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Establishing Criteria for Ports of International Importance in the Republic of Croatia: A Case Study of the Port of Gaženica

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Abstract: The Republic of Croatia is home to six major ports open for public transport. These ports are of significant economic interest and are crucial to the country's maritime traffic and economy. This paper examines the ports' key development criteria and evaluates their relevance and applicability to the Port of Gaženica, which has been selected as a case study. This study identifies geographical, technological, and socio-economic factors influencing the Port of Gaženica's growth, evaluating its current status and future potential. The port's status was analysed using a methodology that included expert input and the evaluation of both existing and proposed criteria. The Port of Gaženica operates well, but there are significant opportunities for investment and improvement, especially in container and RO-RO shipping, and passenger services.

Keywords: Maritime traffic, Criteria, the Port of Gaženica, Expert group, Analysis, Container, RO–RO traffic.

1. Introduction

The term "port area" designates a specific seaport region comprising sea and land areas, commonly referred to as a port basin. These areas act as the operational hub for port activities and fall under jurisdiction of either the port authority, concessionaire, or state administration body [43]. The decision on the location of the port basin is based on spatial plans.

A port open to public traffic is a seaport that can be used by any individual or legal entity equally, as long as it aligns with its intended purpose and within its capacity limits [43]. Ports are vital for connecting land and sea traffic and act as catalysts for the growth of multiple sectors, including production, trade, processing, and services. Furthermore, they contribute to the growth of other sectors, like industry and energy, making them a significant component of a country's national economy. The economic importance of ports is substantial, as they foster income generation,

employment, and significant infrastructure and equipment development. International trade and employment are significantly boosted by their activities, making them drivers of socio-economic progress [44].

The growth of port areas plays a crucial role in the national economy and the surrounding region connected to a specific port. Port areas are significant economic hubs that rely on cargo and passenger traffic. The development of these strategies requires a comprehensive approach that considers factors such as geography, infrastructure, technology, and regulatory framework. The growth of port areas depends on the development and modernisation of port infrastructure. This includes the construction of ports, terminals, and warehouses, as well as enhancing connectivity with both roadways and waterways. Port logistics optimisation and integration with external transportation networks are vital as well. Furthermore, promoting environmental awareness fosters the progression of port areas towards sustainable practices. These actions comprise the reduction of emissions, waste management, the preservation of the marine environment, and the use of renewable energy sources. Smart technologies focused on technological innovations are becoming more crucial in managing port operations, increasing efficiency, reducing costs, and improving safety. Alongside a stable business environment and fair competition, regulatory frameworks and policies are equally crucial for developing port areas. Secure funding is crucial for the development of port infrastructure projects. Numerous ports offer significant tourism development potential for additional revenue. The construction of passenger terminals, marinas and accompanying tourist facilities attracts cruise ships, yachts and visitors who contribute directly and indirectly to the local economy.

The paper is divided into four main parts. After the introduction, the next section discusses the establishment of criteria for port development. These requirements have been created by analysing the current literature. The third part of the paper examines the present state of the Port of Gaženica. Experts assessed the overall criteria outlined in the paper's second section, considering their relevance to the Port of Gaženica. Additionally, the experts have identified further criteria for consideration. The fourth section of the paper discusses strategies for developing the Port of Gaženica, considering the assessed criteria. The paper concludes with a summary of all relevant segments of the research.

2. Criteria and sub-criteria relevant to port development

Decision-making regarding the port development is a complex process. It includes various criteria and sub-criteria that rank possible decisions [36]. Based on a literature review, the criteria and sub-criteria listed in Table 1 are suggested for developing a port.

Table 1- *Proposal of criteria and sub-criteria for the development of the Port of Gaženica.*

Criterion	Sub-criterion
technical/technological	Maritime characteristics (which enable safe ship approach, berthing, mooring or anchoring) The length of the operational shore The port area (coastal land surface) Waste management infrastructure (municipal waste, oil and solid waste, cargo residues, hazardous waste, faecal waters) The condition of the infrastructure communal infrastructure availability (water, electricity, hydrants, lighting, ...) Fuel supply accessibility
socio-economic	Transport connectivity (road, railway, airport) Multiplicative effects Impact on primary activities (agriculture and fishery sectors) Impact on the population Basic food supplies Wireless internet access Proximity to urban and economic centres
ecological	Air quality impact Sea quality impact Noise impact Impact on seabed sediment structure Use of renewable energy sources
safety	Protection against the influence of waves Fire and/or explosion protection Collision protection from another ship or vessel Availability of emergency intervention services
meteorological/ geographical	Wind speed, direction and force Height of waves Sea depth Tidal amplitude

Sources: author as cited in [1] [2] [3] [4] [6] [21-25] [27] [34-35] [39-40].

