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The Reconversion Of Port Spaces In The Cities And Surroundings Of The Ports In Panama. Statistical Study Of Traffic And Its Impact, Proposal For Improvement

Xavier Martínez de Oses, Marilyn López Millán

Panama is a country with a privileged geographical and climatic position, which has allowed it to develop as a center/hub of the Americas. The economy is mainly based on the service sector that includes the Panama Canal, and ports and related activities such as the Colon Free Zone, tourism and airport services, and the International Banking Center. As part of Panama's port logistics development, there is a container transfer system from the Pacific to the Atlantic by road or rail. Currently, the road infrastructure does not have perfect conditions, consequently this does not allow it to generate good logistics performance between the final destinations and the different ports that they serve.For this reason, the ports around the Atlantic and Pacific entrances of the Panama Canal have specialized in the movement of containerized cargo and have developed one of the most recognized transshipment centers in Central America. The objective of the study presented in this initial research proposal is to carry out a bibliographic review. Know the literature that has been written about the main effects on the maritime or access zone, the land or maneuvering zone, and the liaison zones with land transport, which are causing a delay in the mobilization of trucks, in the Panamanian Pacific. The methodology of this work was to carry out an exhaustive bibliographical review of the literature on the effects of waiting times, described by the media, magazines of the maritime sector, and especially how the institutions have generated improvement plans for a development to long-term needs of the sector maritime. The results obtained are the contributions of all those involved in the maritime sector, both the private sector and the state, who seek to improve the process that is currently being developed in the Pacific ports. In conclusion, a series of recommendations of the contributions of the private sector and state institutions are proposed, such as the strengthening of the legal framework, improving the management, exploitation, and promotion of infrastructure, are the goal in which the two sectors agree. Who are analyzing the problems suffered by the infrastructure of the Pacific ports.

KEY WORDS

Optimization, Port, Waiting Time, Movements

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INTRODUCTION

The main objective of this research is to carry out a bibliographical review, and analyze in a qualitative way, what are the main effects in the maritime or access zone, to the land or maneuvering zones, and the link zones, with land transport, that are causing a delay in the mobilization of trucks from the Panamanian Pacific.

The Pacific port area of Panama has its origins in the old French port of La Boca. That port was transformed by the Americans at the beginning of the construction of the Canal, into a modern facility that received the name of Ancon and later became known by its current name Balboa. Since its reopening in 1909, this port was vital for maritime trade in the Pacific, because in its category it was the only one existing between Salina Cruz, Mexico and El Callao, Peru, which represented for the deep draft ships of that time (3000 tons) a journey of two thousand miles between the two points. The port of Balboa has had a geographical advantage as, it has had the possibility of growing at the pace of the demands of world markets and being a business hub (Figure 1). This has put it in the sights of the largest shipping lines in the world. This growth gives Panama Port Company, its current concessionaire, the satisfaction of having 30% of the cargo market that moves in Panamanian ports.

Figure 1. Example of figure representing ship underway (Source: Republic of Panama, 2023).

At present, the waiting times for trucks generate great inconvenience to the community that shares the infrastructure implying an increase in the wait when carrying out vehicular traffic through the areas surrounding the Port. There is also an inacceptable delay when the ship that is carrying out the loading and unloading movements in the port is a Neopanamax size class, because it has a security restriction and must wait a long time until the Panama Canal Authority provides it with permits to continue with their transit.

STATE OF THE QUESTION

The Panama Maritime Authority is a public body, in charge of managing the state and concession ports, they constitute a key element in the creation, modification and reinforcement of the development of the country's maritime industry. The process of selecting priorities for the growth of the port sector is the priority of this institution. To understand it, it is necessary to review the state of the art and the main documents and studies that have already dealt with this issue or very similar issues, and that serve as a solid scientific basis for research. There is now a need to establish that the Strategic Plan for Maritime and Port Development of the Republic of Panama Vision 2040, as a document that has been developed in detail by a series of local and foreign institutions in order to establish the implementation of actions aimed at contributing to the increase in the country's productivity, determining the construction of new terminals, port development and the modernization of existing infrastructures, coastal reordering and the regulation of auxiliary maritime economic activities. From the internal point of view, the Panama Maritime Authority (AMP), had a starting point for the development of the Strategic Plan that carried out a diagnosis of the current situation of the maritime port sector, which has allowed the elaboration of a composition of place about the sector, its competitive position in the environment, the future trends expected within the horizon of the plan and the key factors on which to base future development.

The development of the diagnosis has been structured focusing the analysis from six perspectives: the perspective of the legal framework that regulates the sector, that of the internal organization of the maritime authority of Panama as the body in charge of the regulation, management and administration of the sector in the Republic of Panama, that of the existing port infrastructure, that of auxiliary maritime services, that of land accessibility, both at the global level of the country and from the specific perspective of the port facilities and also from the perspective of the business. When the port infrastructure perspective is put into context, we can explain that the logistics system of the Republic of Panama is one of the key elements of its economy. However, there is a high degree of polarization and a marked contrast between the Canal zone, which includes infrastructures and services consisting of road and rail corridors, ports, airports, border crossings and logistics nodes, and the rest of the country, with a shortage of all these facilities. Currently, all the commercial transport of goods is carried out through the Canal, except for some such as crude oil traffic, bananas, which are exported by Almirante, or mining activity in Punta Rincon. For this reason, it can be assumed that the ports of the Canal area have a network throughout the Republic and beyond, even going so far as to charter to neighboring countries in the Central American region. Most of the country's commercial traffic is carried out through the interoceanic way, which reduces the competitiveness of the most peripheral regions with respect to the canal axis, due to the increase in their logistics costs. In Figure 2, we can see how port development is in the Panamanian Pacific, how activities are carried out in the different port facilities. Those who tell us that the facilities that are close to the city are dedicated to the development of multipurpose terminals.

