COMPARATIVE ANALYSIS OF ALTERNATIVE LAYOUTS FOR THE NEW DEEPWATER BREAKWATER OF GENOA PORT

Paolo De Girolamo[1], Leopoldo Franco[2], Alberto Noli[3], Alberto Scotti[4], Antonio Lizzadro[4], Marco Tartaglini[3], Marco del Bianco[3], Paolo Sammarco[5], Paolo Contini[3].

A new deepwater breakwater for the Port of Genoa, which is the largest Italian port, has been recently designed and construction started in 2023. The goal of the new vertically composite breakwater which reaches 50 m of depth, is to allow access to the new generation container ships (23.000 TEU; length overall 400 m; breath 61,5 m; draught 14,5 m). Basically, two alternative plan layouts have been selected for the new breakwater. The purpose of the paper is to illustrate the alternative solutions identified for the breakwater and to present the corresponding comparative analysis and the final choice.

Keywords: vertical breakwater; port layouts; wave modeling.

INTRODUCTION

A new deepwater breakwater for the Port of Genoa, which is the largest Italian port, has been recently designed and construction started in 2023. The goal of the new vertically composite breakwater which reaches 50 m of depth, is to allow access to the new generation container ships (23.000 TEU; length overall 400 m; breath 61,5 m; draught 14,5 m).

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The purpose of the present paper is to illustrate the alternative solutions identified for the breakwater and to present the corresponding comparative analysis and the final choice.

THE PORT OF GENOA TODAY

With reference to Fig. 1, the port of Genoa is located at the center of the Gulf of Genoa in the Ligurian Sea along a steep rocky coast with very limited sediment transport.

Fig. 1 also shows the meteorological conditions that generate extreme waves in the Gulf of Genoa and the inshore local wave climate off the Port in 50 m depth, as obtained from 40 yr (1979-2018) hourly database hindcasted by Genoa University (Mentaschi et al. 2015).

Prevailing waves come from the SW sector (Libeccio) even if the frequency and intensity of SE and ESE waves (Scirocco) is not negligible and increasing in the last 10 years.

The main wave sector spans from 120°N (Portofino Cape) to 225°N (Noli Cape). Prevailing local winds come from the north.

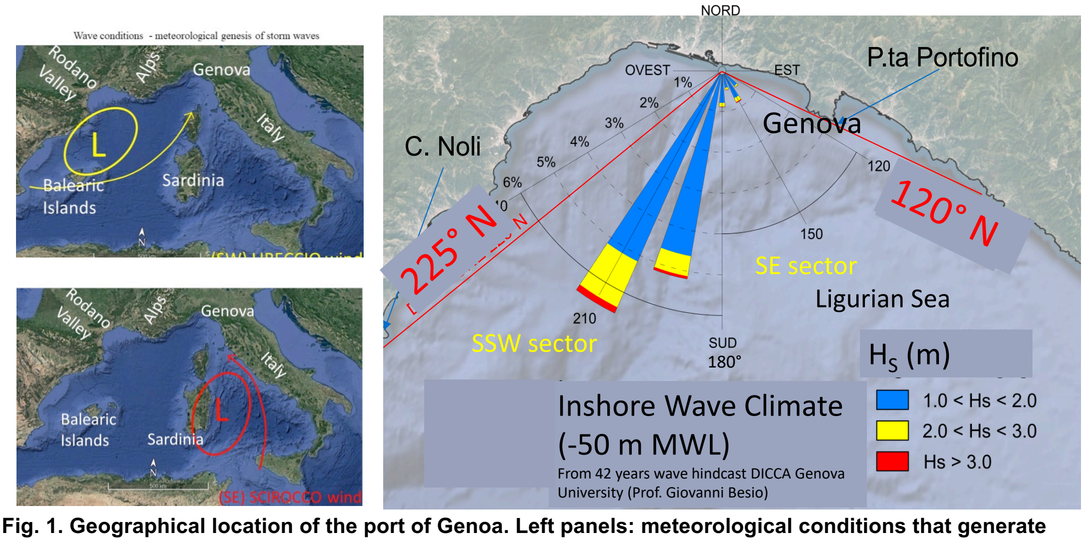
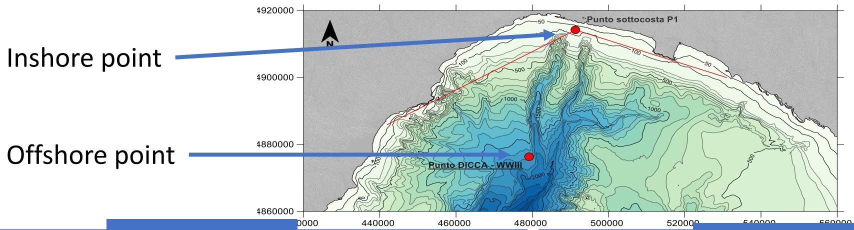