Each port's development characteristics are based on five primary criteria categories. Criteria and sub-criteria can be described using qualitative or quantitative values, depending on the appropriate descriptive

or numerical method. The following explains the primary objective for each proposed criterion.

The technical/technological criteria mentioned in Table 2 influence seaports' competitiveness and operational efficiency, thus establishing their essential role in the global supply and transport chain. The sub-criteria of the technical/technological criterion outlined in Table 2 define the minimum requirements that ports must fulfil to ensure safe, efficient, and cost-effective performance of port activities. Considerations include maritime characteristics, the operational coastline length, the port's land area, the state and availability of waste management infrastructure, and the fuel supply accessibility.

Table 2 - *Technical/technological criterion.*

Criterion	**Sub-criterion**	**Indicator**
Technical/technological criterion	maritime characteristics	limited
		satisfactory
		excellent
	the length of the operational shore	inadequate
		adequate
		excellent
	the port area (coastal land surface)	insufficient space for additional port facilities
		limited offer of additional port facilities
		sufficient space for additional port facilities
	waste management infrastructure	not available
		partially available
		available
	the condition of the infrastructure	non-operational
		partly operational
		operational
	communal infrastructure availability	not available
		partially available
		available
	fuel supply accessibility	not available
		partially available
		available

The socio-economic criterion (Table 3) ensures that implementing activities and/or policies contribute to the economic growth and improve social conditions and the community's well-being. The criterion comprises seven sub-criteria: transport connectivity, multiplicative effects, impact on primary activities and population, basic food supply system, wireless internet access, and proximity to urban and economic centres.

Table 3 - *Socio-economic criterion.*

Criterion	Sub-criterion	Indicator
Socio-economic criterion	transport connectivity	poor
		satisfactory
		excellent
	multiplicative effects	negligible
		moderate
		significant
	impact on primary activities	negligible
		moderate
		significant
	impact on the population	negligible
		moderate
		significant
	basic food supply system	not available
		available near the port area
		available in the port area
	wireless internet access	not available
		available in part of the port area
		available in the entire port area
	proximity to urban and economic centres	the port is over 2 km away from the urban centre
		the port is less than 2 km away from the urban centre
		the port is within the urban centre

Ecological criteria enable the measurement of human impact on the environment and the formulation of sustainable resource management strategies. This criterion includes the following sub-criteria: air quality impact, sea quality impact, noise impact, seabed sediment impact, and use of renewable energy sources.

Table 4 - *Environmental criterion.*

Criterion	Sub-criterion	Indicator
Ecological criterion	air quality impact	negligible
		moderate
		significant
	sea quality impact	negligible
		moderate
		significant
	noise impact	negligible
		moderate
		significant
	seabed sediment impact	minor
		important

		significant
	use of renewable energy sources	not in use
		used moderately
		used significantly

The safety criterion (Table 5) refers to the safety of people, vessels, and cargo. This criterion comprises four sub-criteria: protection against the influence of waves, fire and/or explosion protection, collision protection from another ship or vessel, and the availability of emergency intervention services.

Table 5 - *Safety criterion.*

Criterion	**Sub-criterion**	**Indicator**
Safety criterion	protection against the influence of waves	poor protection
		moderate protection
		good protection
	fire and/or explosion protection	poor protection
		moderate protection
		good protection
	collision protection from another ship or vessel	poor protection
		moderate protection
		good protection
	availability of emergency intervention services	intervention is not possible within 30 minutes
		intervention is possible within 30 minutes
		intervention is possible within 10 minutes

The port's geographic features and weather conditions are described by meteorological/geographic criteria (Table 6). These criteria comprise four sub-criteria: wind impact (speed, direction, and strength), wave influence (height), sea depth, and tidal amplitude.