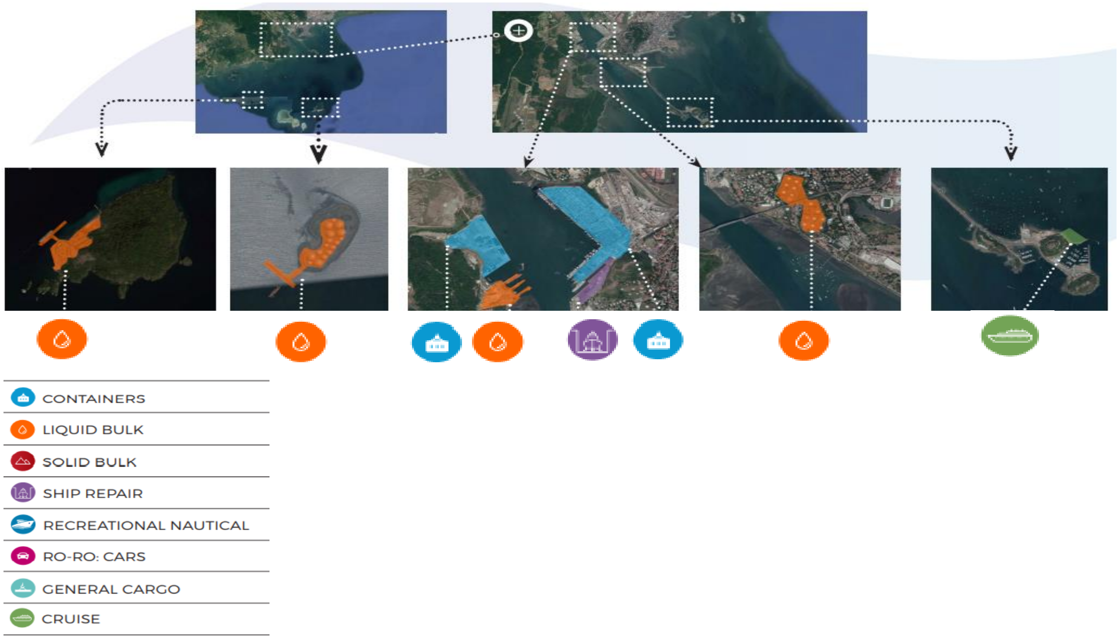

Figure 2. Valuation of port assets in the Balboa port area. (Source: consulting team of the strategic plan for maritime and port development of Panama).

Effect on maritime studies

At the mouth to the Pacific and at the entrance of the Panama Canal a series of restrictions, causes traffic congestion and additional costs in operations. The Panamanian maritime industry is carrying out analysis regarding the security that has been imposed for Neopanamax ships, for the judgment of the actors of the commercial sector of the country, it is causing operational failures.

The context has generated additional costs to the operations of maritime companies, which exceed $2.5 million in six months, added to the negative impact that port activity may have when their competitiveness is reduced, as an example of some consequences that the measure is causing, according to the shipping lines sector. The restrictions involve 80% of the ships that arrive at Panamanian Pacific ports, the port of Balboa and the Panama International Terminal (PSA). This is because the maneuvers that must be carried out so that large ships -such as the Neopanamax- can pass through the Panama Canal, are causing the waiting hours at anchor to be prolonged, generating congestion on the Pacific side, according to executives of shipping companies.

The maneuver consists of crossing two ships head-on at the entrance of the Panama Canal, which are large and is only carried out on the Atlantic side. For this reason, there are restrictions on the Pacific side since the Bridge of the Americas is on the route.

This matter was the topic of conversation at the meeting held by the Maritime Chamber (CAM) 2022, called "A new beginning", in which the problem was aired. Among the data that emanated, it was explained that the ships in reference, together remained 1,400 hours stuck in docks during the last six months of 2021.

These data provided by the coordinator of the shipping lines committee of the Panama Maritime Chamber (CMP), are the result of a study that showed that only on the Pacific side it generated an additional expense of $2.5 million in the last semester of 2021, because of this wait that large ships must comply with while waiting to enter through the expanded route of the Panama Canal. In total, these 1,400 hours represent 58 days in a semester (from July to December 2021) that the ships remain stuck on the Pacific side "doing nothing at the docks," as was said by the coordinator.

One of the main actors in this debate is the Association of Canal Pilots, who are responsible for carrying out the maneuvers.

Effect on terrestrial studies

It was learned that there are some threats that arise in ports such as high demand that increases costs and some prefer to store in nearby warehouses. In addition, delays in container loading and unloading movements due to weather changes or other setbacks, but despite this, they continue to be leaders in port operations. With the expansion of the canal, a growth of 6% of trade focused on these areas was expected, for this reason it was necessary to make investments that will help cargo management and logistic development of these ports (Ruiz 2021), or (Galeano, 2021).

As we can see in Table 1, in the estimated cargo operations times, the Pacific ports, having a smaller number of ships, taking more time in operations.

Table 1. Estimated operating time per ship in Panama terminals. (Source: Auxiliary Maritime Industry Department with data provided by MIT, CCT, PPC, PSA ports).

Port	Number of ships arriving at the port.	Estimated charging operation time
Manzanillo International Terminal (MIT)	6 to 8 ships per day	no more than 12 hours
Colon Container Terminal (CCT)	3 to 4 ships per day	8 to 9 ships small, 15 hours operation normal
Panama Ports Company – Balboa (PPC-B)	2 to 4 ships per day	13.98 hours
Panama Ports Company – Cristobal (PPC- C)	2 ships per day	11.57 hours
PSA Panama	2 ships per day	6 to 8 hours ships container, 8 to 10 hours ships roro.
Colon 2000	20 – 35 ships per month	

METHODOLOGY

To achieve the proposed objectives, the following are analyzed as an object of study: the importance for the authorities, institutions, commerce, and organizations such as the maritime chamber that oversees the development and improvements of the country's maritime sector. The analysis includes a mixed, quantitative, and qualitative methodology: analysis of journalistic discourses on maritime issues, emphasizing the need to make improvements in the maritime sector that have allowed Panama to be one of the main countries on the growth list of the port development.

The research design is based on an exhaustive bibliographical review of the literature on the effects of the media, on the one hand, and on how the institutions have generated improvement plans for a long-term development of the needs of the sector maritime. The empirical work is developed through the application of different techniques appropriate to each unit of study. The scope of this research is descriptive, and the documentary analysis will be carried out through the collection of information from instruments such as media content:

- Web pages: Mainly web pages will be used with information on Panama, the companies that own and the main pages of the port of Balboa, for example: Panama Logistics Portal, Panama Ports Company (PPC).
- Newspapers and magazines: All information related to logistics, investment, and the economic contributions of the port of Balboa will be used, for example: La Estrella de Panamá newspaper. With a sample: articles on science and technology in the two paid newspapers, generalist and national in circulation and with the highest circulation and diffusion: La Estrella de Panamá, La Prensa, El Faro Revista del sector marítimo de Ingeniería Naval for four years 2021 and 2022.
- Repositories: Information is collected from university repositories that contain information associated with the topic.
- Variables: diffusion data; articles of the maritime sector that are developed within the port growth.

