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INFLUENCE OF HYDRO-METEOROLOGICAL ELEMENTS ON THE SHIP MANOEUVRING IN THE CITY PORT OF SPLIT

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Abstract The Port of Split is located in the central part of the eastern Adriatic and is the largest Croatian passenger port. The Port of Split consists of the North Port, for the reception of mainly cargo ships, and the City Port for the reception of passenger ships. Although the port is protected from the open part of the Adriatic by a number of islands, its specific spatial position as well as local hydro-meteorological factors, primarily wind, can significantly affect the safety of navigation, and ultimately close all traffic. The entrance to the City Port is facing to the south; accordingly, the effect of southerly winds and waves will be one of the primary factors influencing the safety of manoeuvring. Also, the wider area of Split is characterized by the strong local, approximately NE wind with sudden gusts (''Bura'') which is especially dangerous for navigation. This paper analyses the effect of significant hydro-meteorological factors on the safety of manoeuvring at the approach and within the City Port of Split. The influence of wind, waves, sea current, tides and visibility will be analysed. Also, these factors will be classified in order of importance with respect to those parts of the port where they predominate as a threat to manoeuvring safety. The obtained results should serve as a basis for future defining of limiting working/manoeuvring conditions.

Keywords: city port of Split; ship manoeuvring; wind, waves; sea currents

Introduction

The Port of Split is located on the central part of the eastern Adriatic coast and is the biggest Dalmatian port, respectively the biggest Croatian passenger port.

Due to its deep coastal indentation and the surrounding (nearby) islands, it is possible to approach the port through coastal and inner waterways such as Drvenik, Šolta Split and Brač channels, and the Strait of Split (Splitska vrata) (Figure 1).

The City Port Basin has 2.136,5 m long operative coastline with 27 berths. The eastern part of the port is protected from the south by a protective breakwater which is approximately 400 m long. The waterway width at the approach to the City Port

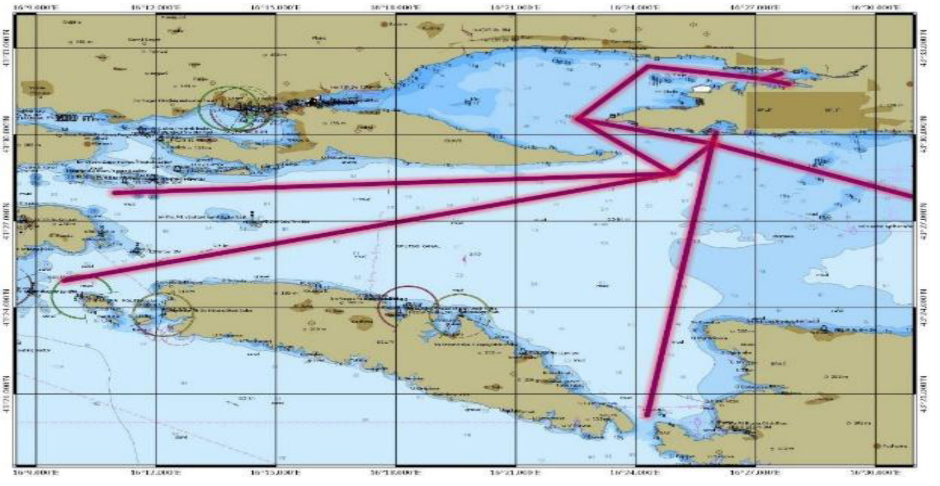

Figure 1. The approach to the Port of Split
Source: Authors

is 315 m and refers to the distance between the head of the eastern breakwater and the head of the ACI marina breakwater.

The City Port accommodates domestic and international passenger ships, smaller vessels for tourist traffic, authority ships, war ships, and in exceptional cases ro-ro ships with up to 10 m draft. In the City Port, ships are moored at the following berths[1)]:

– No. 1 and 2: designated mooring place for liner ships, cruise ships (with lower draft), excursion ships and yachts.

– No. 3: for public transport ships and boats. No. 4, 5 and 6a: for high-speed vessels, liner ships, transfer ships.

– No. 6 (b and c) and 7: for high-speed vessels and cruise ships.

– No. 8: for cruise ships and yachts.

– No. 9 for mooring of high-speed vessels.

– No. 10, 11 (a, b and c), 12 and 13: for liner ships, cruise ships, high-speed vessels and yachts.

– No. 14: for tugs, exceptionally cruise ships and yachts.

– No. 16, 17, 18, 19 and 20: for mooring of international passenger ships, cruise ships, yachts, exceptionally domestic liner ships.