Fig. 1. Geographical location of the port of Genoa. Left panels: meteorological conditions that generate extreme waves in the Gulf of Genoa. Right panel: inshore wave climate from 40 yrs hindcasting.

[1] Sapienza University of Rome, Italy.
[2] University of Roma TRE, Italy.
[3] Modimar S.r.l., Italy
[4] Technital SpA, Italy
[5] University of Rome Tor Vergata, Italy.



SW sector180-240° N

TR [anni]	Offshore H_s [m]	Offshore T_p [s]	Offshore Dir [°N]	Inshore (nel punto P1 (-75 m s.l.m.)) H_s [m]	Inshore T_p [s]	Inshore Dir [°N]
2	5.3	9.6	180	5.2	9.8	179
	5.3	9.6	210	4.8	9.8	203
	5.3	9.6	240	3.3	9.8	216
5	5.9	10.0	180	5.8	10.6	179
	5.9	10.0	210	5.4	10.6	203
	5.9	10.0	240	3.7	9.8	216
10	6.4	10.3	180	6.3	10.6	179
	6.4	10.3	210	5.9	10.6	203
	6.4	10.3	240	4.0	9.8	216
50	7.5	11.0	180	**7.3**	**11.4**	179
	7.5	11.0	210	6.8	11.4	203
	7.5	11.0	240	4.7	11.4	217
100	8.0	11.3	180	7.8	11.4	179
	8.0	11.3	210	7.3	12.3	203
	8.0	11.3	240	5.1	12.3	217
250	8.7	11.6	180	8.5	12.3	179
	8.7	11.6	210	7.9	12.3	203
	8.7	11.6	240	5.5	13.2	217
500	9.2	11.9	180	8.95	12.3	179
	9.2	11.9	210	8.40	12.3	203
	9.2	11.9	240	5.9	13.2	217

SE sector 105-180° N

TR [anni]	Offshore H_s [m]	Offshore T_p [s]	Offshore Dir [°N]	Inshore (punto P1 (-75 m s.l.m.)) H_s [m]	Inshore T_p [s]	Inshore Dir [°N]
2	3.6	7.9	120	3.0	9.1	132
	3.6	7.9	150	3.5	8.5	153
5	4.1	8.4	120	3.5	9.1	132
	4.1	8.4	150	4.0	9.1	152
10	4.6	8.8	120	4.0	9.1	131
	4.6	8.8	150	4.5	9.1	152
50	5.7	9.5	120	5.0	9.1	131
	5.7	9.5	150	**5.6**	**9.8**	152
100	6.1	9.8	120	5.4	9.1	131
	6.1	9.8	150	5.9	10.6	152
250	6.7	10.2	120	5.9	10.6	131
	6.7	10.2	150	6.5	10.6	152
500	7.2	10.5	120	6.4	11.4	131
	7.2	10.5	150	7.0	10.6	152

Fig. 2. Extreme waves from the two main wave sectors.