Article	Study	Contribution
https://amp.gob.pa	Strategic Plan for Maritime and Port Development of Panama 2020	Execute the strategies, regulations and plans that are related to the operation and development of the Maritime Sector.
https://elfarodelcanal.com	Interruptions-in-the-supply-chain-a-look-from-the-perspective-and-performance-of-the-panama-canal-during-fiscal-year-2021/	Learn from the Panama Canal authority how they visualized the supply chain, after the pandemic and the storms that affected port movement in the world "From a forecast reduction of 9% to an increase of 9% in tonnage in the Panama Canal
https://riunet.upv.es/handle/10251/54427	Characterization of the land accesses in the world's most important container terminals.	Maritime traffic is and will continue to be the greatest exponent of international trade due, among other factors, to the appearance of the container that is in the port container terminal at the connection point between land and maritime transport, forming part of a large logistics chain. which encompasses all multimodal transport.
RUIZ TAMAYO, Ingrid Vanesa; GALEANO IBARRA, Paola Andrea	Analysis of the contribution of the port of Balboa to Panama in the last ten years. 2021	The Port of Balboa has been one of the most important for trade in Panama and America since it has an ideal geographical location to grow as a merchandise distribution center.
CEDEÑO CASTILLO, Niza Fiori.	Port and customs development in Panama. 2015	Panama has expanded its port and customs development to be able to compete with the large modern international customs and port facilities, they have had to grant concepts to private companies, they have also considered maritime competitions

SAMUDIO, Elmis	Panamanian port system. 2015	Publicize the entire environment of the Panamanian port system
GUTIERREZ SÁNCHEZ, David	Characterization of the land accesses in the world's most important container terminals. 2015.	It deals with a study of one of the subsystems that make up the port traffic process and that has the greatest importance, we are talking about the reception and delivery subsystem, in which we find many aspects to study, as well as varieties in its mechanism.
CORONADO, Antonio	The role of the Maritime Authority in the international traffic of ships in the Republic of Panama. 2016.	The Panama Maritime Authority is an entity created because of the unification of maritime jurisdictions.
ATEHORTUA VARGAS, Johan Sebastian	Growth of ground transportation and cargo in Panama. 2019	It is very important for a logistics administrator to know and have clear information of the growth and infrastructure of land freight transport in one of the countries of with the largest transit of maritime cargo in the world, it is decided to do a job that provides facts and figures of the growth and importance of this logistics link in this country. In the last ten years there has been a change in the operations of the channel being controlled and administered by the government of this country, this contributes in a very positive way to the logistic development of Panama.
LA PRENSA (Newspapers)	Congestion at the PSA port clogs traffic. 2022	This congestion becomes a productivity problem for the country in the logistics services provided from Panama, because the arrival or departure of the cargo is delayed
LA ESTRELLA DE PANAMA (Newspapers)	Cargo transshipment is the basis for the development of the logistics 'hub' in Panama 2021	'The transshipment of cargo is the basis for the development of the logistics 'hub' in Panama.' The Panama Port Company (PPC) spokesperson also recalled how the pandemic once again framed the relevance of Panama's geographical position for the logistics sector. And how the transshipment of containers from ports prevented, in part, a further contraction of the economy in 2020, since they had growth rates and more cargo volumes that led to the creation of jobs and the entry of foreign currency.
LA ESTRELLA DE PANAMA (Newspapers)	Panamá pierde competitividad debido a restricciones de la ACP 2022.	The passage of vessels through the Panama Canal is being affected by a series of restrictions at the Pacific entrance. The situation causes traffic

		congestion and additional costs in operations.
Revista del sector marítimo de Ingeniería Naval	The 10 largest ports in latin america and the caribbean in terms of container traffic 2017.	It should be noted that, except for the last one, all the ports in this ranking are among the 100 largest ports in the world in terms of container traffic, published annually by Lloyd's List.

Table 2. Analysis of the different bibliographic sources.

RESULTS

After analyzing the scientific information in La Prensa, El Faro and La Estrella de Panamá, during the years of 2021 and 2022, and Table 2 that provides us with the contribution of the different bibliographic sources, we have verified that the transshipment of cargo has been shown to have the potential for the port Hub in Panama. To all those involved in the maritime sector, both the private sector and the state, are seeking to improve the process that is currently being developed in the Pacific ports.

As detailed in Table 3, a series of needs have emerged as results that express to us what are the deadlines that must be met to improve the infrastructure in the Panamanian Pacific area.

To achieve the objectives and comply with the exposed strategic lines, certain actions have been developed to be carried out in the two-time horizons considered: short-term (2019-2021), in the medium term (2024-2030). Once each of the actions has been carried out, they must be evaluated and their contribution to the achievement of the strategic axis to which they belong quantified.

With the Action Plan, it is intended to establish the deadlines in which each of the actions will be carried out, thus establishing an order of priorities among all of them.

What	When	Who
Urban integration of the proposed promenade, which connects Avenida Amador with the Cinta Costera, passing through the Maracaná Stadium	Short term	Institutional Relations Area, Department of Strategic Planning, Department of Infrastructures and Projects
a. Establishment of a collaborative framework with the Mayor's Office of Panama b. Study of high alternatives, evaluating different locations and configurations c. Elaboration of a project with the selected alternative d. Project bidding process and. Project execution		
Urban intermodality	Medium term	Institutional Relations Area, Department of Strategic Planning, Department of Infrastructures and Projects
a. Beginning of conversations with Metro de Panamá, S.A. for the integration study of Line 7 through Avenida Amador, planned in the Master Network for 2040, along the entire Avenida de Amador b. Evaluation of the tourist attractions of the area		

Table 3. Roadmap for the Pacific area (Source: consulting team of the strategic plan for maritime and port development of Panama).

CONCLUSION

The bibliography on the evaluation of the strategic proposal of the Panamanian maritime-port sector is based on the use of the necessary actions to correct the identified weaknesses, protect itself from possible threats, enhance and exploit its strengths and opportunities. In short, the strengthening of the legal and regulatory framework, the improvement in management and exploitation, and the promotion of infrastructure must be addressed with a goal, which must be the economic growth of the Republic of Panama through the maritime port sector.

The country of Panama deploys port development policies and strategies aimed at promoting the transformation process of the sector towards the achievement of efficient port and infrastructure development. Within this framework of fair competition, private initiative in the provision of services is encouraged under a regulatory framework that ensures equal rights and obligations of investors as a mechanism for promoting the sector.

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Decision Support System Software Development for the Maritime Transport Infrastructure Optimization

Iryna Savelieva[1], Inna Lapkina[2], Mykola Malaksiano[3], Yevgen Savchenko[4]

Improving the efficiency of transport systems is of great importance for many companies and regions. Therefore, there is a need to develop innovative methods of planning and management which are capable to significantly improve the performance of complex transport systems by increasing the coordination of cargo flows and optimizing the use of available resources. *Aim:* The aim of this work is to analyze some issues related to the creation of decision support systems for the optimization of the complex maritime transport infrastructure. We consider a project for the decision support system software development to substantiate long-term modernization strategies for the Emden Ro-Ro terminal. When evaluating the operation of the Emden Ro-Ro terminal, it was necessary to take into account the cargo flow trends, specific navigation conditions, the organization of stevedoring operations and a number of other factors. The main tasks facing this study primarily concerned the evaluation and justification of the strategic plans for the long-term development of the terminal. However, the solution of these problems turned out to be impossible without taking into account and analyzing the specifics of a number of processes that should be managed at the operational level. *Methods*: Since the classical analytical methods of queuing theory and optimal control methods did not allow us to study the problems in full, the decision support system software was developed based on the discreet-event simulation approach. *Results*: The proposed decision support system software made it possible to evaluate admissible cargo flow level for the terminal, indicate bottlenecks, substantiate appropriate options for infrastructure modernization in different scenarios of cargo flow changing and perform risk assessment. *Conclusion*: One of the most difficult problems in creating decision support systems for modern maritime transport systems is modeling the operation of dispatch services. Typically, the modeling of dispatch services requires the development of complex algorithms and a specific approach for each individual situation. Despite the complexity of designing and creating simulation models, this approach shows high efficiency.