– No. 21: for high-speed vessels, cruise ships, yachts and transfer ships, hydroplanes and pontoons.

– No. 22-25 are for liner ships, cruise and international traffic ships.

– Berths no. 26 and 27, or the outer berths, are designated mooring places for cruise ships, international traffic ships and liner traffic ships[2)].

The berth lengths for cruise ships vary from 63 to 173 m, max depth is 8,2 m. On the outer berths the length of the pier is 245 – 265 m, and the depth 10,7 m. The largest cruise ship may have length 250 m, max. draft 8,2 m. The port also accommodates the ACI marina Split with 355 berths and 30 dry berth units, and a small harbour for boats in Matejuška bay.

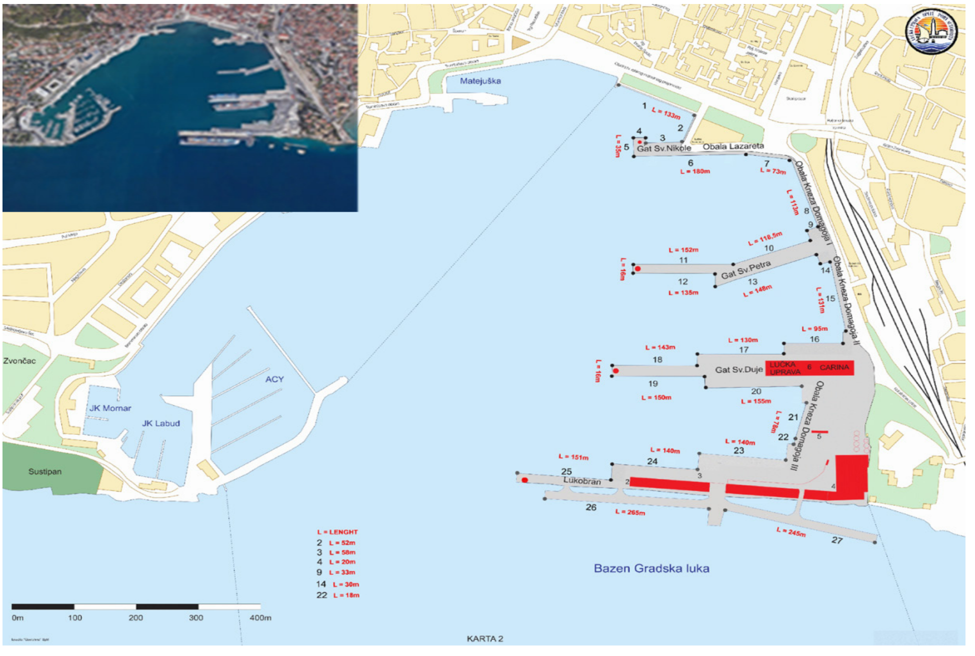

Figure 2. City Port of Split[2), 3)]

In accordance with Ordinance on the Order in Ports, no manoeuvring conditions have been formally defined, apart from the limited ship speed of 6 knots. Furthermore, ships leaving the port take precedence in manoeuvring and no disrupting is recommended. Anchoring in the whole port area, unless in emergency, is strictly forbidden for the same reason. Piloting is mandatory for ships over 500 GT, and place of embarkation is 0,5 nautical miles off the breakwater[4)].

The main goal of this paper is to single out individual parts of the port from the point of view of the specificity of manoeuvring in the conditions of different hydro-meteorological factors. Comparative analysis of individual berths of the Port of Split in relation to the prevailing meteorological and oceanographic influences is the main research method.

Hydro-meteorological characteristics

Based on long-term measurements of wind direction and speed from Split-Marjan weather station it can be concluded that NE (23,8%), SE (13,8%) and SW (10,9%) winds predominate in the Split area. Stronger breezes (6 and 7 on Beaufort Scale) approximately occur 120 days a year, while gales (8 and 9 on Beaufort Scale) approximately occur 64 days a year and are most frequent in February and January. Hurricanes (12 on Beaufort Scale) approximately occur 22 days a year. Maximum expected gusts with 50-year return period are 47 m/s (bura, NE wind), 37 m/s (jugo, SE wind) and 36 m/s (lebić, SW wind)[5)].

Oceanographic current measurements in the wider City Port of Split basin were carried out on four stations (one within the port and three just outside the port area) in two periods: summer (June 27 to August 28, 2007) and winter (January 8 to February 12, 2008).

Table 1. Probability of occurrence [‰] per wind direction, 2006-2015[5)].