The offshore and inshore extreme waves for the two main wave sectors are shown in Fig. 2 for different return periods. The inshore significant wave heights and spectral peak periods for a 50-year return period are highlighted, with values of 7,3 m and 11,4 s for the SW sector and 5.6 m and 9,8 s for the SE sector.

Fig. 3 shows the current situation of the port of Genoa and the position of the new container terminal at Calata Bettolo located in the area of Sampierdarena.

The port is divided into two areas: the Old Port and Sampierdarena, where the main commercial traffic takes place.

Today, the only port entrance for large commercial ships is the East entrance, which allows access to both areas of the port. The Est port entrance is oriented to 115°N, and is partly sheltered by Portofino Cape (Fig. 1).

With reference to Fig. 3, the current dimensions of the navigation channels and turning basins do not allow the entry of the design container ships, which are 400 m long and 60 m wide.

BRIEF HISTORY OF THE GENOA PORT LAYOUT

The port of Genoa after World War II is shown in Fig. 4 - panel a.

The reference the port layout (similar to the near Port of Marseille in France) may be classified as "Port with main breakwater parallel to the coast" (see Fig. 4 – panel b). From a navigational point of view, it is one of the best possible port design for a rocky coast because it has a double entrance in opposite directions which guarantee:

- (i) excellent nautical access to the port even in different weather conditions;
- (ii) the ability to perform emergency maneuvers for ships, for instance, in cases where the stopping maneuver of a ship might fail due to the inability to reverse the direction of the propellers' rotation (as occurred in May 2013 in Genoa, when the pilot tower was destroyed by the impact caused by the container ship *Jolly Nero*);
- (iii) excellent water exchange and, consequently, high water quality, a particularly important aspect in the case of microtidal ports.

As shown by Fig. 5, unfortunately, in the 50's of the last century the new reclaimed airport was incorrectly protected by a breakwater overlapping the existing one, and thus it made impossible to use the Port West entrance for the large ships.

This very serious mistake has increased naval traffic at the eastern entrance, reducing the port's operability and decreasing the safety of navigation for ships sailing through the only accessible port entrance located at the East.

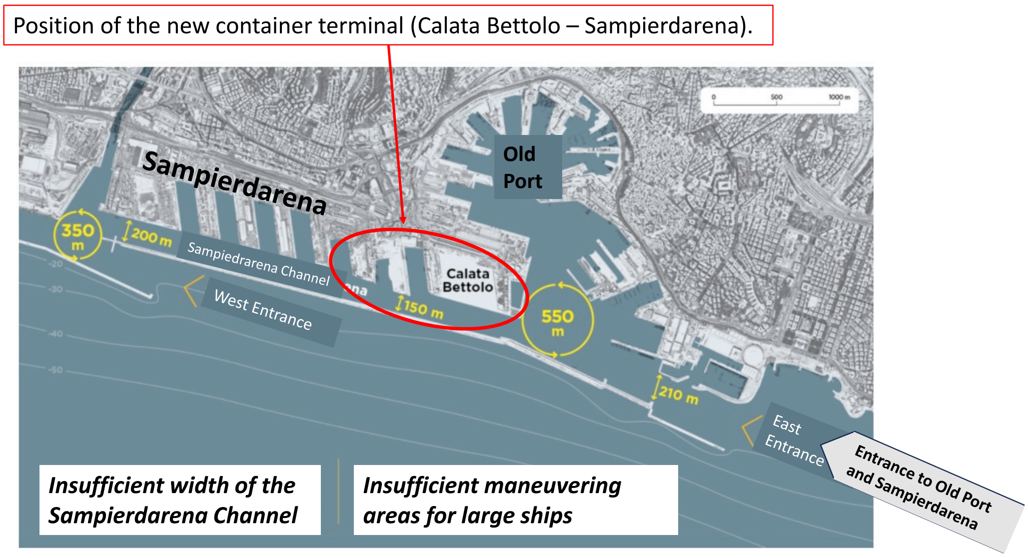


Figure 3. Current (2023) Genoa Port configuration.