KEY WORDS

Maritime transportation, Decision support system software,Optimization of transport infrastructure,Ro-Ro terminal

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INTRODUCTION

Improving the efficiency of transport systems is of great importance for many companies and regions. Therefore, there is a need to develop innovative technologies in the field of transportation, both at the national level of states and at the level of international organizations, including the strategic planning and conducting theoretical research aimed at development and implementation of innovative technologies and intelligent transport systems (Min et al., 2017; Blanco et al., 2011; Onishchenko et al., 2016). In some cases, implementation of information technologies allows to significantly improve the performance of transport systems by refining the coordination of cargo flows and optimizing the use of available resources. The study of ways to improve the efficiency of modern maritime transport systems is the subject of increasing attention for a number of scientific publications. The issues of sustainable functioning of transport systems in conditions of irregular cargo flow were studied in (Lapkina and Malaksiano, 2018; Melnyk et al., 2022a). In (Lapkina et al., 2020), the choice of the optimal structure of the equipment fleet was substantiated using simulation modelling methods. Along with economic efficiency, the safety and sustainability issues are of great importance for maritime logistics systems. These issues are covered in articles (Melnyk et al., 2022b; Onyshchenko et al., 2022).

In (Crainic et al., 2011), a review was made and a classification of modern methods of analysis for intermodal transport systems is proposed, as well as trends and prospects for development in this direction are indicated. The problems of determining the optimal strategies for transport infrastructure modernization are studied in (Malaksiano, 2012) using the random processes methods. The issues of determining the optimal service life of transport systems equipment under conditions of uncertainty, taking into account the possibilities of its restoration, were studied in (Lapkina and Malaksiano, 2018). In (Rudenko et al., 2022), multi-criteria assessments were used to reduce risks when planning repairs and replacements of complex port facilities operating under conditions of not entirely predictable cargo traffic. One of the demanded and practically effective approaches for designing and optimization of modern complex transport systems is the one based on the decision support systems development using the simulation methods.

THE PURPOSE OF THE ARTICLE

As part of the business project study, our team was involved in creation of the decision support system software aimed at substantiation of the strategic development plans for the Emden Ro-Ro port terminal. In this paper we analyze the difficulties we face and discuss the ways to overcome them.

The purpose of this article is to discuss the problem of assessing the key performance and sustainability indicators for the Ro-Ro terminal port of Emden when determining its optimal modernization option, taking into account the trends in the structure and intensity of cargo traffic, the specifics of navigation conditions and organization of cargo operations.

METHODS AND RESULTS

Ro-Ro terminal port of Emden is a major logistic hub with a cargo flow of more than 5 thousand vehicles per day. The terminal includes four deep water berths, two train loading stations and storage area of more than 1.5 million m^2. The port of Emden is located at the mouth of the Ems River (Fig. 1, 2). As a result of low tides, the movement of ships with a large draft on the Ems River is limited for a significant part of the day. When evaluating the terminal key performance indicators, it was necessary to take into account the trends in the cargo flows changes and the related changes in the schedules of ship calls carrying out both liner and tramp transportations as well as the specifics of the stevedoring operations and a number of other factors.

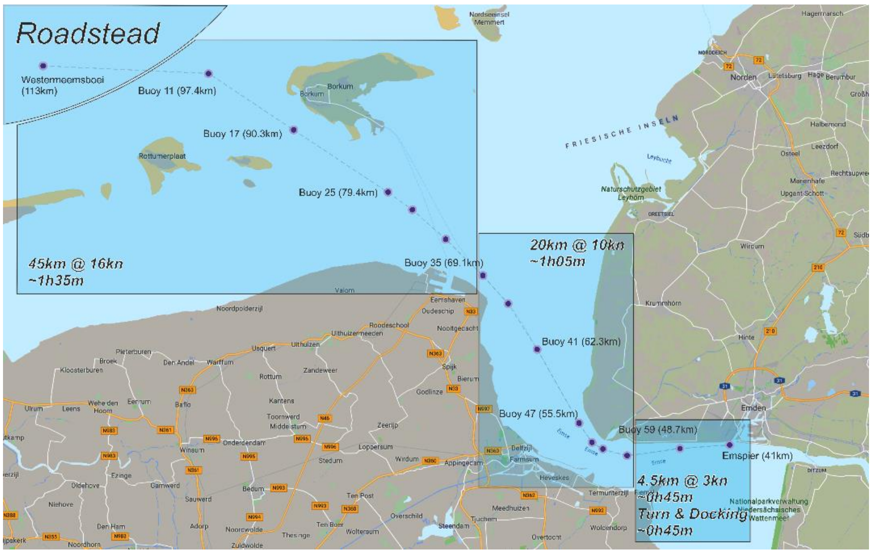

Figure 1. Scheme of vessel traffic to the Ro-Ro terminal of the port of Emden (Web Site, 2023).

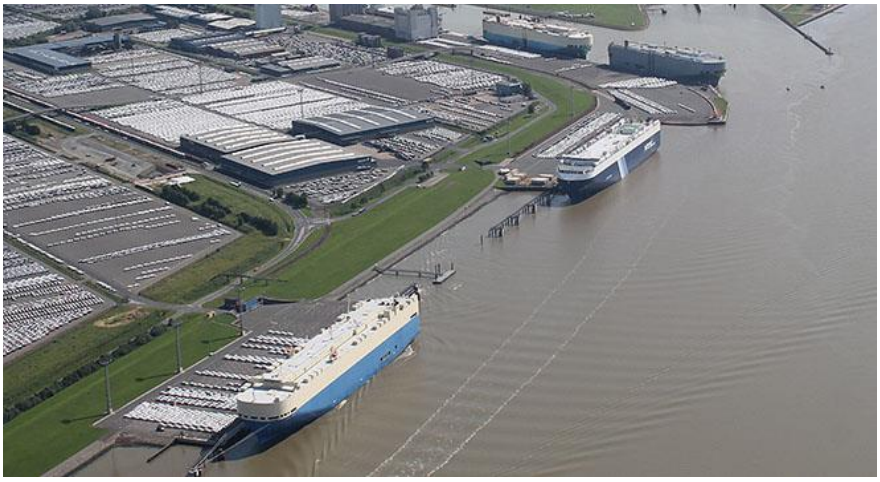

Figure 2. Deep water berths at Ro-Ro terminal port of Emden (Web Site, 2022).