Strength (on Beaufort Scale)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**total**
speed (m/sec)	0,0-0,2	0,3-1,5	1,6-3,3	3,4-5,4	5,5-7,9	8,0-10,7	10,8-13,8	13,9-17,1	17,2-20,7	20,8-24,4	24,5-28,4	28,5-32,6	32,7-36,9	
N		14,7	12,9	4,2	1,5	0,4	0,1	0,0						33,9
NNE		13,0	16,3	8,6	6,4	4,0	1,7	0,6	0,2	0,1	0,0			50,9
NE		21,4	55,2	53,8	54,1	36,7	12,1	3,2	1,0	0,3	0,0			237,7
ENE		15,8	49,9	25,9	6,4	2,2	0,4	0,0						100,7
E		12,2	18,3	9,1	1,7	0,2	0,0							41,6
ESE		8,9	12,8	12,9	11,6	5,5	1,7	0,5	0,1					54,0
SE		12,2	15,4	21,6	36,2	30,6	17,1	4,3	0,4	0,0				137,9
SSE		7,3	5,9	2,3	1,8	2,2	1,6	0,5	0,0					21,5
S		15,2	14,2	2,7	2,0	1,9	0,9	0,3	0,1					37,3
SSW		10,5	12,5	1,7	1,3	1,2	0,8	0,3	0,0					28,3
SW		28,2	61,5	17,1	1,7	0,6	0,3	0,0						109,4
WSW		18,1	25,4	20,2	2,3	0,0								66,1
W		4,0	6,9	2,4	0,3	0,0								13,6
WNW		3,1	6,1	0,8	0,0									10,1
NW		10,5	20,9	4,6	0,4									36,3
NNW		6,4	5,0	1,2	0,3	0,1								12,9
C	7,6													7,6
Total	7,6	201,5	339,3	189,1	128,2	85,4	36,7	9,8	1,9	0,4	0,1	0	0	1000

Current measurements in summer period were characterised by a predominant alongshore flow (with bathymetry) which was mainly vertically homogeneous.

Generally speaking, the current was flowing in the City Port mainly along the main City Port breakwater and flowing out along the ACI marina breakwater. Within the port, the N flow prevailed over the E flow, but it was significantly weaker than on the outer stations. Winter current measurements showed that the incoming current flow along the main breakwater and outgoing flow along the ACI marina breakwater predominates at the entrance to the City Port. The flow was significantly weaker within the port with a slightly larger percentage of the N flow over the E flow. Current flow within the port fluctuated and was of low intensity. Maximum measured speed within the port was 21 cm/s (summer) and 28 cm/s (winter), along the main breakwater 58 cm/s (summer) and 48 cm/s (winter), and along the ACI marina breakwater 51 cm/s (summer) and 41 cm/s (winter). Maximum measured speed in the area of outer berths was 60 cm/s (summer) and 49 cm/s (winter)[6].

Measurements of surface wind waves in the vicinity of the City Port of Split entrance over an eight-month period (deep water waves) showed that small waves occur most commonly. Maximum wave height of Hmax= 2,84 m was measured in winter (December 3, 2007) during a strong and stormy SE wind. Significant wave height was Hs=0,92 m. ESE and SE waves predominate, and calm sea is significantly common, 31,7%. It is important to point out that in 99,4% of cases the wave height was less than 1m, and in 99,9% less than 2m. Through expert evaluation method, the maximum wave at the entrance to the City Port of Split (deep water wave) is estimated to approx. 5m[7].

Figure 3 shows the exposure of wider City Port of Split basin area to dominant winds, which are divided in specific sectors. Using the Groen-Dorrenstein diagram,

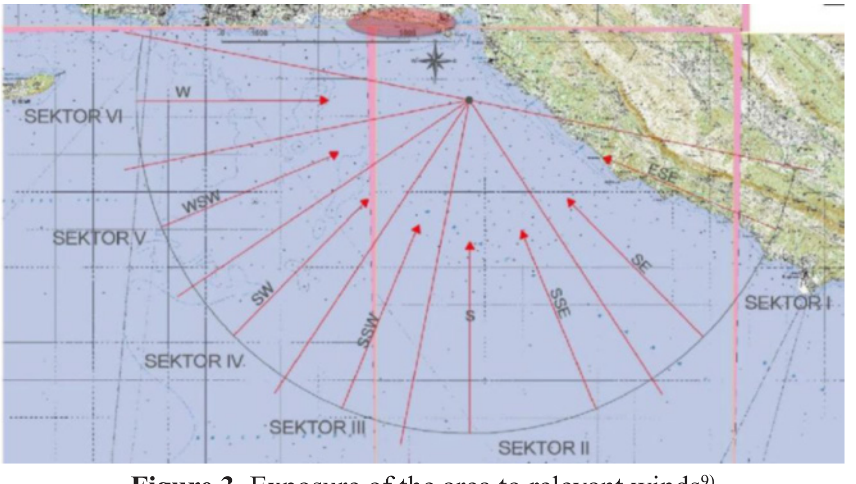

Figure 3. Exposure of the area to relevant winds[9]

a pattern of significant wave height Hs and wave periods Ts (table 2) has been determined for different categories of wind speed and their upper levels, as well as the corresponding fetch of individual sectors.