Table 6 - *Meteorological/ geographical criterion.*

Criterion	**Sub-criterion**	**Indicator**
Meteorological/ geographical criterion	the wind impact	negligible
		moderate
		significant
	the influence of waves	negligible
		moderate
		significant
	sea depth influence	negligible
		moderate
		significant
	tidal amplitude influence	negligible
		moderate
		significant

The criteria and sub-criteria mentioned are used to facilitate the decision-making process and determine the course of port development.

3. Case study, the Port of Gaženica

A thorough understanding of the current situation is crucial in establishing development standards for the Port of Gaženica. Analysing the current situation provides a clear understanding of the present state, enabling a comparison between the port's current status and its potential future development. Following an analysis of the current situation, the expert group presented and evaluated the development criteria for the port of Gaženica.

3.1. Analysis of the current situation

The port of Gaženica is a port open to public traffic and is of special (international) economic interest for the Republic of Croatia [29]. This location can handle a wide variety of traffic, including island, coastal, and international ferry traffic, as well as passengers from large cruise ships and roll-on/roll-off cargo, and has the necessary infrastructure. The primary benefit of the Port of Gaženica lies in its convenient access to the highway and its traffic link to Zadar's hinterland, along with its favourable maritime features [28]. Specifically, the port is connected to neighbouring European countries via the Zadar-Sveti Rok tunnel – Bosiljevo - Zagreb highway and railway. However, the railway line that connects Zadar and Zagreb is insufficient in terms of its technical characteristics [26]. The Port of Gaženica is 3.5 km from the city centre and about 10 km from the airport.
The Zadar Port Authority has had jurisdiction over the area of the Gaženica port since 2005. The port authority does not carry out port operations, but oversees and coordinates them. The actual work operations within the port area are performed by concessionaires, which are economic entities authorised by the port authority to carry out specific activities within the port [18].

The port area includes cargo, passenger, and fishing ports. In front of the port, there is a designated anchorage. The depth of the sea at the anchorage is 40 meters. Buoys are required for ships of 500 GT or more. In recent years, the Port Authority Zadar has recorded average annual traffic of about 2.5 million passengers, 570,000 vehicles, and over 542,000 tons of cargo traffic [20]. The data presented in the Maritime Study for the Port of Gaženica [40] indicates that weather conditions do not significantly restrict vessel navigation within the approach waterways. The prevailing winds predominantly come from the southeast, east, and northwest directions,

while the most intense winds typically arise from the first and second quadrants (NE-ENE and ESE-SSE).

Even the strongest winds will not significantly affect the safety and manoeuvrability of cargo ships and larger passenger ships. Despite this, it may obstruct the berthing of smaller vessels when faced with strong and stormy winds. Also, smaller vessels may experience the influence of waves during winter. The chances of a negative impact resulting from reduced visibility are small or negligible. Sea currents do not have a significant impact on navigation safety and manoeuvring. Tides can considerably affect the safety of navigation, specifically for ships entering the cargo port**.** The height of the water is mostly higher than the one displayed on the nautical charts (Hydrographic Zero or Chart Datum), so the ships with larger drafts than those calculated in the Port of Gaženica Maritime Study can easily berth.

Sea bathing water quality regulations set standards and limits for microbiological parameters and other water characteristics at sea beaches. [41]. Based on the measurements, the sea quality at Punta Bajlo, the area closest to the Port of Gaženica, was excellent from 2019 to 2023 [11].

It is important to note that the planned development of the port-terminal system in the Port of Gaženica complies with the provisions outlined in the Zadar County Spatial Plan [33]. The passenger port is designed to accommodate the simultaneous embarking/loading and disembarking/discharging of passengers and vehicles on local, international, and tourist routes. The strategy for the cargo port involves accommodating container ships and building infrastructure in the storage and handling areas to promote intermodal transportation.

The cargo port of Gaženica is managed by the joint-stock company, Luka Zadar d.d. In 2014, Luka Zadar d.d. was granted a 25-year extension for the use of the port to initiate a new investment cycle. The planned investments will concentrate on building new port facilities and infrastructure, maintaining and improving existing port facilities, obtaining transhipment and other port equipment, upgrading operational surfaces, and implementing environmental protection measures [31]. The company operates an area of 200,000 m^2.