The way for vessels from the anchoring place to the Emden Ro-Ro terminal takes on average about 3.5 hours (Fig. 1). The depth along the fairway varies from 14.23 to 10.5 m. At the same time, the amplitude of water level fluctuations cased by high and low tides during the day can exceed 4 m, and during the week up to 6 m (Fig. 3).

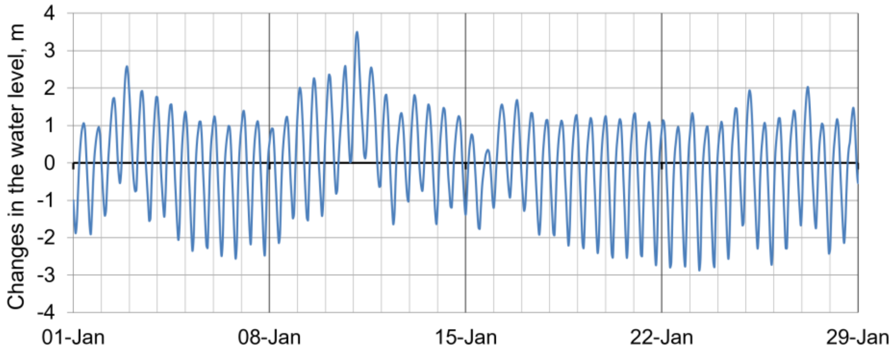

Figure 3. A fragment of the graph of water level changes near the Ro-Ro terminal port of Emden.

Therefore, at low tides the movement of vessels with large draft in the mouth of the Ems River is limited. This has a significant impact on the throughput of the terminal and the vessels port service time. In addition, this makes it difficult to predict the values of the indicators of efficiency and stability of the terminal in the conditions of an increase in the intensity and irregularity of cargo flows.

Taking into account the trends in the structure and intensity of cargo traffic and the increase in capacity and draught of vessels, the terminal administration considered several alternative options for modernizing the terminal infrastructure. When substantiating the choice of the best option for the development of the terminal, it became necessary to assess the indicators of terminal efficiency and sustainability for each of the considered options as well as for various possible scenarios of changes in the structure and intensity of cargo traffic. As a possible options for the modernization of the terminal, the construction of an additional deep-water berth, various options for carrying out a complex of dredging works, an increase in the intensity of stevedore operations, as well as various combinations of these activities were considered.

Since the classical analytical methods of the queuing theory and optimal control methods do not allow us to study the problem in full, we have developed an appropriate decision support system. This decision support system was implemented as a software application with a graphical interface, 3D animation, input and output data modules.

After launch, the software reads the input data from an appropriately structured file containing information about the scenarios for changing the cargo flow, the ship calls schedules, the schedule of the stevedoring shifts, the parameters of tugboats, and other model parameters and perform verification of the input data. The developed decision support system can operate both in the single run mode with a 3D animation, as well as in the highly efficiency mode without visualization when performing a series of runs. When launched in the single run mode, the software displays 3D animation that allows to monitor the processes taking place on the terminal in real time. The screenshots of the decision support system software operating in the single run mode with a 3D animation for the basic and one of the design options are shown on Fig. 4, 5.

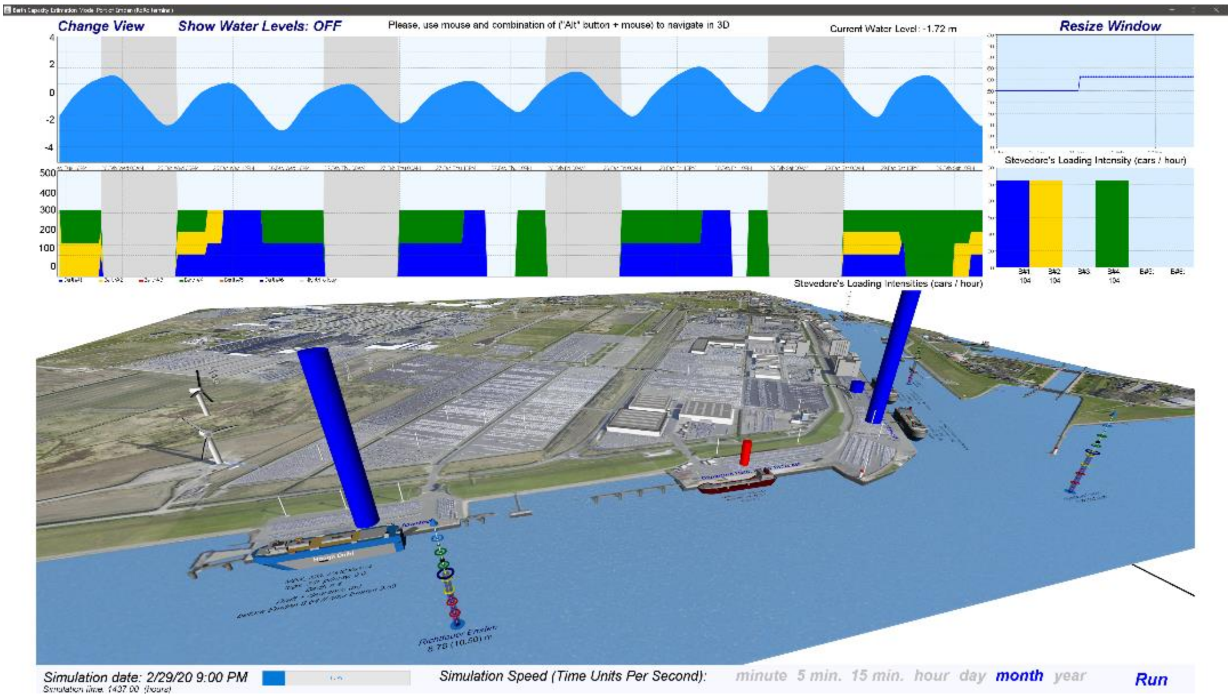

Figure 4. Screenshot of the decision support system software launched in the single run mode for basic option.