Furthermore, long-term prediction of significant wave height Hs with return period RP = 5, 10, 20, 50 and 100 years (table 3) has been created based on the pattern of significant wave height Hs[8)].

Analysing the obtained results shown in tables 2 and 3, it can be concluded that the maximal wave height at the entrance to the City Port of Split (deep water wave) is estimated to be approx. 5 m return periods 50 and 100 years), which roughly corresponds to the value obtained through expert evaluation based on the wave measurements[7)].

Table 2. Significant wave heights Hs and associated wave periods Ts[9)]

Sector	Speed (upper)	5,4	7,9	10,7	13,8	17,1	2 0,7	24,4	28,4
	Bf	3	4	5	6	7	8	9	10
I	Fetch (km)	2,6							
	Frequency	801	1051	1248	636	130	23	4	
	T_s(s)	2,44	2,9	3,25	3,55	3,9	4,2	4,45	
	H_s(m)	0,45	0,73	1,05	1,4	1,85	2,4	2,62	
II	Fetch (km)	13,7							
	Frequency	264	193	276	178	56	7	2	
	T_s(s)	2,25	2,7	2,9	3,2	3,6	3,9	4,6	
	H_s(m)	0,42	0,65	0,93	1,3	1,8	2,1	2,9	
III	Fetch	12,5							
	Frequency	783	88	37	14	6	2		
	T_s(s)	2,25	2,57	2,85	3,19	3,49	3,7		
	H_s(m)	0,4	0,6	0,91	1,15	1,57	1,96		
IV	Fetch (km)	16,0							
	Frequency	665	152	10	4				
	T_s(s)	2,31	2,62	2,93	3,3				
	H_s(m)	0,42	0,62	0,96	1,22				
V	Fetch (km)	18,3							
	Frequency	437	66	8	1				
	T_s(s)	2,34	2,7	3,05	3,3				
	H_s(m)	0,43	0,65	1	1,35				
VI	Fetch (km)	15,3							
	Frequency	54	8						
	T_s(s)	2,3	2,62						
	H_s(m)	0,42	0,63						

Table 3. Predicted wave height values and associated wave periods[9)]

Return period	Sector 1						
	H_s(m)	$H_{1/10}$(m)	$H_{1/100}$(m)	H_{max}(m)	T_0(s)	L_0(m)	T_p(m)
100	3,05	3,87	5,09	5,49	4,96	38,4	5,46
50	2,88	3,66	4,81	5,18	4,80	36	5,28
20	2,64	3,35	4,41	4,75	4,58	32,8	5,04
10	2,46	3,12	4,11	4,43	4,42	30,5	4,86
5	2,28	2,9	3,81	4,1	4,26	28,3	4,69

(for the frequency of occurrence of mean hourly wind speeds for Split, for period 1982 – 2011).

Concerning the distribution of wave heights within the City Port of Split basin and using MIKE 21/SW numerical model for three basic wind directions S, SE and SW and with recurrence interval of 100 years (Figure 4) it has been concluded that maximum expected wave height in front of the coastline of the head of Gat sv. Petra is from 2,6 to 2,7m (SE, S and SW) (for deep-water southern waves Hs=3,0m) (Lončar et al. 2009).

Long-period sea-level oscillation (periods longer than 1 min) in the City Port of Split basin are low. Average daily oscillation of the sea level (mean tidal range) is 25 cm. Total sea level fluctuation range is 153 cm[6)]. In meteorological events with deep cyclone (extremely low pressure) and stormy and hurricane winds coming from SE to SW, extreme long-period oscillations of the sea level can occur, as well as the coastal flooding in the area of berths 1 – 5.