Eight piers are scheduled to be built within the port area, along with six operational. Zadar Port Authority has announced a public tender for constructing piers seven and eight at the Gaženica cargo port. The tender refers to the financing, construction, management, and maintenance of a designated part of the cargo port of Gaženica. Table 7 lists the features of the piers.

Table 7- *The features of the piers in the Gaženica cargo port.*

Pier No.	Purpose	Length (m)	Depth (m)
1	liquid cargo	60 (berthing of vessels up to 190 m)	10.3 - 12
2	the oil platform supply	180	4.8 – 7.1
3	bulk cargo	140	12
4	general cargo transhipment	135	7 – 11.4
5&6	general cargo transhipment	170	7 – 8.7
6	general cargo transshipment with RO-RO ramp	150	8.7 – 10.2

Source: [16]

It is important to note that Piers 7 and 8, situated in this specific section of the port, currently serve no significant purpose.

The cargo port has different storage areas. These include 150,000 m2 of open warehouse space, 30,600 m2 of closed warehouse space, 3,400 m2 of cold storage warehousing, 75,000 m3 of liquid cargo tanks, and 9,000 m3 of vinyl chloride monomer (VCM) storage tanks.

In April 2015, the passenger port of Gaženica became the designated location for both local and international ferry traffic and most cruise traffic. The individual berths in the Gaženica passenger port serve the following purpose: [23]

- Berths 1, 2, 3-berthing of passenger ships in regular service on domestic voyages
- Berths 4, 5, 6, 7-berthing of passenger ships in regular service on domestic voyages
- Berths 8, 9, 10, 11, 12–berthing of passenger ships in international traffic, with berths 8 and 9 used for accommodation ships in international liner service.

Table 8 shows the technical characteristics of berths.

Table 8 - *Technical characteristics of berths in the Gaženica passenger port.*

Berth No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Length (m)	63	86	86	98	98	170	170	180	180	235	275	180
Depth (m)	5	5	5	7	7	8	9	10	10	10	12	12

Source: [38]

The petrol station is in the far north-eastern section of the passenger port, between the fishing boat loading and discharging area and berth 1. It stretches along the eastern coast for 45 meters and the southern coast for 83 meters. The station provides fuel for vehicles and vessels.

The fishing port of Gaženica is located within the passenger port in the northern section of the port area. The designated shore for the reception of fishing boats, fish loading and unloading, and vessel raising and lowering should be 210 meters long.

The strategic plan includes reconstructing the existing port infrastructure in the fishing port [45]. The port can accommodate seine trawlers ranging from 14 to 40 meters in length, 4 to 7 meters in width, and with a draught of 1.5 to 3.5 meters. Trawlers of varying dimensions, from 10 to 30 meters in length, 3 to 8 meters in width, and with a draft of approximately 4.0 meters, are also expected. To accommodate these vessels, it will be necessary to deepen the seabed. The planned berths will handle three vessels no longer than 9.6 meters and five vessels ranging in size from 9.6 to 30.0 meters. The plans involve building a coastal wall, an operational area, and an access road for berthing, loading, unloading, and supplying fishing vessels.

3.2. Development criteria for the port of Gaženica, expert evaluation

A thorough expert assessment was conducted to identify the key features driving the development of the Port of Gaženica. The significance of the criteria and sub-criteria in determining the development direction of the Port of Gaženica was assessed using a value scale ranging from 1 to 5 (1 – Not Important, 2 – Slightly Important, 3 – Neither Important nor Unimportant, 4 – Important, 5 – Very Important). The evaluation process involved professionals with relevant educational backgrounds, expertise, and experience and representatives from the Port Authority, the University, masters, and pilots. Regarding educational attainment, six individuals hold PhDs, two have a bachelor's degree, and three have a higher professional degree. The expert evaluation also analysed the relevance of the criteria and sub-criteria. Experts were also invited to propose additional criteria and sub-criteria.

The graphic below illustrates the expert evaluation.