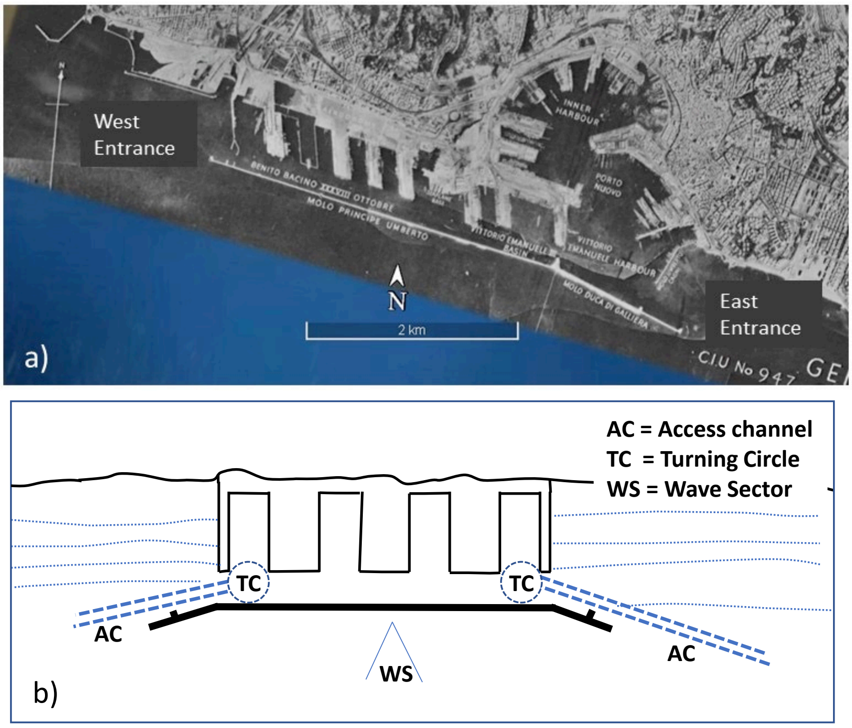


Figure 4. Panel a): Genoa Port Lay-out after Word War II. Panel b) Reference port Layout: «Port with main breakwater parallel to the coast and double entrance».

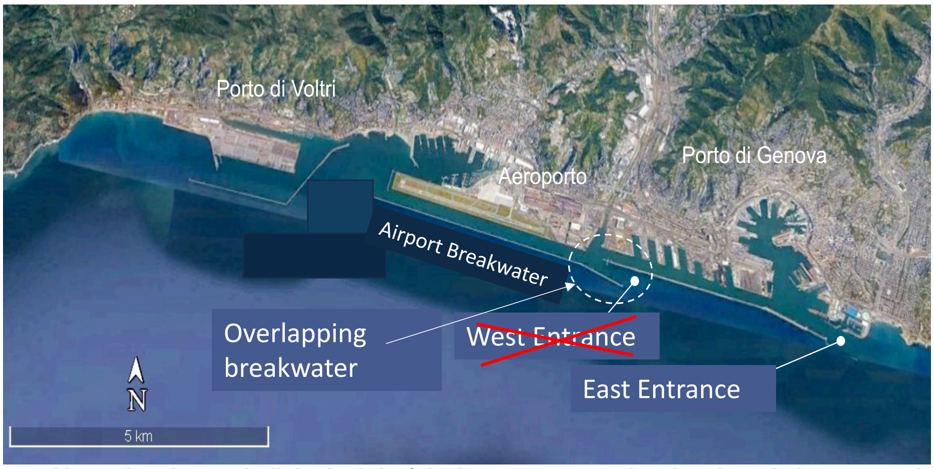


Fig. 5. Airport breakwater built in the '50 of the last century overlapping the existing one made it impossible to use the Port west entrance.

