminal (VNT), where vessels are moored in Mediterranean berthing mode, i.e. with a stern ramp on the shore and with two anchors. Ro-Ro vessels can also be moored at the terminal TRT, especially at the forward berth. Occasionally, vessels are also bunkered at different berths. All this traffic and activity could potentially affect the safe passage of naval vessels moored at the proposed Ro-Ro 4 berth. There are a total of 80 vessel calls, which equates to approximately 240 manoeuvring hours (a single manoeuvre takes an average of 1.5 hours). The layout of the harbour basin is shown in Figure 1.

Table 1. Vessel traffic in the period 2017-2020, broken down by berth and vessel type.

basin 3	TRT 1 2017	TRT 1 2018	TRT 1 2019	TRT 1 2020	TRT 2 2017	TRT 2 2018	TRT 2 2019	TRT 2 2020	TRT 3 2017	TRT 3 2018	TRT 3 2019	TRT 3 2020	VNT 2017	VNT 2018	VNT 2019	VNT 2020	RORO 4 2017	RORO 4 2018	RORO 4 2019	RORO 4 2020
BULK CARRIER	36	44	35	20	21	14	10	6	13	13	8	8								
GENERAL CARGO				2				1	9	5	4	8								
HEAVY LOAD CARRIER				1																
CARGO SHIP	**36**	**44**	**35**	**23**	**21**	**14**	**10**	**7**	**22**	**18**	**12**	**16**								
RO-RO									**44**	**21**	**21**	**15**	**13**	**31**	**18**					**69**
TANKER BUNKER					1				1											
BARGES BUNKER			1					2	1											5
BUNKER			**1**		**1**			**2**	**2**											**5**
BARGES DRY CARGO			**2**		**11**	**2**	**4**	**1**	**147**	**137**	**65**	**7**			**1**	**3**				**1**
TUGS			**2**	**3**	**12**	**1**	**5**	**2**	**294**	**277**	**137**	**15**			**2**	**3**				**5**
DREDGER												1								
NAVY VESSEL				2																
OTHER SHIP				**2**								**1**								
Grand Total	36	44	40	28	45	17	19	12	509	453	235	54	13	31	21	6				80

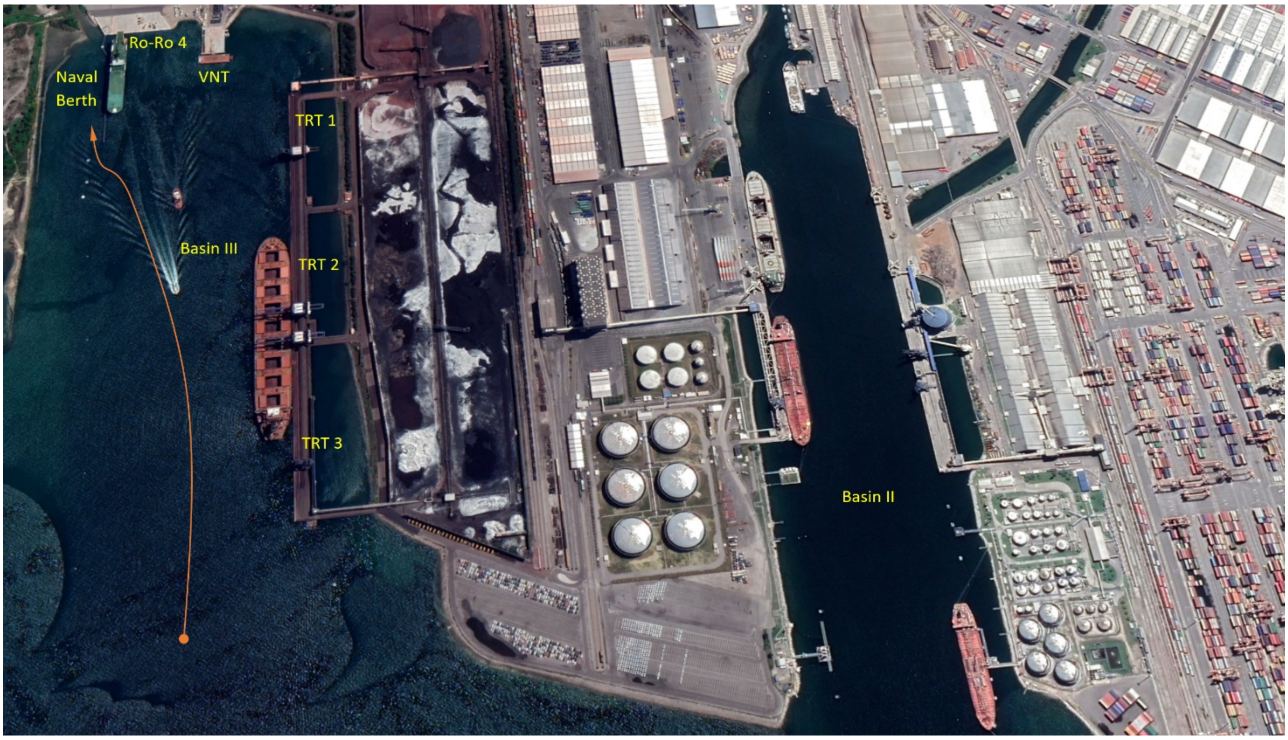

Figure 1. Basin III layout and proposed navy berth location.

2.3.WEATHER CONDITIONS

A good understanding and knowledge of meteorological and oceanographic conditions is key to safety at sea. The Gulf of Trieste is mainly exposed to bora and southerly winds (sirocco) that stir up the sea. The most common wind is the northeast wind (bora). The bora is a stormy and gusty wind that causes irregular waves up to 3 m high. The waves along the bora are short, narrow and steep and break picturesquely, forming a spray of water droplets on the water surface. The bora pushes the surface water away from the coast and the sea level then drops. On average, more than a third of all winds blow from this direction each year. The bora is particularly frequent from November to March. This is followed by the southeast and the south, which blow fairly evenly throughout the year. The waves have a more regular shape and can be up to 4 m or more high. Moderate southerly winds raise the water level by up to 25 cm and by up to 0.5 m in autumn and winter. From October to December, due to weather conditions accompanied by strong south-easterly winds, the tides push towards the Slovenian and northern Italian coasts at high tide. Since the water masses at the bottom cannot flow away fast enough, flooding occurs. The sea level then rises by more than 85 cm compared to the mean level, with the water level rising to more than 3 m and flooding the lower parts of Piran, Izola and Koper [Deželjin, 2001]. On the waterway and in the port itself, the most pronounced feature of navigational risk is wind. Summer storms are particularly dangerous and can catch ships just in time to dock. In the port of Koper, there have been several incidents in the past related to strong bora winds and storms. When the wind is strong, it is more difficult for ships to follow the planned route, so they increase their speed, which indirectly affects the ships at the berths. Similarly, the strength of the wind limits the supply of fuel to ships, and if the wind is stronger, the transhipment process is stopped. From Table 2, which shows the wind data measured by two different 3D anemometers (one near the VNT terminal and the second at the head of the container terminal - CT), sampling the data at 20 Hz, we can summarise that the presence of stronger winds (above 8 m/s), time averaged over one second, is really low. Unfavourable directions for the proposed naval berth are E-SE and SW-W winds. The occurrence of winds of this strength from these directions is less than 1% per year or less than 100 hours per year or 4 full days. The table also shows the occurrence of winds over one minute, 10 minutes, one hour and one year [Perkovič et al., 2014, 2021]. It should be noted, however, that in the area of the northern Adriatic in summer there are sudden storms that are extremely difficult to predict and immediately reach speeds of up to 70 or even 80 knots.