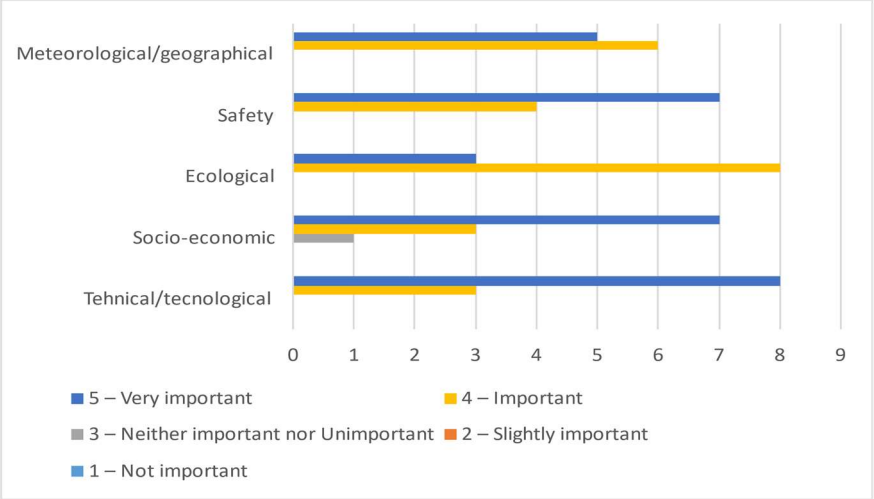

Fig. 1. - *Determining the importance of criteria in the development of the Port of Gaženica.*

The graphical representation shows that experts prioritise the technical/technological criterion as the most significant. This is followed by socio-economic, safety and meteorological/geographical criteria. Experts believe that the ecological criterion holds importance, although not to a very substantial degree. Regarding the socio-economic criterion, 9% of experts remain neutral about its significance.

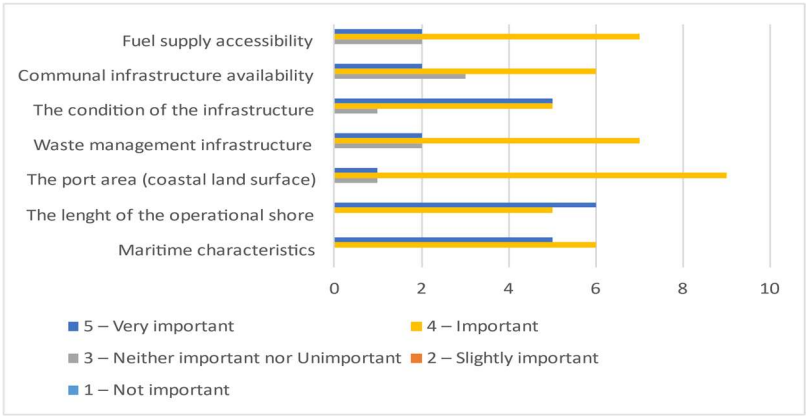

Fig. 2. - *Determining the importance of sub-criteria for the technical/technological criterion in the development of the Port of Gaženica.*

According to experts, the length of the operational coastline is of the utmost importance, followed by maritime characteristics and the functional condition of the infrastructure. Notably, 82% of experts consider the sub-criterion regarding the surface of the port area (land part) to be important.

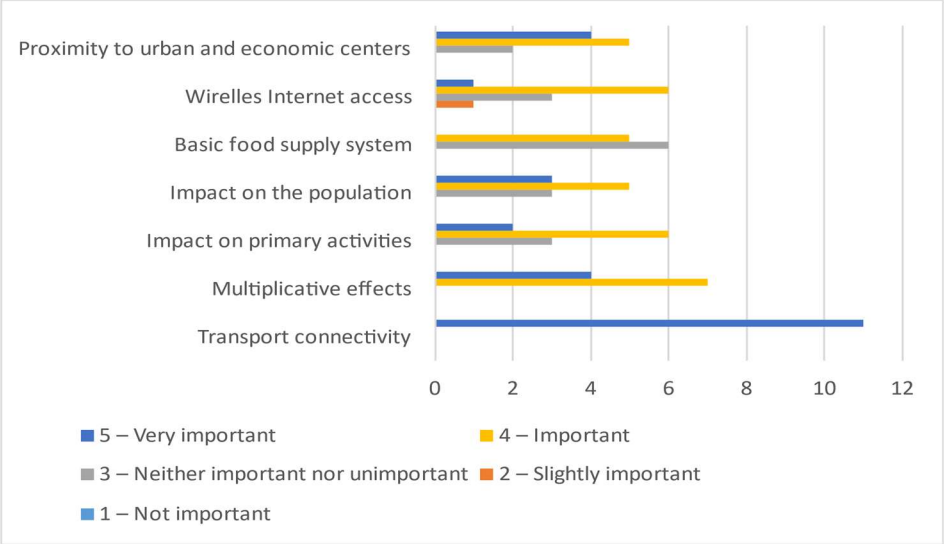

Fig. 3. - *Determining the importance of sub-criteria for the socio-economic criterion in the development of the Port of Gaženica.*

All experts ranked traffic connectivity as the most important. Conversely, the sub-criterion of wireless internet access availability was ranked as the least important.