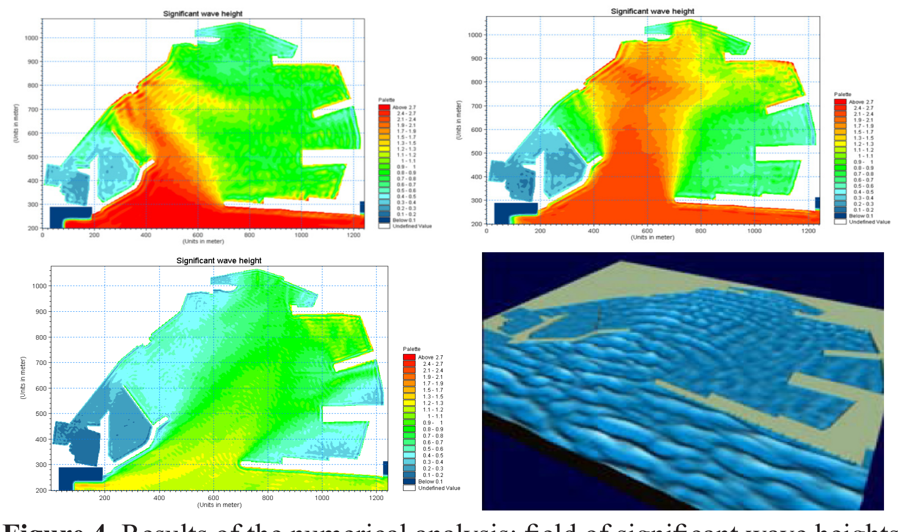

Figure 4. Results of the numerical analysis: field of significant wave heights (SE, S, SW). (Lončar et al. 2009)

Visibility in the City Port of Split area is mostly high. Fog is relatively rare in the Split area since the annual average number of foggy days in ten-years period is 1,9 days. Maximal annual number of foggy days is 7[5)].

General and special recommendations

The Port of Split has no formal limiting conditions for manoeuvring and staying at berth, and consequently everything is left to the subjective assessment of the Master, pilot or the Harbour Master`s Office. But there are good practices and well-known general recommendations. The following are the more important ones, applicable to the port of Split, and which should be taken into account when defining the limiting manoeuvring conditions.

Minimal waterway width and passing distance. According to the Pianc guidelines (2014), the minimum necessary width of waterway for ships with excellent manoeuvrability is 1,3 ship width, 1,5 ship width for ships with average manoeuvring characteristics and 1,8 ship width for ships with poor manoeuvring characteristics. These values should be increased depending on the assessment of external factors impact. On a small range, the distance between ships must not be less than two times the bigger ship’s length. The distance of a ship arriving/departing from a moored ship must not be less than two times ship’s width for ships under 4 knots of speed, i.e., not less than 4 times ship’s width for speeds up to 6 knots.

Turning circle area. Turning circle diameter should not be less than two times the length of the ship. If there is no tug assistance or a strong current or wind-driven drift is expected, the diameter should be 3 and more times the length of the ship. Minimum turning circle area should be determined in accordance with risk assessment i.e., depending on the type and characteristics of the ship, area characteristics, cargo being transported and expected external factors that have impact on the ship.

Depths and speed on waterway. Required sea-depth for a ship with a certain draft to be accommodated can be determined in the following way:

$$D+\Delta D = T + Z1 + Z2 + Z3 + Z4 \quad (1)$$

where:

D – is depth in the manoeuvring area in relation to the hydrographic zero,

ΔD – is correction for the effect of tidal forces,

T – is greatest draft, taking into account the water density,

Z1 – is draft change (due to the effect of waves, squat effect, the change in trim, lateral inclination etc.)

Z2 – is net under-keel depth which depends on the type of the seabed,

Z3 – is change in the sea level due to the change in atmospheric pressure and other adverse hydro-meteorological conditions, Z4 – is change in the seabed level (mudded seabed due to the dredging, a dredging mistake, a depth measurement error etc.).

Taking into account the speed limit in the observed area, it can be estimated that squat effect for the biggest ships will not be greater than 0,3 m. The inclination effect on the draft change can be calculated using 1/2B x tg inclination angle formula. Using the assumption that ship inclination is 2°, the draft increase, e.g. for a ship of 28,0 m width is 0,49 m, and for a ship of 49,0 m width it is 0,86m (Z1)[10].

Net under-keel depth (Z2) depends on the type of the seabed, and for the observed area (muddy seabed and sea density of minimal oscillations), 0,5 m can be used.

Factor Z3 depends on the change in atmospheric pressure and other meteorological and oceanographic conditions. With the assumption that "Bura" blows for three days on average speed of 20-25 knots, the sea level can be decreased by approx. 0,15m. On the other hand, the change in pressure of 1hPa changes the sea level by 1cm.

Factor Z4 can be ignored.

The speed in the port basin is limited to 6 knots. In accordance with the Ordinance on Safety of Maritime Transport[11], all vessels are required to navigate with special attention within 150 m off the coast, with the speed less than 5 knots, and within 150 to 300 m off the coast all vessels have to navigate with special attention and speed not higher than 8 knots.