THE ALTERNATIVE LAYOUT SOLUTIONS

With reference to Fig. 6, two main basic port layout schemes have been selected after an initial screening to comply with the following minimum requirements for the new entrance:

(i) access channel length 2.000 m (5 LOA);
(ii) access channel width 310 m (5 B);
(iii) turning circle diameter 800 m (2 LOA);
(iv) rectilinear planshape of the access channel;
(v) limited demolition of the historical breakwater.

Scheme 1 creates a new entrance to the East, which must necessarily be parallel to the existing entrance because, for navigational safety reasons, the two access routes cannot intersect each other.

Scheme 2 reopens the old port entrance with an access route from the West, which, as mentioned before, had been mistakenly made unusable by the airport breakwater.

The cost of the two schemes is roughly the same. The new breakwater is made by a vertical composite scheme (with 25 m high r.c. caissons) reaching 50 m of depth.

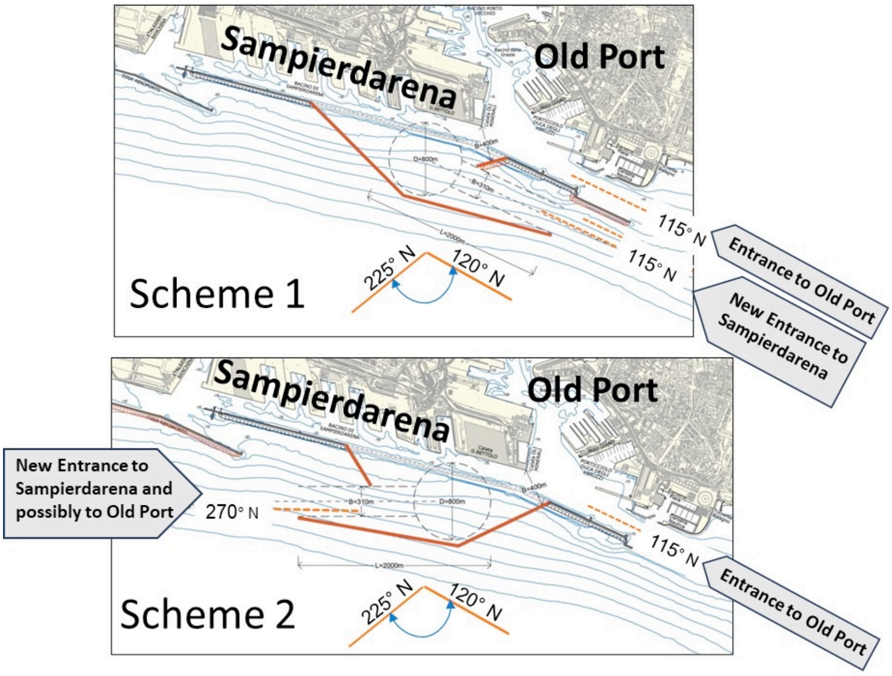


Fig. 6. The selected two main basic port layout schemes.