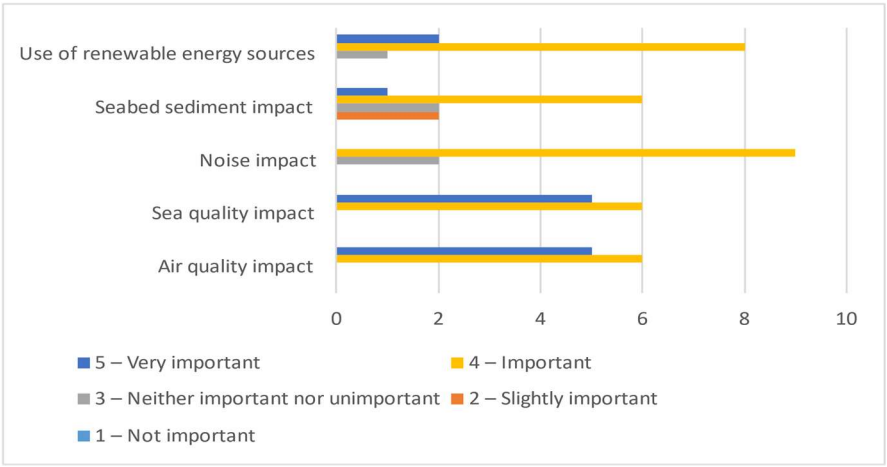

Fig. 4. - *Determining the importance of sub-criteria for the ecological criterion in the development of the Port of Gaženica.*

Experts highlighted the importance of sea and air quality, the use of renewable energy sources, and the implications for seabed sediment.

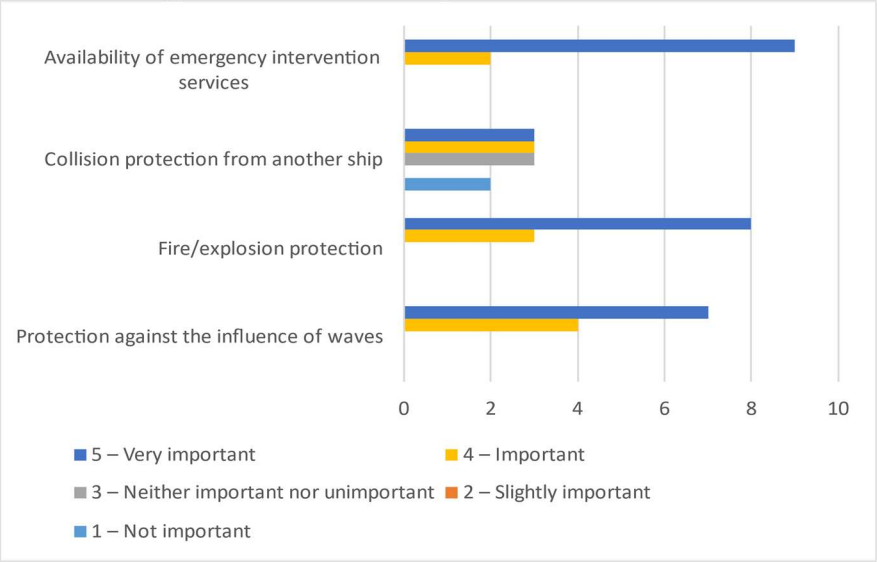

Fig. 5. - *Determining the importance of sub-criteria for the safety criterion in the development of the Port of Gaženica.*

The sub-criterion related to the protection against collisions with other ships or vessels was considered the least important. The sub-criterion concerning the availability of emergency intervention services was rated as the most significant, with 82% of experts considering it to be very important.