Table 4. Recommended speed of lateral movement toward the dock [8, 12]

Distance M or m	**VLCC/LNG/Tanker speed in knots (m/s)**	**Container/passenger ship speed in knots (m/s)**
3	6	/
1	3	6
0,5	2	4
L	1	2
200 m	0,39 (0,2 m/s)	/
100 m	0,29 (0,15 m/s)	0,39-0,58 (0,02-0,03 m/s)
60 m	0,19 (0,1 m/s)	0,29 (0,15 m/s)
30 m	0,1 (0,05 m/s)	0,19 (0,1 m/s)
End	0,04-0,08 (0,02-0,04 m/s)	0,16 (0,08 m/s)

Limiting manoeuvring and safety conditions. It is difficult to generalise limiting manoeuvring conditions given the fact that there are various different vessels and conditions they can find themselves in. On the other hand, most research show that the upper limit for safe manoeuvring is within these parameters (it does not apply to ships with exceptionally good maneuverability or the use of tug assistance)[5, 10, 13]:

– wind 10-12 m/s,
– waves to 1m,
– currents to 1 knot,
– Visibility 500 to 1.000.
– Limiting conditions for vessel berthing, according to Pianc (2014) are, as follows[14]:
– Forces longitudinal to the quay: wind(1min) 17 m/s, currents(1min) 1,0 m/s, waves(Hs) 2,0 m,
– Forces transversal to the quay: wind(1min) 10m/s, currents(1min) 1,0 m/s, waves(Hs) 1,5 m.

For loading and unloading operation stoppage (embarkation/disembarking):
– Liners and Cruise ships: wind(1min) 22 m/s, currents(1min) 0,7 m/s, waves(Hs) 0,3 m,
– Container ships, Ro-Ro and ferries: wind(1min) 22 m/s, currents(1 min) 0,5 m/s, waves(Hs) 0,3 m.
– Vessels at quay (Liners and Cruise ships):
– Actions longitudinal to the quay: Wind(1min) 22 m/s, Currents(1min) 1,5 m/s, waves(Hs) 1,0 m,
– Actions transversal to the quay: Wind(1min) 22 m/s, Currents(1min) 0,7 m/s, waves(Hs) 0,7 m.

For limiting working conditions on passenger and ro-ro ships, vertical and horizontal wharf motions can be taken into account, as well as the motion angle.

For limiting values significant amplitudes of 0,1 m for longitudinal motion and 0,5 m for transversal and vertical motion can be considered, and 2° for significant vacillation amplitude. The crucial parameter for safe berthing conditions is kinetic energy which is connected to the size of the ship and its roll dynamics; recommended limiting values are 0,3 m/s for the significant amplitude of the ship`s running and inclination speed, and 1,0°/s for vacillation speed[15].

Table 5. Safe work and berthing conditions criteria and limiting values[15]

	Criteria and limiting values						
	Safe work conditions				Safe berthing conditions		
	longitudinal motion	transversal motion	vertical motion	vacillation angle	running speed	inclination speed	vacillation speed
Limiting values	± 0,1 m	± 0,5 m	± 0,5 m	± 2°	0,3 m/s	0,3 m/s	1°/s

Outer berth

The analysis of ship behaviour shows that limiting value for safe work conditions on larger cruise ships under the influence of south wind is significant wave height of 1,2 m, and for limiting berthing conditions it is 2,5 m. Under the influence of north winds this limit is significant wave height of 2,2 m for safe work conditions, and 2,5 m for limiting berthing conditions[15)].

From the safe stay at berth point of view of the largest reference ship (L approx. 320m) with permitted motion amplitude, a ship can be at berth up to the significant wave height of 2,5 m, but as the result of the increased draft due to the ship inclination around the longitudinal axis and the available depth at berth site, it is not possible as the significant wave height of 1,2 m results in the maximum allowed inclination. Limiting wave height for ro-ro passenger ships and high speed vessels of up to 100m in length is from 0,6 to 0,8 m. Wind speed, which is in correlation with the wave direction and height, is estimated for each wave height[12)].

Therefore, during the influence of south winds the key element of the safe stay at berth are waves, while during the influence of north winds the key factor will be the wind itself. There is a similar situation with determining limiting manoeuvring conditions. North winds do not create higher waves, so the wind remains the key factor, which defines safe manoeuvring conditions. On the other hand, south winds have enough space to create higher waves, so both factors should be taken into account. For larger ships limiting wind value should not exceed 10 m/s for south winds and 12,5 m/s for other winds, while limiting wave value should not surpass 1,2 m and currents speed 0,5 m/s.