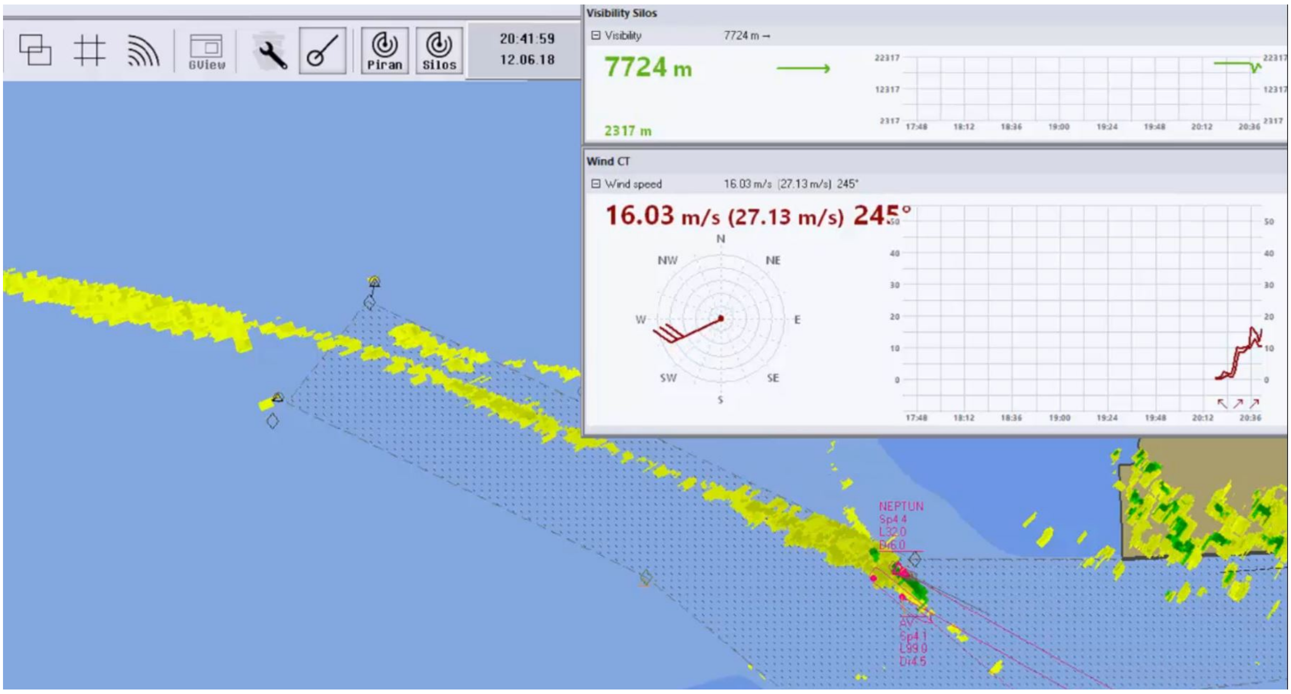

Figure 2. Sudden gusts of wind and vessel RADAR track represented by the system for traffic control (VTS).

They blow from the direction W-SW or N-NE. If such a storm hits the ship during the approach manoeuvre, the ship may lose control and drift uncontrollably. Figure 2 shows such an example when Lebicada (SW gale-force wind) occurs during the passage through the channel. The wind reaches gusts of 27 m/s or 53 knots in one minute without wind.

Table 2. Winds in the port of Koper for the year 2020 (to the second, to the minute, hourly, daily and annual wind distribution at two different locations in the port area).

Location	CT	01.01.2020 - 31.12.2020								
Temporal resolution	1s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	1.30	3.20	9.10	2.50	1.00	1.50	2.30	1.70	22.50
	1.5-4.0	1.60	7.40	24.20	2.80	1.80	2.70	8.70	2.20	51.50
	4-8.	1.90	7.70	1.70	1.00	1.40	2.90	3.40	0.70	20.70
	8-12.	0.50	2.80	0.30	0.20	0.20	0.20	0.10	0.10	4.30
	12-20.	0.10	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.90
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	5.30	21.80	35.30	6.50	4.50	7.30	14.60	4.70	100.00

Location	VNT	01.01.2020 - 31.12.2020								
Temporal resolution	1s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.89	1.98	6.05	2.69	1.53	1.05	1.69	1.34	17.21
	1.5-4.0	1.54	4.65	24.79	5.40	1.08	1.71	9.44	1.92	50.54
	4-8.	0.94	7.98	4.50	1.86	0.75	1.09	7.07	0.50	24.70
	8-12.	0.18	4.07	0.70	0.45	0.08	0.06	0.14	0.03	5.71
	12-20.	0.03	1.53	0.15	0.05	0.00	0.00	0.02	0.01	1.80
	20-30.	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.05
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	3.59	20.25	36.19	10.45	3.45	3.90	18.36	3.81	100.00

Location	CT	01.01.2020 - 31.12.2020								
Temporal resolution	60s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.60	3.00	9.30	2.50	1.20	1.60	2.40	1.20	21.70
	1.5-4.0	1.10	7.50	25.40	2.60	1.80	2.80	8.90	1.90	52.00
	4-8.	1.70	8.60	1.50	1.10	1.40	3.00	3.40	0.60	21.30
	8-12.	0.30	3.00	0.40	0.10	0.20	0.20	0.10	0.00	4.30
	12-20.	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.70
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	3.70	22.70	36.60	6.30	4.60	7.60	14.80	3.70	100.00

Location	VNT	01.01.2020 - 31.12.2020								
Temporal resolution	60s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.50	1.99	6.24	2.68	1.59	1.18	1.82	0.88	16.87
	1.5-4.0	1.27	4.61	25.45	5.06	1.13	1.78	9.74	1.58	50.62
	4-8.	0.82	8.54	4.29	1.92	0.82	1.16	7.09	0.39	25.03
	8-12.	0.13	4.45	0.52	0.47	0.05	0.05	0.13	0.02	5.82
	12-20.	0.01	1.52	0.06	0.03	0.00	0.00	0.02	0.01	1.66
	20-30.	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	2.74	21.13	36.56	10.15	3.59	4.16	18.80	2.87	100.00