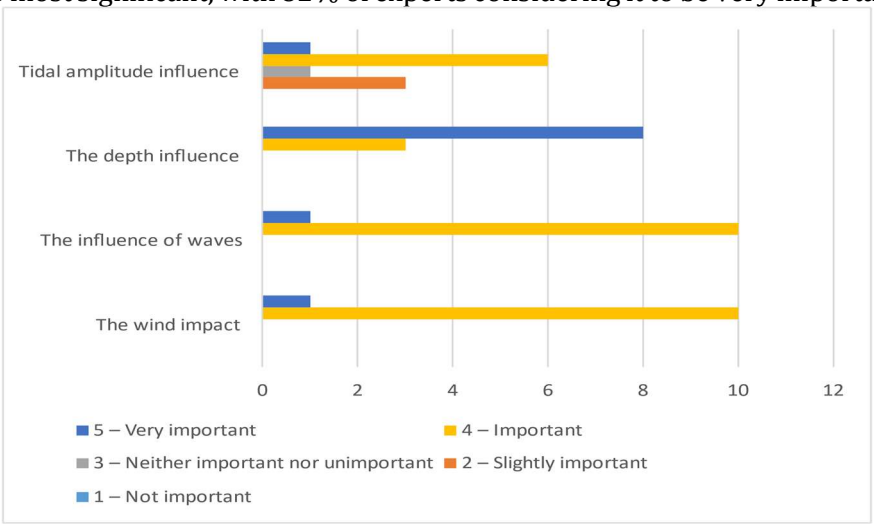

Fig. 6. - *Determining the importance of sub-criteria for the meteorological/geographical criterion in the development of the Port of Gaženica.*

According to experts, the depth of the sea plays a crucial role in determining the meteorological and geographical criteria for the development of the Port of Gaženica. Secondary factors include wind and wave conditions, with tidal amplitude playing a relatively minor role.

The experts stress that the proposed sub-criteria are not relevant. They argue that assessing wave protection is unnecessary under the safety criteria. Specifically, they believe that the impact of waves falls under the meteorological/geographical criterion. Also, experts think that protection against collisions with other vessels is unrelated to the safety standard. They also note that the tidal amplitude has minimal impact on the Gaženica port, making this sub-criterion irrelevant to the meteorological/geographical criterion. Furthermore, experts recommended the addition of more sub-criteria to the existing criteria, intending to establish the course of action for the development of the Port of Gaženica. They recommended the addition of more sub-criteria and identified potential development directions for the port, including the integration of modern tug boats and the availability of a Port Control Centre within the technical/technological criterion, as well as the appeal of the destination for tourism within the socio-economic criterion. Other suggested sub-criteria included using land-based electricity supply and the impact of climate change, specifically sea level rise, to meet the ecological and environmental criteria, respectively.

The criteria and sub-criteria analysed serve to establish the development course for the Port of Gaženica. The potential development directions for the port of Gaženica are as follows.

4. Potential development directions for the Port of Gaženica

This section discusses the potential development options for Piers 7 and 8 at the Port of Gaženica. Pier 7 is 291 m long with a depth of 9 m, while Pier 8 is 320 m long with a depth of 10 m. It is crucial to emphasise the necessity of deepening the depth along pier 7 to a minimum of 10 m. The shoal next to pier 7, which requires dredging, should not be overlooked.

The primary factor in determining development directions is the compatibility between ship characteristics and designated berths. The second aspect pertains to the transport infrastructure facilitating cargo transportation to and from the vessel. The third element to consider involves the variations in supply and demand for specific types of cargo. However, the supply and demand for certain types of cargo is not discussed in this paper. Table 9 lists the general ships' particulars.

Table 9 - *General ship's particulars.*

Type of vessel	Length (m)	Beam (m)	Draught (m)
General cargo vessel	100 – 225.5	32 - 49	7.9 - 12
Bulk carrier	90 – 360	15.5 - 65	5.6 - 24
Container vessel	137 – 400	17 - 64	9-16
RO-RO vessel	60 – 265	29.8 – 32	2.2 – 11
Car Carriers	150 – 265	25.2 – 34.1	6.5 – 11
Tanker	170 – 458.45	23.8 – 68.6	7.92 – 24.61
LNG	120 - 300	40	12
Cruise ship	102 - 345	16-44	4-10

Source: author as cited in [5] [7-10] [12-15] [30] [37] [46]