Inner berths

For inner berths the upper limit for safe manoeuvring is up to 15 m/s (1 min), under condition that currents do not exceed 0,5 knots nor waves 1 m in height. Bearing in mind that typical ro-ro passenger ships have significantly larger surfaces exposed to wind, no matter how good their manoeuvring characteristics are, their upper limit for safe manoeuvring should not exceed 12 m/s (30 sec.) in crosswind conditions i.e.,15 m/s (30 sec.) in headwind conditions[15)]. Unless ships have typical propulsion systems performance or their manoeuvring characteristics are poorer than expected, limiting manoeuvring values will decrease. Manoeuvring limit can also increase provided there is tug assistance or in exceptional emergency situations with the consent of the Harbour Master`s Office. Moreover, the limit can be increased for ships with exceptional manoeuvring characteristics, which can generate above-average lateral thrust forces.

Staying at berth can be regarded safe even during the strongest winds provided proper usage of mooring lines and mooring system in general. Up to 25 m/s (30 sec.) can be regarded a safe stay at berth for ships with exceptionally large lateral surfaces. In the event of extreme south or almost south generated waves, the limiting factor will be the waves, especially for smaller vessels. Smaller ships are moored at the far inner berths of which northeast and northwest ones will be mostly exposed to waves. Arriving and berthing manoeuvre, as well as unberthing and departing manoeuvre is possible during the day and night. The effect of currents can be regarded as negligible.

Fog could interrupt all traffic but it is very rare and, as such, is also negligible.

Influence of factors on maritime risk

Taking into account all aforementioned characteristics of the City Port of Split, at least 4 specific areas can be singled out based on the specific effect of external factors, primarily wind and waves. These areas are: outer berths, main inner/easter berths, western berths and far N/NE inner berths (Figure 5).

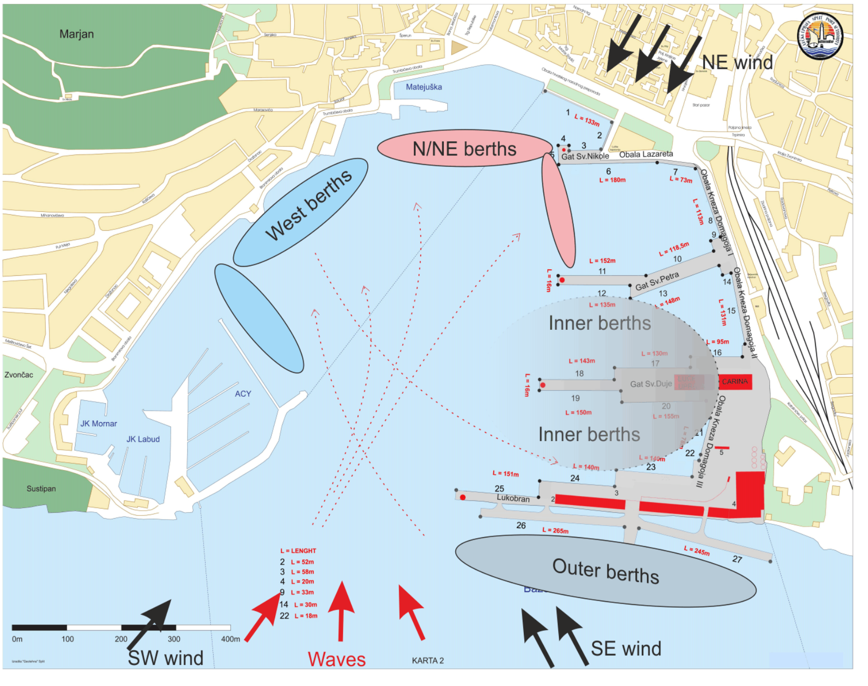

Figure 5. City Port of Split – areas of berths
Source: Authors

Outer berths

Outer berths are exposed to the open sea and consequently waves will mostly affect limiting work and berthing conditions. Under the influence of north winds, waves cannot grow significantly higher, so the wind remains the key factor for limiting conditions evaluation. Under the influence of south winds limiting value can generally be a wave of 1,2 m height, and for north winds 12,5 m/s speed of wind. Currents rarely exceed the value of 0,5 m/s, while fog can be expected approximately for up to 2 days. These berths are generally used by cruise ships and larger passenger ships.