Location	CT	01.01.2020 - 31.12.2020								
Temporal resolution	600s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.20	2.30	9.50	2.80	1.30	1.80	2.30	0.70	20.90
	1.5-4.0	0.60	7.50	26.60	2.50	1.80	2.80	9.20	1.60	52.60
	4-8.	1.50	9.50	1.40	1.10	1.50	3.00	3.40	0.50	21.90
	8-12.	0.20	3.00	0.40	0.10	0.10	0.20	0.10	0.00	4.10
	12-20.	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.60
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	2.40	22.70	37.90	6.50	4.80	7.60	15.10	2.90	100.00

Location	VNT	01.01.2020 - 31.12.2020								
Temporal resolution	600s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.15	1.59	6.24	2.69	1.83	1.30	1.71	0.45	15.96
	1.5-4.0	0.98	4.09	27.30	4.51	1.22	1.75	10.14	1.24	51.22
	4-8.	0.63	9.17	4.22	1.96	0.87	1.15	7.15	0.33	25.48
	8-12.	0.08	4.65	0.42	0.48	0.02	0.04	0.13	0.02	5.83
	12-20.	0.00	1.43	0.03	0.01	0.00	0.00	0.02	0.00	1.51
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	1.84	20.94	38.21	9.65	3.94	4.24	19.14	2.04	100.00

Location	CT	01.01.2020 - 31.12.2020								
Temporal resolution	3600s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.00	0.90	9.30	3.10	2.00	1.80	1.70	0.10	19.00
	1.5-4.0	0.20	6.60	29.00	2.80	2.30	2.90	10.10	0.90	54.60
	4-8.	1.10	10.10	1.40	1.30	1.60	2.90	3.50	0.40	22.20
	8-12.	0.10	2.90	0.40	0.10	0.10	0.10	0.10	0.00	3.80
	12-20.	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.40
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	1.40	20.80	40.10	7.30	6.00	7.60	15.30	1.30	100.00

Location	VNT	01.01.2020 - 31.12.2020								
Temporal resolution	3600s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.01	0.47	5.41	2.87	2.46	1.40	0.97	0.06	13.63
	1.5-4.0	0.65	2.73	31.74	3.64	1.98	2.23	10.23	0.58	53.77
	4-8.	0.32	9.62	4.16	2.09	1.00	1.09	7.19	0.17	25.63
	8-12.	0.04	4.63	0.35	0.45	0.02	0.03	0.10	0.00	5.62
	12-20.	0.00	1.31	0.02	0.01	0.00	0.00	0.01	0.00	1.35
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	1.01	18.75	41.67	9.06	5.46	4.75	18.49	0.81	100.00

Location	CT	01.01.2020 - 31.12.2020								
Temporal resolution	86400s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.00	0.00	0.40	2.80	1.60	0.10	0.00	0.00	5.00
	1.5-4.0	0.00	3.30	10.10	32.30	28.20	0.70	0.00	0.00	74.60
	4-8.	0.00	10.30	4.20	3.30	0.50	0.00	0.00	0.00	18.30
	8-12.	0.00	2.10	0.10	0.00	0.00	0.00	0.00	0.00	2.20
	12-20.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.00	15.60	14.80	38.30	30.40	0.80	0.00	0.00	100.00

Location	VNT	01.01.2020 - 31.12.2020								
Temporal resolution	86400s m/s|deg	N-NE 0-44	NE-E 45-89	E-SE 90-135	SE-S 135-179	S-SW 180-224	SW-W 225-260	W-NW 270-314	NW-N 315-359	Total
Speed Range	0-1.5	0.00	0.00	0.17	1.87	1.72	0.11	0.00	0.00	3.87
	1.5-4.0	0.28	0.44	6.70	29.53	30.74	0.40	0.03	0.00	68.12
	4-8.	0.00	7.11	9.01	7.10	1.21	0.00	0.00	0.00	24.42
	8-12.	0.00	2.64	0.17	0.02	0.00	0.00	0.00	0.00	2.83
	12-20.	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.76
	20-30.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	>30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.28	10.94	16.05	38.52	33.67	0.51	0.03	0.00	100.00

Compared to the wind, the sea currents and tides have less influence on ship manoeuvres in the port of Koper, while the occurrence of fog and the associated limited visibility in the autumn and winter months can also lead to a temporary closure of the port.

2.4.NAVIGATION CHANNEL

The latest valid electronic navigational chart (ENC) is shown in Figure 3. All three access channels and part of the basin III are marked, which is deepened to -18 m. Another new feature is the additional position for the pilot entry (for large vessels), which is 2.2 NM from the outer buoy of the channel [FAL, 2020]. On the far left of the chart, the "port limit" is marked with a speed limit of 6 knots, which is a significant improvement in safety as vessels no longer perform manoeuvres at uncontrolled speeds. The anchorages are also marked. On the far right, the place for temporary mooring of naval vessels is shown.

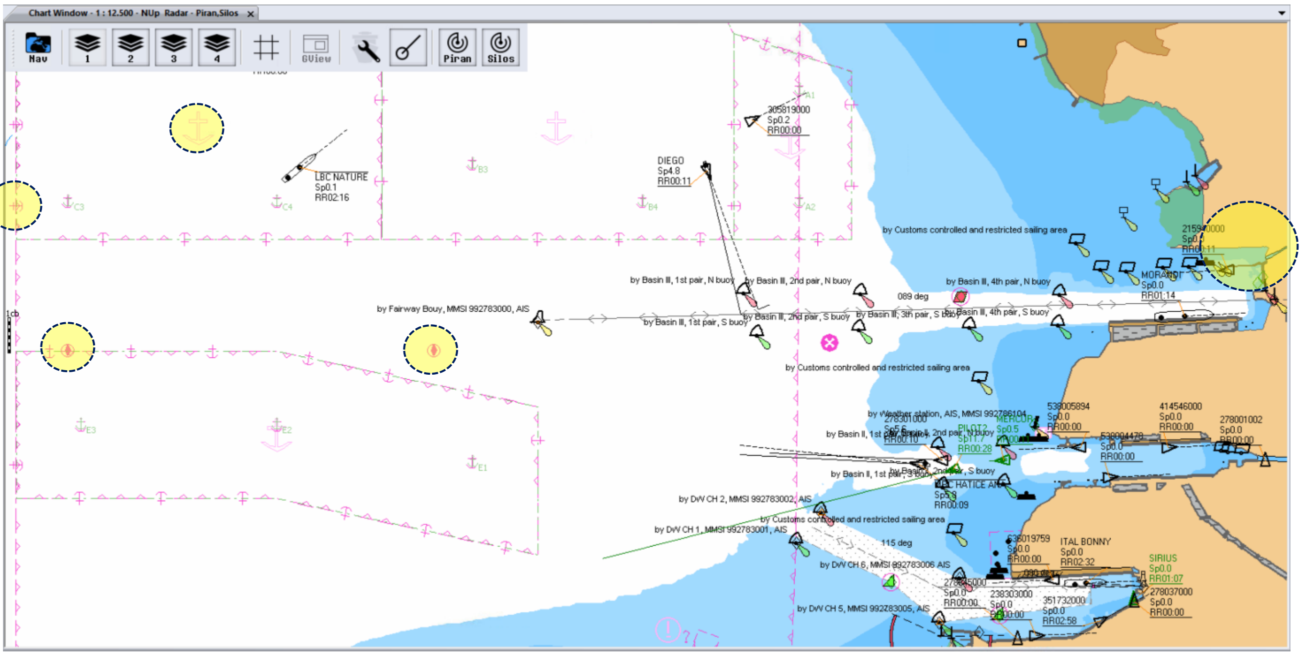

Figure 3. Valid ENC map showing depths, harbour area, anchorages, two pilot stations and the planned location for temporary mooring of naval vessels.