Given their characteristics, Piers 7 and 8 are suitable for accommodating the ships mentioned in the table. However, only smaller ships that meet specific length and draft requirements are considered eligible. Piers 7 and 8 are ideal for car carriers and cruise ships as they perfectly meet the requirements. The earlier proposals focused on container and RO-RO traffic and constructing terminals to supply liquefied natural gas and petroleum gas. The Zadar County Spatial Plan also includes provisions for berthing container ships and establishing storage and handling infrastructure to enhance intermodal transportation (by ship, rail, and road). The 2004 Master Plan for Gaženica cargo port aimed at developing this port as a container cargo port. It is important to mention that despite the availability of a plateau next to Piers 7 and 8, the current space is inadequate for container storage. The economic zone Crno, in the port's hinterland, should enable all the reception and logistics potential of the Port of Gaženica, including the accommodation of containers. The 2023 Zadar County Spatial Plan includes the construction of the Zadar-Gaženica-Zadar Airport railway link, the railway bypass of Bibinje, and the Gaženica freight station. However, rail transport is still far from reaching its full functionality, and container transport is predominantly carried out by road.

It is important to mention that the port does not have the necessary infrastructure to support LNG ships, such as a fenced area, protection measures, onshore tanks, or the capability to store liquefied natural gas. The planned port development can be accomplished by making significant investments and ensuring compliance with the required safety measures for accommodating LNG ships. It's important to note that the port can also receive smaller LNG ships, known as small-scale LNG.

The passenger terminal, which is equipped with all the infrastructure, is located at the Gaženica passenger port and is oriented towards becoming a home port. It is estimated that there will be 230 cruise ship calls at the port in 2024. Because of the increasing number of cruise ships, there is likely to be a greater need for additional berths. Piers 7 and 8 are deep enough to

accommodate cruise ships. Good traffic connections to the city centre and the airport's proximity make Piers 7 and 8 ideal for accommodating cruise ships. However, the current capacities are enough to meet the existing demand.

Accommodating RO-RO ships, especially Car Carriers, at piers 7 and 8 is suitable and worth considering. Conveniently linked to the expressway, the port provides easy access to the A1 highway, which is 20 km away. Trucks carrying cars do not encounter any intersections or traffic lights on the road to Zagreb or to the Slovenian or Hungarian border. Many shipping companies note the trend of transitioning from RO-RO to exclusive car carriers due to increased efficiency and safety [19].

This paper outlines the criteria for port development suitable for seaport projects. However, this study focuses specifically on the development of the Port of Gaženica, which holds strategic importance for the City of Zadar, the Zadar region, and the Republic of Croatia. The Port of Gaženica meets most key development criteria and sub-criteria, with clear potential for enhancement in those underdeveloped areas. These improvements should increase the port's importance in the national maritime economy and strengthen its regional and international transport connections.

5. Conclusion

Selection of a course of action for the Port of Gaženica's development demands analysis based on multiple criteria and sub-criteria. Five primary criteria groups form the development characteristics of the port, and their qualitative and quantitative analysis assists in ranking possible decisions. Technical/technological criteria directly affect the competitiveness and operational efficiency of the port. In contrast, the socio-economic criteria ensure a balance between economic growth and social well-being of the community. The ecological criterion assesses environmental impact, while the safety criterion ensures protection for people, vessels, and cargo. The meteorological/geographical criterion analyses the port’s meteorological and geographical characteristics. The mentioned criteria have been designed to aid in decision-making that will shape the future development of the Port of Gaženica. The aim is to ensure safe, sustainable, and cost-effective port operations while also enhancing the social and economic well-being of the community. The proposed criteria and sub-criteria for developing the Port of Gaženica have undergone expert evaluation. Experts have highlighted the irrelevance of certain sub-criteria and proposed additional sub-criteria that could significantly affect the port's development.

Therefore, in future research on the criteria for developing the Port of Gaženica, it may be beneficial to consider including additional sub-criteria as suggested by experts.

Given the current port facilities, unused berths are best suited for the growing number of passenger ships (cruise liners). The Port of Gaženica is expected to become a significant hub in the future. By investing more in infrastructure, the berths could accommodate various types of ships, such as RO-RO vessels (car carriers), container ships, or smaller LNG carriers, thus boosting the growth of the cargo port. Irrespective of the future direction in which the port may develop, it will remain a pivotal component in the maritime transport network of Croatia and its surrounding region.

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