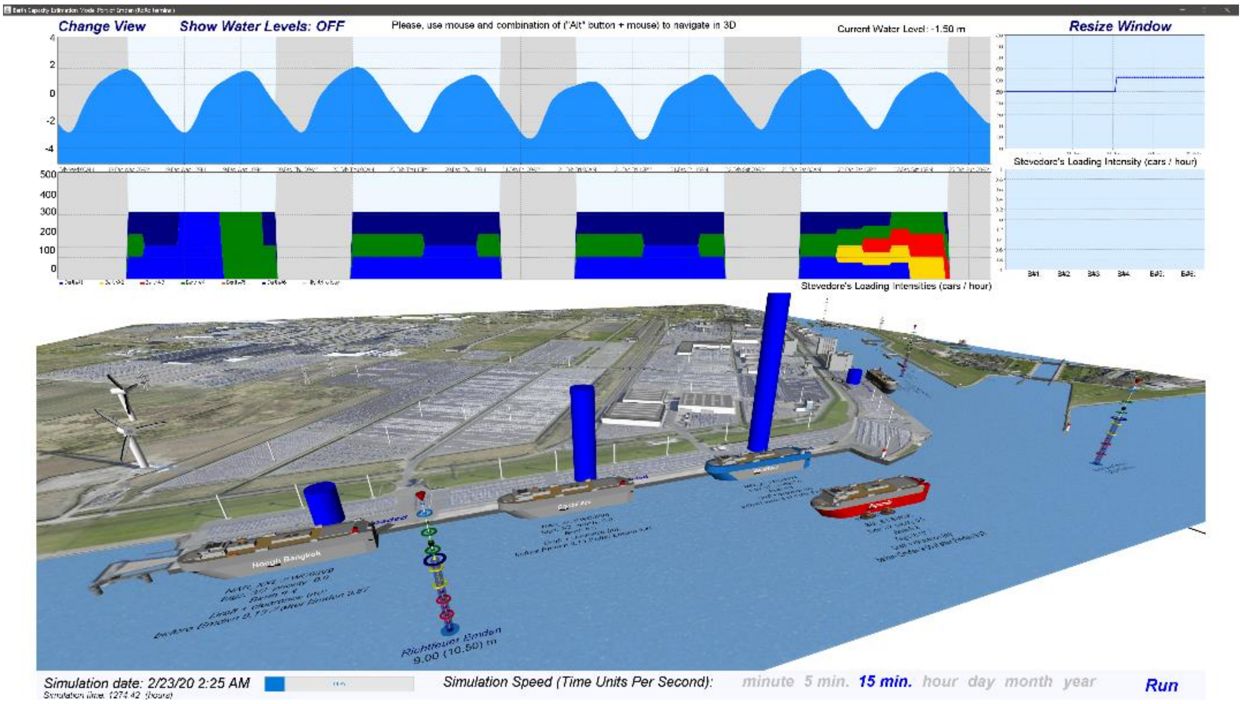

Figure 5. Screenshot of the decision support system software launched in the single run mode for one of the design options that involves the construction of an additional deep-water berth.

In the upper part of the decision support system software window (Fig. 4, 5) there is a graph of water level changes and a diagram of the distribution of stevedoring crews between berths. Cylindrical bars of blue and red, located above the berths reflect the progress of the vessel handling process. The indicators at the buoys along the fairway show changes in the water level with an error of ± 0.01 m.

In order to reproduce the operation of the terminal's dispatching services, it was necessary to develop algorithms which allow to effectively manage the vessels traffic along the Ems River, taking into account changes in the water level in each section of the fairway and control the operation of the towing service. Close attention was paid to accurate simulation of ship calls schedules, considering seasonal variations in cargo flows, parameters of the vessels and influence of random factors. The possibility of modeling the traffic of vessels with established schedules as well as tramp vessels traffic was implemented. The decision support system allows to perform sensitivity analysis for the terminal key performance indicators using appropriate configurations of the random number generators so that some random processes occurring on the terminal are reproduced uniquely or identically from run to run.

An important aspect in creating the decision support system was the design of the input data structure and implementation of output. On the one hand, the input data structure should allow accurate reproduction for the given ship calls schedules so that it would be possible to check the adequacy of the model based on the actual data of previous years, and it would also be possible to study the operation of the terminal in the near short term. On the other hand, the proposed structure of the input data should make it possible to conveniently describe scenarios of cargo flows that are possible in the distant future for which there are no exact ship traffic schedules but only a general description of trends. In order to make data input convenient and intuitive for the user, various visual aids have been used. At the same time, a two-level check of the entered information was implemented.

After the end of the run, the model generates a file that contains a general statistical indicators of the terminal operations during a given period of time and a detailed protocol with every second fixation for all events that occurred on the terminal during the run of the model. Emergence of crisis situations, queues and circumstances that caused them can be tracked when analyzing this file. Study of the output data allow to detect bottlenecks and evaluate how quickly the system is able to overcome crisis situations.

The decision support system was written in Java and optimized in such a way that it takes less than 0.5 second to simulate one year of operation of the terminal. This allowed us to effectively implement a series of multiple runs. Based on the results of multiple runs, the average values of the key performance indicators were evaluated for the terminal and estimations of sustainability were obtained considering fluctuations in cargo traffic and random deviations in vessel calls. Estimates of the average ship idle time in the roadstead, the values of the occupancy rates of berths and other indicators were obtained and the corresponding distribution density functions were constructed for different scenarios of cargo flow changes and various options for modernizing the terminal. So, estimations for the key performance indicators were obtained for different scenarios, appropriate confidence intervals were determined and trends for their changes were studied. For example, the changes in the berthing time for several options of the terminal upgrading are presented in the Fig. 6, provided that cargo flow intensity is gradually increases (Lapkina et al., 2020).

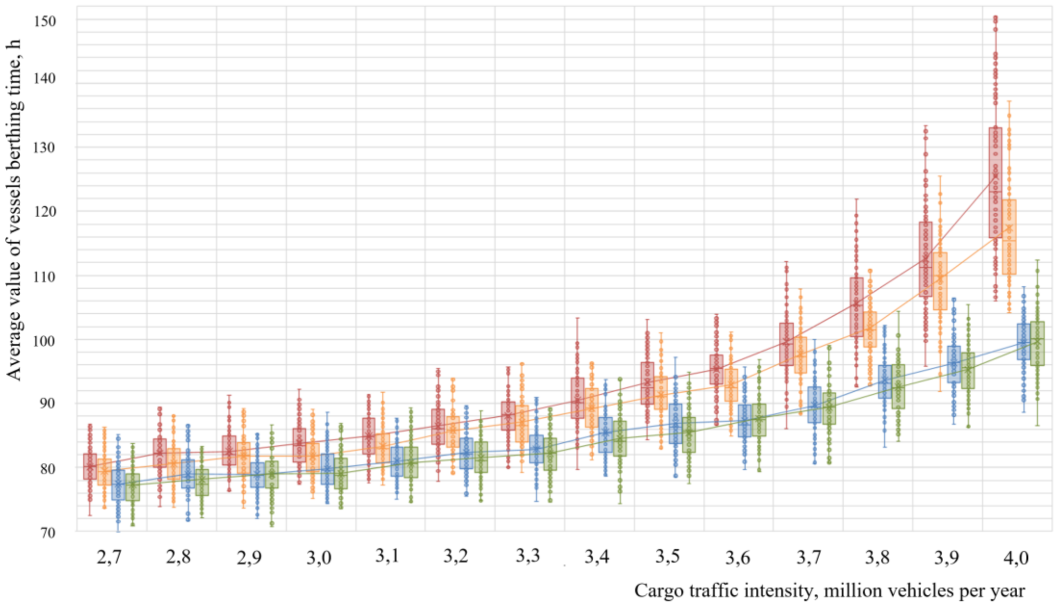

Figure 6. Changes in the average vessels berthing time for some alternative options of upgrading the terminal, provided increasing in the cargo flow intensity.