The critical segment is undoubtedly a 40 m wide manoeuvre section where the depth is exactly 3 m, as shown in Figure 4.

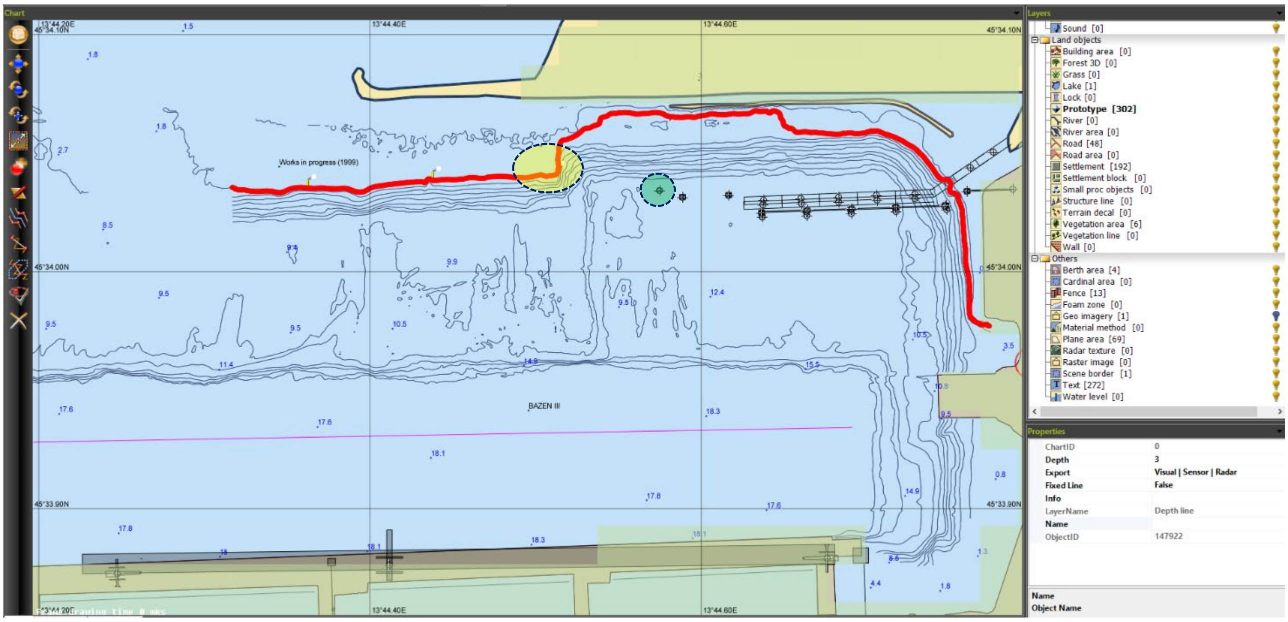

Figure 4. Depths and the red 3-metre depth contour (created in Model Wizard).

The current mooring device (marked in green) also slightly restricts the navigation channel, so it is proposed to extend the chain by 10 m. The red line shows the contour of the 3 m depth. The yellow-marked edge of the contour, which is the most obstructive to navigation, is also shown. It is proposed to partially deepen the marked segment (alignment of the line).

Naval vessels have sufficient depth below the keel on the waterway so that the potential impact of the squat effect [Flory, 2002] is practically negligible.

In 2014, PIANC issued new recommendations for the planning of ports and waterways. The following table shows the factors for determining the width of the straight part of the navigational channel.

Table 3. PIANC [2014] factors for determining the width of the straight part of the navigational channel.

Ship Manoeuvrability	Good	Moderate	Poor
Basic Manoeuvring Lane, W_{BM}	1.3 *B*	1.5 *B*	1.8 *B*

Width W_i	Vessel Speed	Outer Channel (open water)	Inner Channel (protected water)
(a) Vessel speed V_s (kts, with respect to the water)			
$V_s \geq 12$ kts	fast	0.1 B	
8 kts $\leq V_s <$ 12 kts	mod	0.0	
5 kts $\leq V_s <$ 8 kts	slow	0.0	
(b) Prevailing cross wind V_{cw} (kts)			
- mild	fast	0.1 B	
$V_{cw} <$ 15 kts	mod	0.2 B	
(< Beaufort 4)	slow	0.3 B	
- moderate	fast	0.3 B	
15 kts $\leq V_{cw} <$ 33 kts	mod	0.4 B	
(Beaufort 4 - Beaufort 7)	slow	0.6 B	
- strong	fast	0.5 B	
33 kts $\leq V_{cw} <$ 48 kts	mod	0.7 B	
(Beaufort 7 - Beaufort 9)	slow	1.1 B	
(c) Prevailing cross-current V_{cc} (kts)			
- negligible $V_{cc} <$ 0.2 kts	all	0.0	0.0
- low	fast	0.2 B	0.1 B
0.2 kts $\leq V_{cc} <$ 0.5 kts	mod	0.25 B	0.2 B
	slow	0.3 B	0.3 B
- moderate	fast	0.5 B	0.4 B
0.5 kts $\leq V_{cc} <$ 1.5 kts	mod	0.7 B	0.6 B
	slow	1.0 B	0.8 B
- strong	fast	1.0 B	-
1.5 kts $\leq V_{cc} <$ 2.0kts	mod	1.2 B	-
	slow	1.6 B	-
(d) Prevailing longitudinal current V_{lC} (kts)			
- low $V_{lC} <$ 1.5 kts	all	0.0	
- moderate	fast	0.0	
1.5 kts $\leq V_{lC} <$ 3 kts	mod	0.1 B	
	slow	0.2 B	
- strong	fast	0.1 B	
$V_{lC} \geq$ 3 kts	mod	0.2 B	
	slow	0.4 B	
(e) Beam and stern quartering wave height H_s (m)			
- $H_s \leq$ 1 m	all	0.0	0.0
- 1 m < H_s < 3 m	all	~0.5 B	-
- $H_s \geq$ 3 m	all	~1.0 B	-
(f) Aids to Navigation (AtoN)			
- excellent		0.0	
- good		0.2B	
- moderate		0.4 B	
(g) Bottom surface			
- if depth $h \geq 1.5\,T$		0.0	
- if depth $h < 1.5\,T$ then			
- smooth and soft		0.1 B	
- rough and hard		0.2 B	
(h) Depth of waterway *h*		$h \geq 1.5\,T$: 0.0 *B* $1.5\,T > h \geq 1.25\,T$: 0.1 *B* $h < 1.25\,T$: 0.2 *B*	$h \geq 1.5\,T$: 0.0 *B* $1.5\,T > h \geq 1.15\,T$: 0.2 *B* $h < 1.15\,T$: 0.4 *B*
(i) High cargo hazards		See explanation in box(i) overleaf	