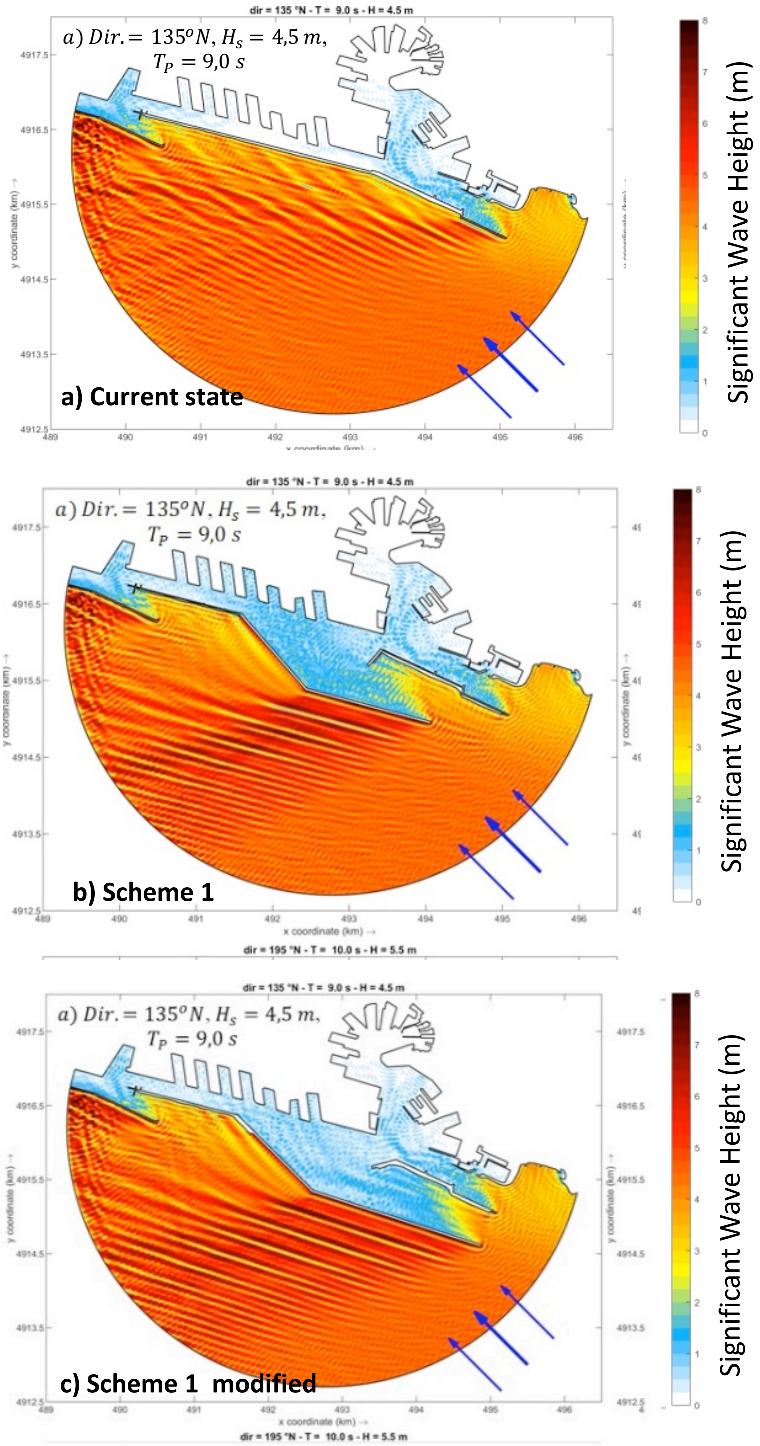


Fig. 7. Example of the numerical study of the internal port wave agitation which showed the need to extend the breakwater of scheme 1 by 800 m to obtain a wave agitation comparable to the current one.

The study of internal port wave agitation showed that Scheme 1 results in greater wave agitation compared to the current state.

Since the Port Authority had set the design requirement not to worsen the port’s wave agitation compared to the current conditions, it became necessary to extend the new breakwater by 800 m, leading to a cost increase of about 20% (see Fig. 7 c).

In Figure 7, the results obtained for a sea state with a return period (Tr) of 10 years and coming from 135° N are presented as an example. These results pertain to: a) the current state; b) Scheme 1; c) the modified Scheme 1 (breakwater extended by 800 m). The simulation results clearly show that, since waves coming from the southeast can have a very small angle relative to the axis of the port entrance (for the test shown in the figure, this angle is equal to 135° N - 115° N = 20°), placing the new entrance to the east of the port significantly increases wave penetration into the harbor compared to the current situation.

The same issue, however, cannot occur with Layout 2, because the minimum angle formed between the waves coming from the southwest and the new port access route positioned to the west (270° N) is equal to 225° N – 270° N = 45°. This value should be compared to the minimum value for Layout 1, which is only 120° N – 115° N = 5°.