Points in Fig. 6 show the average vessels berthing time for one year of the terminal operation. Each curve in the figure shows the trend of the average vessels berthing time for a specific option of upgrading the terminal with varying intensity of cargo flow intensity. Fig. 6 also demonstrates how the stability of the key performance indicators changes when the cargo traffic intensity increases. Each box in Fig. 6 indicates the upper and lower quartiles of the average vessels berthing time for a given cargo flow intensity and terminal modernization option.

Note: We cannot publish here the precise data and detailed simulation results concerned with the project due to commercial secrecy. So, the data shown in Fig. 6 was intentionally modified and should be taken only as a schematic illustration of the methodology used.

When cargo flow is low (from 2.7 to 3.5 million vehicles per year), we observe slight gradual growth in the average vessel berthing time and all curves in Fig. 6 of the mean values are almost parallel while the volatility of average vessels berthing time is rather small and almost the same for all four options of upgrading the terminal. But when cargo flow intensity increases significantly (more than 3.7 million vehicles per year), a substantial nonlinear growth is observed in the average values and in the level of volatility for the first and second variants of terminal upgrades (Fig. 6). At the same time, the mean values and volatility of terminal key performance indicators for the third and fourth options of upgrading the terminal increase much slower even when cargo flow intensity is high.

CONCLUSION

The main tasks facing this study primarily concerned the evaluation and justification of the strategic plans for the long-term development of the terminal. However, the solution of these problems turned out to be impossible without taking into account and analyzing the specific of a number of processes that should be managed at the operational level. The main difficulties that we encountered with when creating the decision support system concerned precisely the development and implementation of the optimal control algorithms for the processes occurring at the operational level. Thus, algorithms for the operational control of the movement of vessels at the mouth of the Ems River, considering the dynamics of tides were implemented within the decision support system, as well as algorithms for the operational allocation of tugs and stevedoring crews. These algorithms were designed to perform the functions of dispatch services at the operational level but on their basis, it become possible to predict with high accuracy the performance indicators of the terminal for various options of its strategic development.

One of the most difficult problems in creating decision support systems for modern maritime transport systems is modeling the operation of dispatch services. Dispatching services are engaged in optimizing the movement of vehicles, coordinating a number of parallel processes, and also carrying out the operational redistribution of available resources. The efficient functioning of these services substantially affects the performance and stability of most transport systems. Typically, the modeling of dispatch services requires the development of complex algorithms and a specific approach for each individual situation. But, despite the complexity of designing and creating simulation models, as well as the difficulty of collecting and analyzing input and output data, the expediency of using this approach in many cases is due to its high accuracy and the possibility of effective use in the study of modern complex transport systems.

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The Lika Railway as a Constraint Factor of Maritime Freight Transport in Dalmatian Ports

Luka Vukić[1], Filip Rogošić[2], Matej Kutle[2], Jure Biočina[2]

Maritime freight transport in Dalmatian ports is of strategic national and regional importance. However, due to omissions in providing essential investments, it is seriously jeopardized by the limitations of the rail infrastructure on the Lika railroad. These deficiencies are mainly reflected in the higher train costs per transported ton compared to the other routes. It is a direct consequence of unfavorable line topography, limited demand, and high energy consumption of diesel locomotives. The paper examines the competitiveness of rail transport on the Lika railroad line by focusing on the cost of energy used and providing an analysis of the fuel types available to power locomotives. In addition to the lack of competitiveness of diesel-powered freight transport, the extent of savings from electric and hydrogen-powered transportation is notable. The fuel conversion cost and electrification are also mentioned. By introducing green hydrogen production technology, the Republic of Croatia could permanently solve the limitations of rail transport in Dalmatian cities and become a regional leader in hydrogen.

KEY WORDS

Lika railway, Dalmatian ports, port competitiveness, hydrogen

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INTRODUCTION

Maritime transport and industrial production are still essential macroeconomic indicators of economic prosperity, and transport services significantly participate in the commercial exchange of goods. Businesses and investments in the development of ports, which are components and hubs of maritime transport, have strategic importance in the country's development, especially in the regions where they are located. The development stagnation and uncertain future of cargo ports in Zadar, Šibenik, and Split, in conditions of increased demand for maritime transport, is a first-class issue that requires a detailed analysis of port operations and strategic development plans. However, investing in port development and modernization and improving the quality of transport services is not enough to attract cargo. Nor is the high-quality road connection of the port sufficient. Railway transport is an essential link for the survival and development of the port. This paper aims to show the dependence of maritime freight transport on high-quality rail transport, clarify why cargo avoids Dalmatian ports, and point out possible solutions and development directions.

MATERIALS AND METHODS

The technological neglect and low quality of transport services of Croatian railways have long been notorious fact that does not need to be proven. The track condition and diesel engine drive contribute to this fact equally. The Dalmatian ports are via the hub in Knin, by the Lika railway, connected to Ogulin (Oštarije), and the Una railway through Bosnia and Herzegovina with Novska, being re-including in the network of Croatian railways. The Una railway was damaged in the war and was not restored, and the Lika railway is in operation, partially reconstructed but not electrified. Built 150 years ago and only partly modernized, the Lika railway, with the railways from Knin to Zadar and Perković to Šibenik and Split, is burdened with significant technological limitations. The inclines of the railway, especially on the Perković-Split route, reach 26 ‰, and the axle pressure is 22.5 t from Ogulin to Gračac (Brkić, 2022) and is further limited to 20 t (Mandić, 2022). The diesel drive of the transport and the track condition limit the net capacity of the train to 500-620 t per 2 MW engine (HŽ Cargo, 2022). Electric railways have higher nominal power, better utilization, lower energy costs, and do not pollute the environment (Mandić, 2022). The technological limits of the drive and track increase the cost of transportation per ton of goods and, comparing with the cost of transportation on modern electric-powered railways, make this transport route uncompetitive. The consequence is the stagnation of business and the development of Dalmatian ports, which are focused on transport along the Lika railway. Figure 1 shows the stagnation curves of goods traffic in Dalmatian ports.