The starting approach has remained the same as before; ships are divided into three categories: good, medium and less maneuverable. In addition, of course, there are factors that further complicate navigation, such as weather conditions, ship speed, available depth, and the like. When the factors cannot adequately assess a particular situation, real-time simulations are proposed, which are now a widely used method for planning ports, waterways and moorings. PIANC's deterministic approach shows that the available width of the channel and basin is sufficient (36 m for vessels with a draught of 3.5 m and 50 m available width for vessels with a draught of 2.5 m). From the outer to the inner part of the basin, the ship changes direction. Naturally, the warship is excellently manoeuvrable forward (three engines, two asynchronous rudders and a bow thruster). In reverse, the manoeuvrability is less, as the ship cannot turn 360 degrees in the basin due to its size, and the ship is also considered quite susceptible to wind. Therefore, simulations under different weather conditions should also be carried out.

2.5.THE SHIP BERTHING AREA

In order to make the mooring system on the pontoon sustainable, we have estimated the forces transmitted through the ropes to the moorings under different wind and wave conditions, taking into account that the tides have no significant influence as the ship is moored on a floating pontoon [Del Estado, 1990, 2000, 2007, Thorsen, 2014]. According to PIANC, the distance between moorings is 15% of the ship's length. The deterministic method was used to determine the payload capacity of 10 tonnes based on the vessel displacement as recommended [BS 6349, 2013; ROM, 1990; PIANC 1993-2016]) for vessels with displacement up to 2,000 tonnes and cylindrical foam filled fenders 610x2440 certified by the US Navy [Trelleborg, 2008, 2017; Fender team, 2012, Shibata, 2017].

The dynamic simulation of the mathematical model of a naval vessel also determined the loads on the mooring lines [UFC, 2005; Roubos et al.; 2018] for the entire compass rose of 50 knots (Figure 5) and on the fenders (Figure 6).

The waviness (up to 0.4 m) causes an additional load on the ropes and bollards. The load on the bow and stern is more than 20 tonnes, so the larger warship has to be moored to two different bow and stern bollards, as shown in Figure 5 [DoD, 1999; Naval Sea Systems Command, 2002; UFC, 2017].

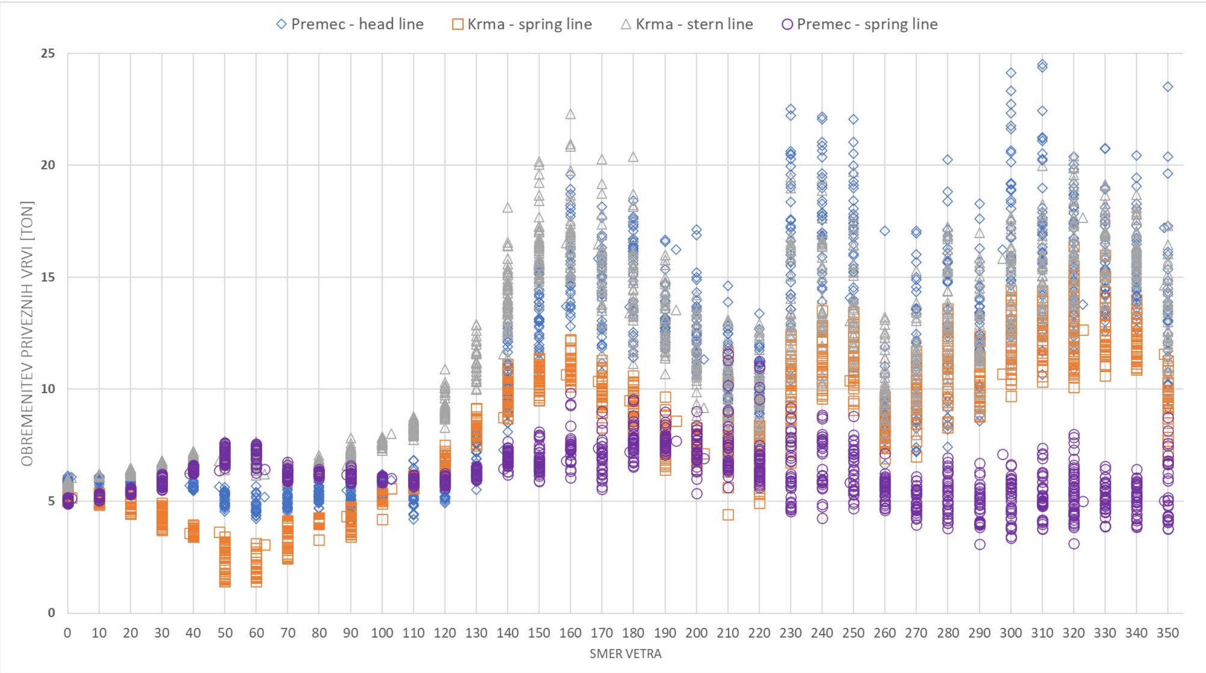

Figure 5. Loads on the mooring rope.

Figure 6 shows the normal load on the fender and pontoon (blue vertical lines) of 15 tonnes and up to 35 tonnes for the expected wave.