In Fig. 8 the two final alternative port layouts are shown. The modified layout 1 foresees that the new entrance, which will be dedicated to the new container terminal, will have an access route parallel to the current one. The existing entrance will allow access to the Old Port. It is noted that the two parallel access routes, due to their proximity, may potentially create dangerous situations from a navigational safety perspective.

On the other hand, the new entrance in Layout 2 will allow easy access to both the new container terminal and the Old Port, making the nautical accessibility to the port much more efficient and flexible, as compared to Layout 1.

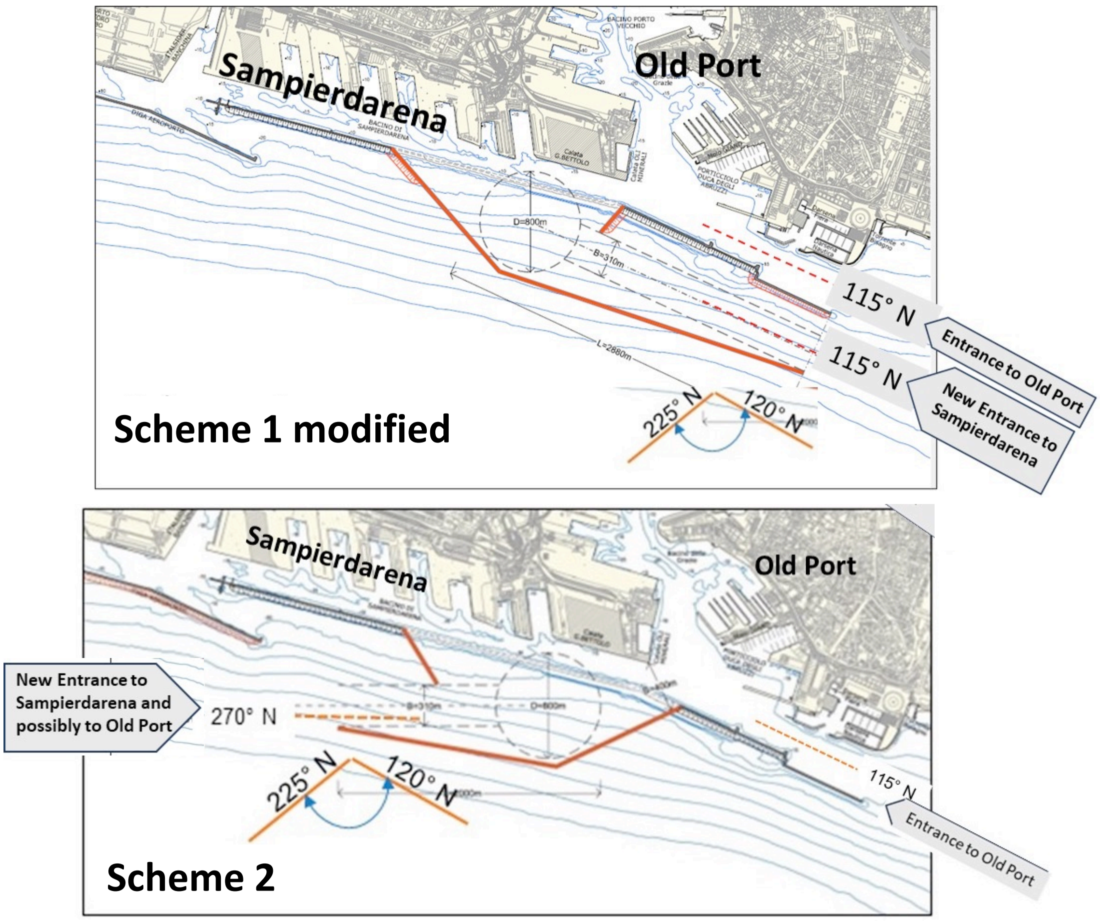


Fig. 8. Final alternative Port layouts.