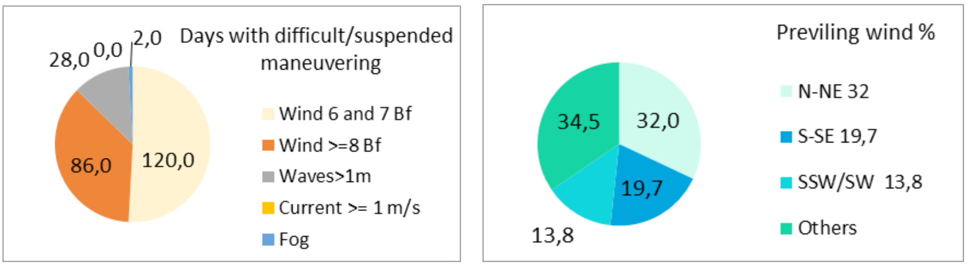

Figure 6. General wind characteristics
Source: Authors (based on Table 2)

Inner berths

Wind is the primary factor for defining limiting manoeuvring and berthing conditions on inner berths. The port offers good protection from waves, except from the SE to SW generated ones. Fog is rare, but when it occurs it can completely interrupt traffic. The currents effect is negligible and can rarely exceed 0,5 m/s. Considering that typical ro-ro passenger ships usually have much larger surfaces exposed to wind, no matter how good their manoeuvring characteristics are, the upper limit for safe manoeuvring should not exceed 12,5 m/s in crosswind conditions. Possibly, this limit can be increased to 15 m/s in headwind conditions. These conditions require ro-ro passenger ships with very good manoeuvring characteristics and redundancy (and duplication of propulsion system) (Shigunov 2018).

In stormy and hurricane situations coming from SE to SW sector, due to the overall impact of winds and waves in the City Port of Split, it is advisable not to use

Figure 7. Vessel departure in 19 m/s SE wind 28.12.2020
Source: Authors

berths 5 – 11 and 22 – 25, and west coast berths. Sea level fluctuations can exceed 150 cm.

In meteorological events with deep cyclone and stormy and hurricane winds coming from SE to SW, extreme long-period oscillations in sea level can occur, as well as the coastal flooding in the area of berths 1 – 5.

Far N and NE inner berths, and west coast berths

These berths are also part of the inner berths, but they are specific because they are mostly used for catamarans, smaller tourist and other vessels. They are also exposed to SE to SW generated waves and sea level oscillations (Figure 8). In extremely adverse weather conditions, vessels are required to leave these berths.

Figure 8. SW generated waves inside the City Port of Split 20.11.1999
Source: Authors

Manoeuvring in limiting conditions, or above them, is extremely precarious, especially bearing in mind the fact that these are all passenger or ro-ro passenger ships, i.e., ships with a large number of people and vehicles, and that manoeuvring itself is performed in the immediate vicinity of coastal pedestrian zones and generally in the vicinity of valuable infrastructure. Marine accident statistics show that one of the most frequent types of accidents are groundings due to the failure of one of the ship`s systems or to the loss of control as a result of adverse weather conditions, and they happen on average every two to three years (Lušić et al. 2016). There have not been any accidents with major consequences in the recent history, which does not mean that the level of safe manoeuvring within the port is on a satisfactory level considering there are no formally defined limiting conditions. The traffic of smaller vessels, which can seriously interfere with the manoeuvring of larger ones, especially during the summer season, is a major navigational safety hazard (Figure 9). A mitigating circumstance is that this type of traffic hardly exists in adverse hydro-meteorological conditions and therefore it cannot affect the manoeuvring of larger vessels.

Figure 9. Sports and recreational navigation[16)]

Conclusions

The City Port Split is the biggest and the most important Croatian passenger port. The City Port, as well as the whole city of Split area, is exposed to specific northern winds with sudden and strong gusts, which are exactly one of the biggest navigational safety problems. Another significant wind in this area is the southeast wind, which is usually weaker, but more continuous and can easily generate higher waves. This, and other southern winds make the City Port very vulnerable i.e., poorly protected, so higher waves can occur even within the port itself. The City Port offers the outer berths as well, primarily for large cruise ships during the summer season, which are completely exposed to the open sea. Waves are, or can be, a major factor jeopardizing safe stay at these berths, but also at far N and NE berths and west coast berths. Major safety risk factor for other berths, and all the berths in general when there is no south or approximately south wind, is the wind. Currents are almost insignificant, and fog occurs one to two days a year. Comparing these external factors and characteristics of individual berths, four basic parts of the port can be distinguished, given the specificity and safety of manoeuvring. Division of the City Port into specific areas regarding the effects of external factors, which have been discussed in this study could help in risk assessment but also as a basis for determining the future formal limiting conditions for the ships manoeuvring, work and stay at berth.

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