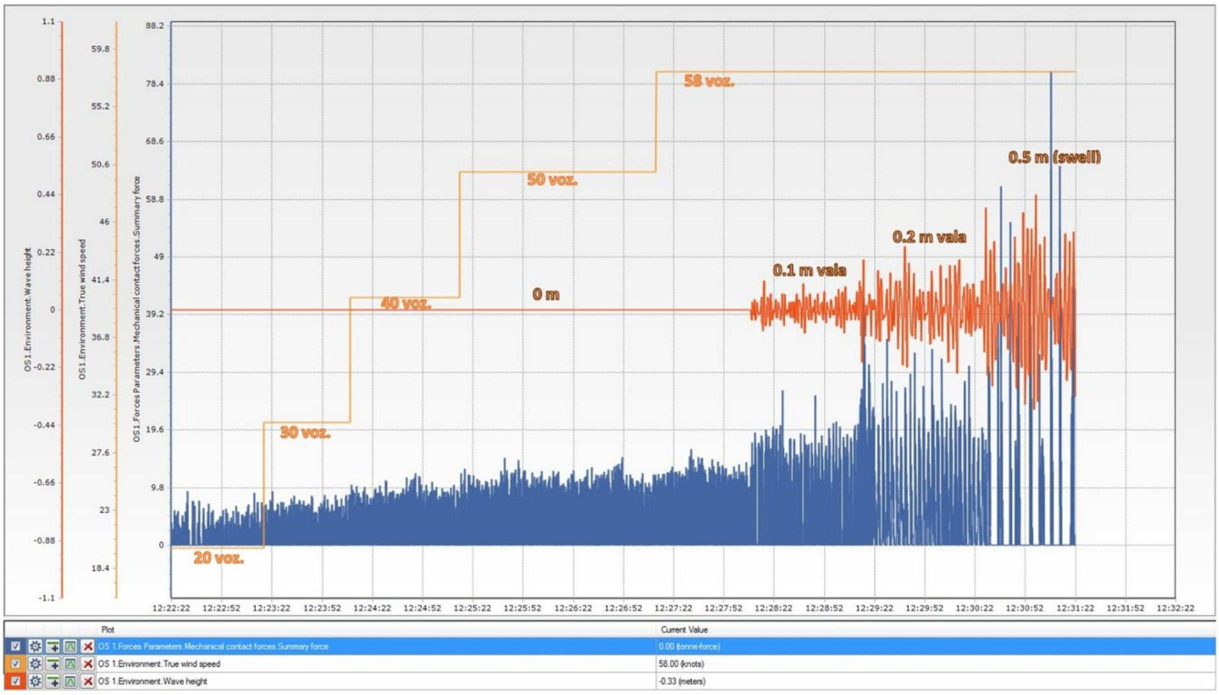

Figure 6. Fender forces, dynamic simulation at different wind and sea conditions for a model naval vessel.

3. RESULTS OF MANOUVERING SIMULATIONS

On the Transas / Wartsila NTPro 5000 simulator, hundreds of repetitions of the entry and exit manoeuvre were carried out in reproduced weather conditions with four different types of vessels from 35 m to 86 m in length at the new planned berth for Slovenian Navy vessels in the harbour basin III of the Port of Koper.

The following vessels were used:

a) 35 m long Coast Guard vessel with two marine engines without bow thrusters, as an equivalent comparison to the manoeuvrability of the fast patrol boat Ankaran 21;

b) Svetlyak, a 50-metre patrol boat with three engines without bow thruster. The above class is also the multi-purpose vessel Triglav 11, except that it is also equipped with a bow thruster and thus has much better manoeuvrability;

c) 65-metre single-engine Coast Guard vessel equipped with both a bow and stern thruster and an equivalent replacement for a smaller OPV;

d) An 85-metre superyacht with two engines and a bow thruster as an equivalent replacement for a larger OPV.

The manoeuvres were carried out under both optimal and adverse weather conditions. By optimal conditions we mean 0 to 2 according to the Beaufort scale (wind speed from 0 to 3.3 m/s, wave height up to 1 m) and under adverse weather conditions manoeuvres up to 6 Beaufort (strong wind up to 10.5 m/s or 20 knots, wave height at sea up to 4 m). For manoeuvring under difficult conditions, the two winds that occur most frequently on our coast were simulated, namely the bora, which blows from north-northeast (NNE) to east-northeast (ENE), and the southeast winds, which blow from east-southeast (ESE) to south-southeast (SSE).

The simulations have shown that manoeuvring with 35 and 50 m vessels is possible without any problems in a wind force (south / bora) of 20 knots. The width of the fairway also allows a complete 360-degree turning manoeuvre in the middle of the temporary berth for naval vessels, as shown in Figure 7.

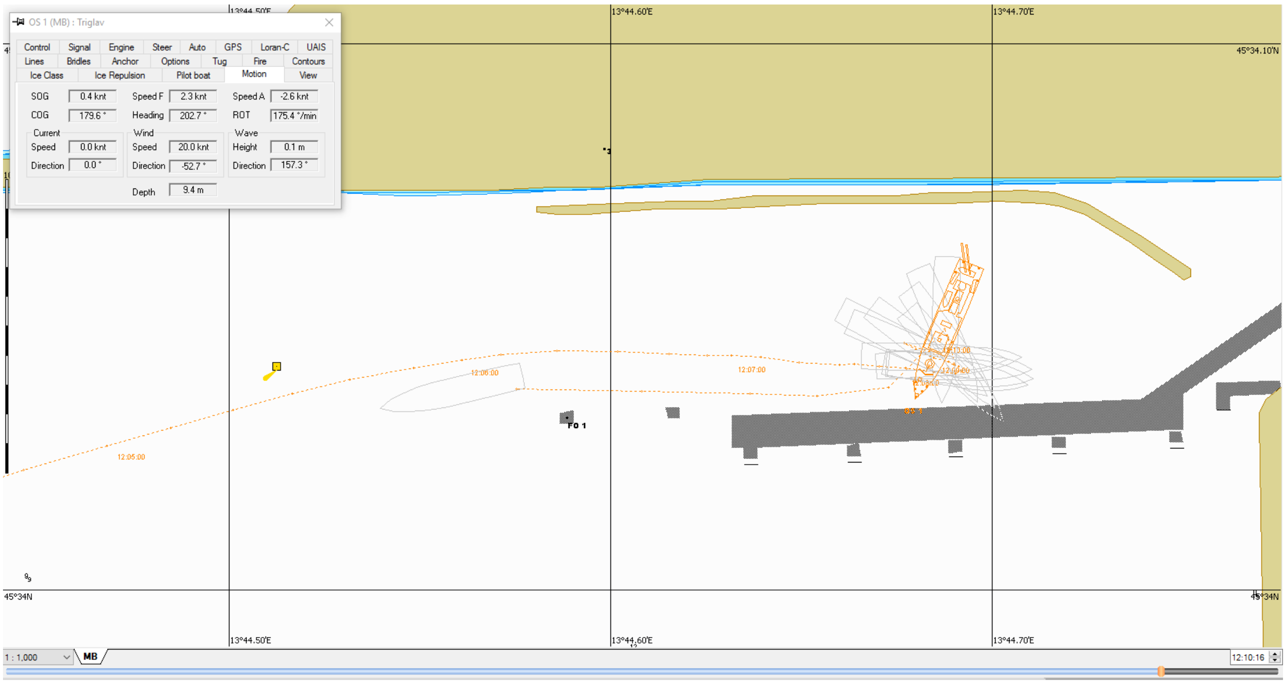

Figure 7. Screenshot of the full 360 degree turn manoeuvre of a 50 m patrol boat in a strong southerly wind (20 knots).