COMPARATIVE ANALYSIS BETWEEN THE TWO LAYOUTS FINALLY SELECTED

The two layouts were compared considering the following factors:

a) navigation safety (assessed with a desk study considering for Scheme 1 both the proximity of the two routes and the possibility that ships, especially smaller ones, might be induced to cross the adjacent navigation route);

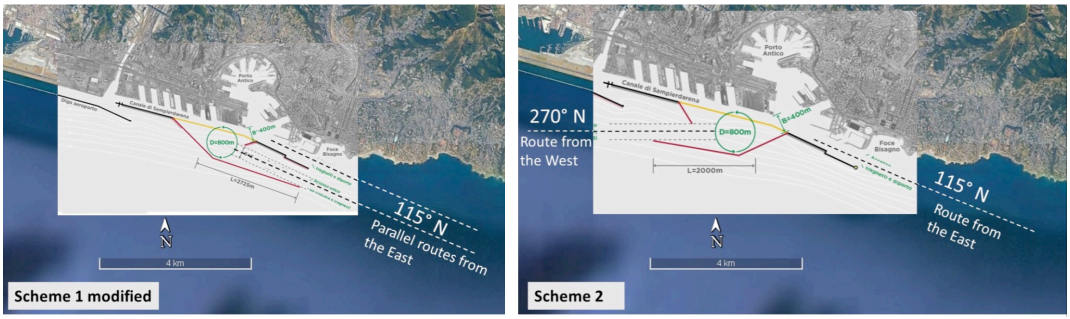
b) nautical accessibility (assessed using the HR Wallingford real-time maneuvering simulator in presence of the Genoa Port Pilots);

c) non-operational period of the quays (assessed numerically using annual mean wave conditions and assuming a significant wave height limit value of 0.5 m);

d) safety of moored ships in extreme weather condition (assessed numerically using extreme waves and water levels with a return period of 10 years, and assuming a significant wave height limit value less than 2.5 m);

e) Port Water Exchange (assessed numerically width Delft 3D numerical model);

f) Cost.



BEST SOLUTION

	OBJECTIVE FACTOR	SUBJECTIVE FACTOR
a) Navigation safety		Scheme 2 (green) Scheme 1 (red)
b) Nautical Accessibility		Scheme 2 (green) Scheme 1 (red)
c) Non-operational period of the quays	Scheme 2	
d) Safety of moored ships in extreme weather condition	Scheme 2	
e) Port Water Exchange	Scheme 1 - Scheme2	
f) Cost	Scheme 2	

In green the designers' evaluation
In red the pilots' evaluation

Fig. 9 - Results of the comparative analysis between the two layouts finally selected.

Fig. 9 shows the results obtained from the comparative analysis.

We can divide the factors under evaluation into objective factors, which are verified with numerical results, and subjective factors, which are the others. The evaluations of all the objective factors favoured Scheme 2. As for the subjective factors, the designers preferred Scheme 2, while the Pilots favoured Scheme 1.

Ultimately the opinion of the local port pilots prevailed and scheme 1 was chosen.

It is emphasized that the pilot from Wallingford expressed an opinion in agreement with the designers.

The main reason given by the local pilots was their reluctance to modify the current procedure for ships entering and leaving the port because the vertical breakwater of the airport reflects the waves and, in their opinion, this would create problems for ships accessing the port through the new West entrance.

The designers stated that this issue could be easily overcome, at the same cost, by reducing the reflection coefficient of the airport breakwater (with a sloping armour), which also requires maintenance work. It is also noted that the steep rocky coast facing the East entrance is also reflective.

In conclusion, the designers believe that another opportunity has been missed to provide the Port of Genoa with a new, efficient, and safe breakwater by adopting the best port layout currently available.

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REFERENCES

Mentaschi, L., Besio, G., Cassola, F., Mazzino, A. (2015). Performance evaluation of Wavewatch III in the Mediterranean Sea. Ocean Modelling, Vol. 90, pp. 82-94.