This was followed by a test of manoeuvring with a 65 m vessel, which summarised the characteristics of a smaller OPV. The combination of one engine and two bow and stern thrusters is a guarantee for easy manoeuvring. With the aforementioned vessel, it is possible to perform manoeuvres in extreme weather conditions. The negative influence of the wind can be fully compensated by the correct use of the two effective thrusters, as shown in Figure 8.

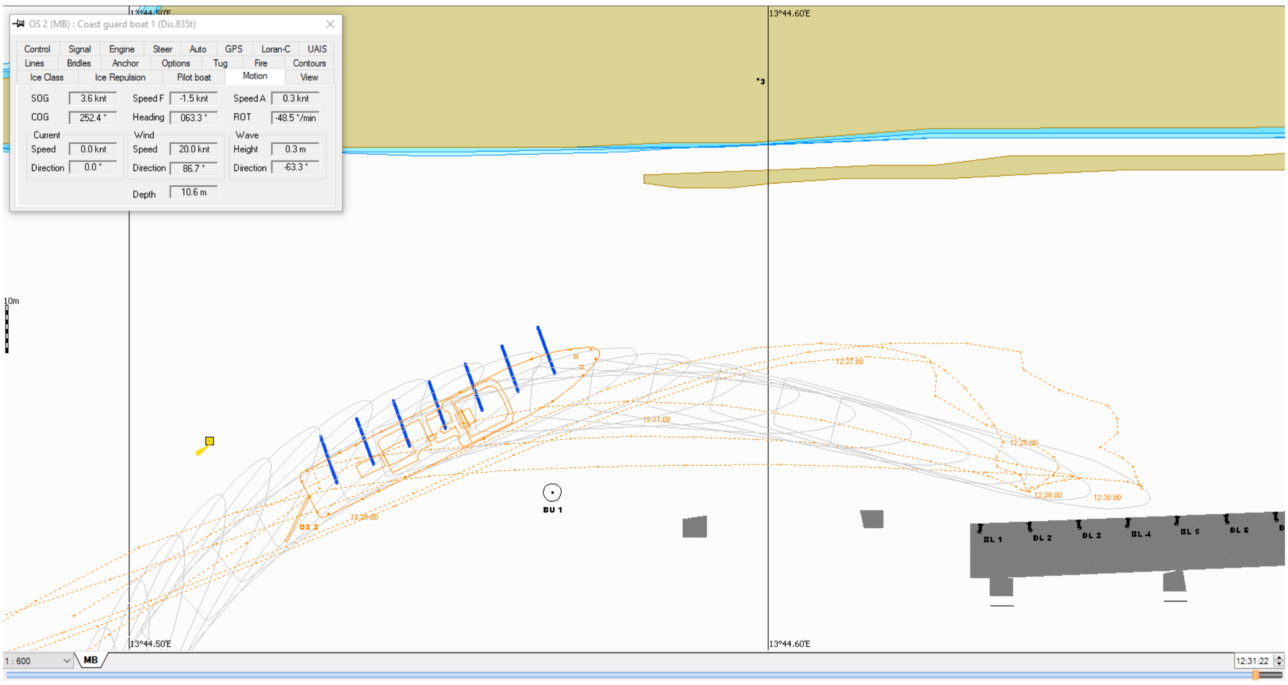

Figure 8. Screenshot of the manoeuvre of a 66 m Coast Guard vessel in strong southerly winds (20 knots).

The biggest challenge was manoeuvring an 85 m twin-engine superyacht equipped with a bow thruster, which was presented as an equivalent replacement for the larger OPV. As can be seen from Figures 9 and 10, the simulations showed that entering and leaving the temporary berth of naval vessels is possible in strong bora or southerly winds, but depending on the narrowness of the channel, it is only feasible with a trained crew and an experienced captain. Be that as it may, such a vessel is indeed oversized to carry out manoeuvres at the planned new temporary berth.

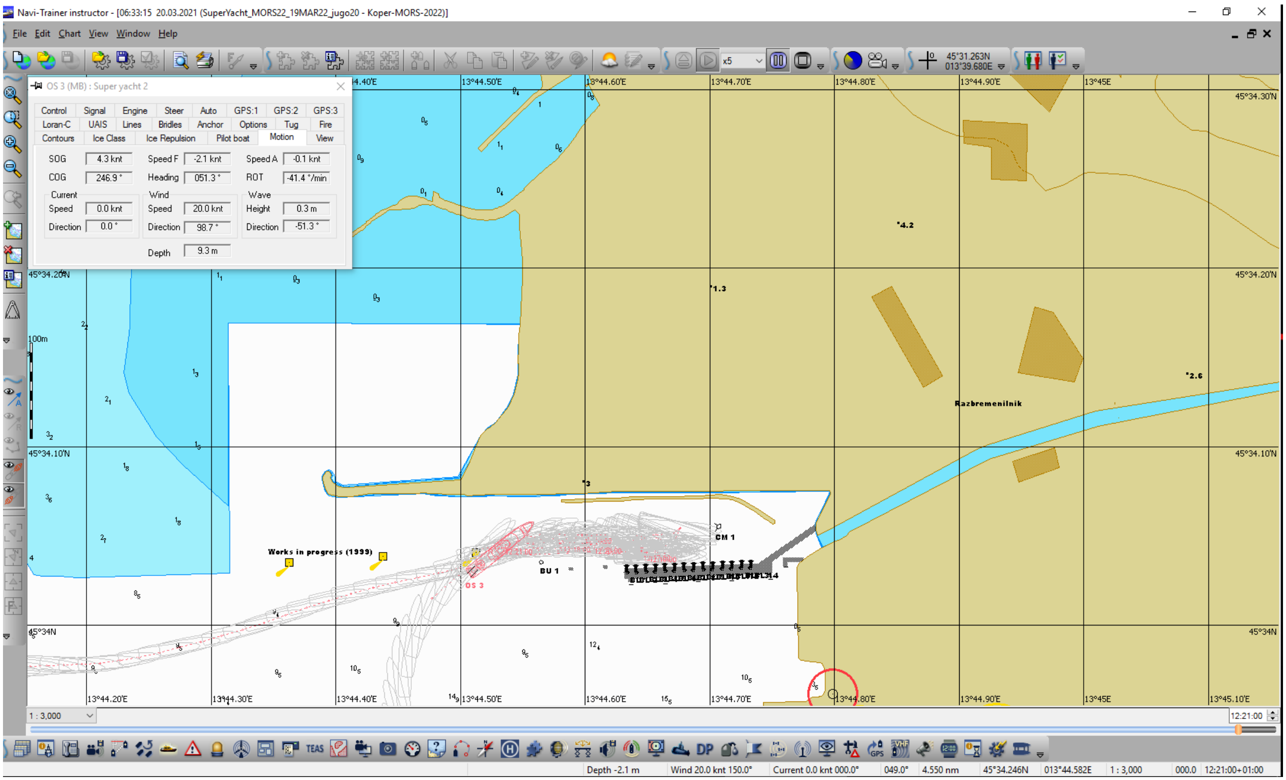

Figure 9. Screenshot of the manoeuvre of a 85-metre superyacht in a strong southerly wind (20 knots).

Figure 10. Floor plan of of the manoeuvre of a 85-metre superyacht in strong winds (20 knots).

4. CONCLUSION AND DISCUSSION

Simulations of the manoeuvres for the planned temporary berth for Slovenian naval vessels in the port of Koper (Ro-Ro 4 berth in the 3rd basin of the port of Koper) were successfully carried out with all types of vessels in different weather conditions, taking into account the position of the current mooring device (buoy) for Ro-Ro vessels.

The available width of the fairway and the harbour basin proved to be sufficient. The actual width of the waterway is 36 metres for vessels with a draught of 3.5 metres and 50 metres for vessels with a draught of 2.5 metres. A 40-metre wide navigation channel with a depth of at least 3 metres allows manoeuvring with a 50-metre warship under controlled conditions. In order to facilitate the entrance to the inner part of the Slovenian Navy's temporary berth in the port of Koper, it is proposed to move three yellow buoys to the isobath of -3 metres and partially deepen the entrance to a depth of -3 metres. The mooring system of the Ro-Ro vessels slightly restricts the navigation channel, so it is proposed to extend the mooring chain by 10 metres.

The presence of stronger winds (above 8 m/s), measured by the second average, is low. Unfavourable directions for mooring vessels are E-SE and SW-W. The occurrence of winds of this strength from these directions is less than 1% per year. Currents, tides and outflows of rivers in the harbour basin III of the port of Koper have little influence on mooring manoeuvres. Visibility may be limited due to occasional fog. As a rule, naval vessels do not interfere with commercial activities and manoeuvring of naval vessels takes place outside the navigation channel. A selection of moorings and fenders is proposed to accommodate vessels with a displacement of up to 2,000 tonnes.

The only possible interaction is between the Ro-Ro vessel during the manoeuvre and the vessels moored at the proposed location, as a more intense manoeuvre during the departure of the Ro-Ro vessel could indirectly affect the mooring pontoon (propeller wash).

The planned temporary mooring of the Slovenian naval vessels in the port of Koper will allow safe manoeuvring and use of the planned floating pontoon, taking into account all the above findings and proposals.

REFERENCES

1. BS6349: 1-4 Part 4. Code of Practice for Design of Fendering and Mooring Systems, 2013.
2. Del Estado P. General Procedure and Requirements in the Design of Harbor and Maritime Structures. ROM 0.0 Part I: Recommendations for Maritime Structures, Ministerio de Fomento, Puertos del Estado, 2000.
3. Department of Defense. Mooring Design, Military Handbook 1026/4A, 1999.
4. Deželjin D. Porazdelitev jakosti in pogostosti tokov po smereh na lokaciji oceanografske boje. Institute Terra Viva, 2001.
5. FAL. Ongoing challenges to ports: the increasing size of container ships, 2020, Bulletin 379, no.3, ISSN 1564-4227.
6. Fender Team. Product Catalog, 2012.
7. Flory JF. The effect of passing ships on moored ships. In Prevention First 2002, Symposium 2002 Sep (pp. 1-11).
8. Naval Sea Systems Command. U.S. Navy Towing Manual, 2002, p.522, available on: https://www.navsea.navy.mil/ (accessed: May 12, 2022).
9. Perkovič M, Felicjan M, Suban V, Luin B, Vidmar P. Navigability Regime Assessment Study in Basin I, UL FPP, 2014, pp.206.
10. Perkovič M, Felicjan M, Batista M, Androjna A. Nautival study in Basin I, berths 1-5, UL FPP, 2021.

11. PIANC report WG121. Harbor approach changes design guidelines from 2014 including the latest design information on vessels, PIANC, Brussels 2014.
12. PIANC report WG24. Criteria for Movements of Moored Ships in harbours – A Practical guide, PIANC, Brussels 1995.
13. PIANC report WG33 (2002) Guidelines for the Design of Fender Systems, PIANC, Brussels 2002.
14. PIANC, Criteria for Movements of Moored Ships in Harbours, Working Group n°28, Suppliment to Bulletin n°88. PIANC, Brussels 1993.
15. PIANC, EnviCom Working Group 143, Initial Assessment of Environmental Effects of Navigation and Infrastructure Projects, PIANC, Brussels 2014.
16. PIANC, Guidelines for the design of fender systems, MarCom Working Group 33, PIANC, Brussels 2002.
17. PIANC, Harbour Approach Channels - Design Guidelines, MarCom Working Group 121, PIANC, Brussels 2014.
18. PIANC, Masterplans for the development of existing ports, PIANC, Brussels 2014.
19. PIANC, Recommendations for the Design and Assessment of Marine Oil and Petrochemical Terminals, Maritime Navigation Commission, Report N° 153, PIANC, Brussles 2016.
20. PIANC, Safety Aspects Affecting the Berthing Operations of tankers to Oil and Gas terminals, PIANC, Brussles 2012
21. PIANC, Sustainable Maritime Navigation, EnviCom Working Group 136, PIANC, Brussels 2013.
22. PIANC, Working with Nature PIANC Position Paper, PIANC, Brussels 2011.
23. PIANC-IAPH Working Group II-30 in cooperation with IMPA and IALA, “Approach Channels - A Guide for Design”, Brussels, 1997.
24. ROM (Del Estado P.), Action in the Design of Maritime and Harbour Works, ROM 0.2-90. CEDEX, 1990.
25. ROM (Del Estado P.), Recommendations for Designing the Maritime Configuration of Ports, Approach Channels and Harbour Basins”. ROM 3.1-99. CEDEX, 2007.
26. Roubos A.A., Groenewegen L., Ollero J., Hein C. & Wal E. vd. Design values for berthing velocity of large Seagoing vessels, PIANC World Congress Panama 2018.
27. Roubos, A., Peters D.J., Groenewegen L. & Steenbergen R.D.J.M. Partial safety factors for berthing velocity and loads on marine structures. Marines Structures 2018, 58. pp.73-91.
28. Shibata. Product Information Cylindrical Fenders, 2017, available on http://shibata-fender.team/ (accessed: May 12, 2022)
29. Thorsen, C.A. Port Designer's Handbook, ICE Publishing 2014, p.607.
30. Trelleborg Marine Systems, Fender Design, available on: www.trelleborg.com/marine (accessed: May 12, 2022)
31. Trelleborg. Bollards - Product Brochure, 2017.
32. Trelleborg. Safe Berthing and Mooring, 2008.

33. UNIFIED FACILITIES CRITERIA (UFC), DESIGN: PIERS AND WHARVES, 2017, p.183, available on https://www.wbdg.org/FFC/DOD/UFC/ufc_4_152_01_2017.pdf (accessed: May 12, 2022).
34. Unified Facilities Criteria UFC 4-159-03 Design: Moorings, 2005.