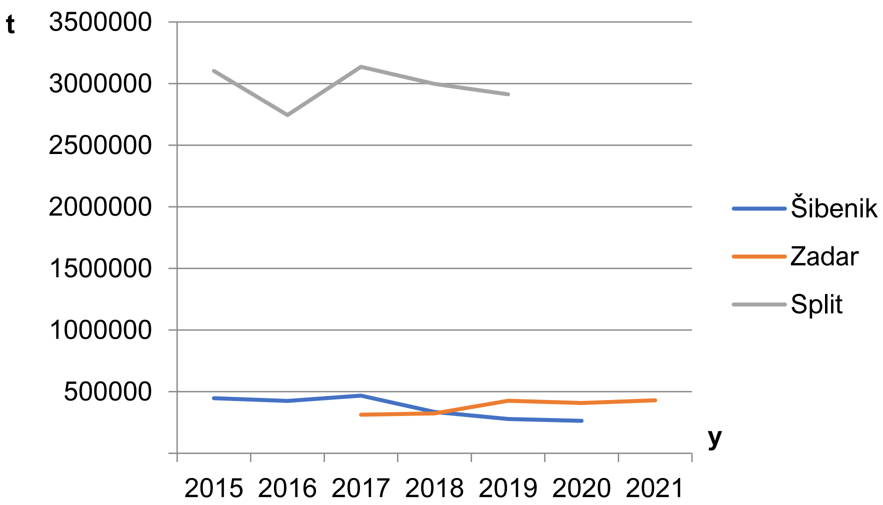

Figure 1. Overview of annual cargo transshipment in Dalmatian ports from 2015-2021 (tons) (Port authority Zadar, 2022; Port authority Split, 2019; Port authority Šibenik, 2021; mod)

Despite the investments in the port of Gaženica in Zadar, the turnover of 607,154 tons achieved in 2010 did not reach. Cargo traffic in the port of Šibenik has halved. The annual turnover of the North Port of Split of 2.5-3 million tons, without significant investments in the port supra and infrastructure, shows that the demand on the internal and external market of transport services exists despite the described limitations of rail transport. These indicators point to the potentially significant role of rail transport in cargo port operations, encouraging experts' expectations that the modernization and electrification of the Lika railway and links with Dalmatian ports would attract a much larger cargo volume. Considering the current costs of diesel transportation on the Lika railway from Ogulin to Split, the comparison was made with the costs of the potential electric one in the same section using existing data on fuel costs on Croatian railways (Brkić, 2022).

Based on data from HŽ Cargo on the Tovarnik-Rijeka section on fuel costs for transporting cargo with a net mass (m) of 1,600 t by electric railway (z1) and the length of the transport route s1(rt), as a sample model, and fuel costs for transporting the same cargo by electric railway on section Tovarnik-Ogulin and diesel propulsion on the route Ogulin-Solin (z2, z3, z4), under the conditions of the transport route s2 (rt), the potential fuel costs by electric railway on the route Tovarnik-Solin (x1) and Ogulin-Solin were calculated (x2) under the same conditions. The route conditions include dividing the composition into two light trains on the Ogulin-Perković section, then facilitated with three wagons less on the Perković-Solin route, and subsequent leaving for the remaining six wagons from Perković to Solin. The potential electric railway transportation costs on the Lika railway and the Knin-Split connection are compared with the current ones. Also, the latter is compared with potential transportation costs in ideal track conditions, i.e., after the Lika railway and the Knin-Solin railway reconstructions. In addition, the data of the three-month and nine-month volumes of transported cargo in rail and maritime traffic in the four years period in the Republic of Croatia are used. The goal is to determine the dependence of the marine transport size on rail transport by linear regression and correlation.

RESULTS

The input data showing the current fuel costs and the length of the railway routes on selected sections are presented in Table 1.

Section (*m*=1600)	Fuel costs *z*						Length of the transport route *s* in *km* (*rt*)*
	Electricity		Diesel		Electricity+Diesel		
	€	€/t	€	€/t	€	€/t	
Tovarnik-Rijeka (*z1*)	5930	3,71					1582 (*s1*)
Tovarnik-Ogulin(*z2*)	3481						1203
Ogulin-Solin (*z3*)			18030	11,27			2263
Tovarnik-Solin (*z4*)					21511	13,44	3466 (*s2*)

**rt= wheel circumference x number of wheel rotation*

Table 1. Current costs of fuel and the length of transportation on selected railway sections (HŽ Cargo, 2022)

The results after potential electrification (x1,x2) and electrification+modernization/reconstruction of the Lička railway and the Knin-Split section to the quality level of the Tovarnik-Rijeka section (x3,x4) are shown in Table 2.

Section (*m*=1600)	Electricity costs *x*		Length of the transport route *s* in *km*(*rt*)*
	€	€/t	
Tovarnik-Solin *(x1=z1+s2/s1)*	12992	8,12	3466 (*s2*)
Ogulin-Solin *(x2=x1-z2)*	9511	5,94	2263
Tovarnik-Solin *(x3=z1+s3/s1)*	8130	5,08	2169 (*s3*)
Ogulin-Solin *(x4=z1+s4/s1)*	3621	2,26	966 (*s4*)

**rt*= wheel circumference x number of wheel rotation

Table 2. Potential fuel costs after electrification (x1,x2) and electrification and modernization (x3,x4) with the lengths of transport routes on selected railway sections

An overview of the cargo transportation volumes (in thousands of tons) in rail and sea transport in the same periods from 2019-2022 in the Republic of Croatia is shown in Table 3.

2019		**2020**			**2021**		**2022**	
7-9	1-9	7-9	1-9	month	7-9	1-9	7-9	1-9
3588	10581	3558	10919	rail	3783	11000	4172	12350
4990	13501	5116	12366	maritime	4826	13331	3576	12215

Table 3. Volumes of maritime and rail transport in the Republic of Croatia in the three-month and nine-month periods from 2019 to 2022 (CBS, 2022a; CBS, 2020; CBS, 2022b)

The results of the dependence of the size of maritime transport on the size of rail transport (in thousand tons) using the linear regression method in the period from 2019-2022 in the Republic of Croatia are shown in Figure 2. The same dependence by correlation test amounts to 0.967597.

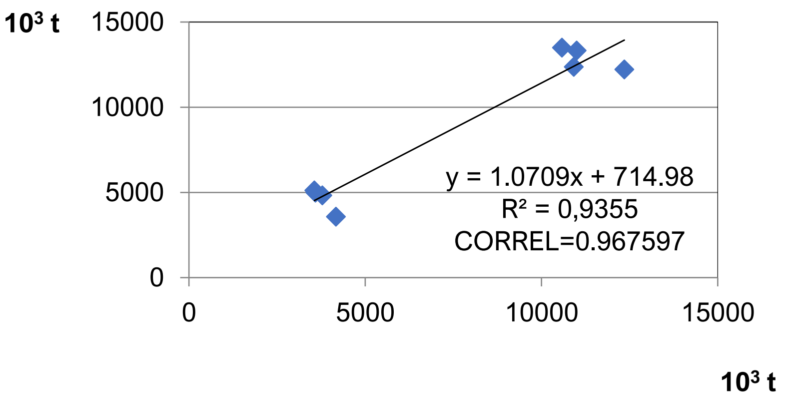

Figure 2. Dependence of the size of maritime transport on the size of rail transport from 2019-2022 in the Republic of Croatia (thousands of tons)

DISCUSSION

The Tovarnik-Solin transport route is 39% longer than the Tovarnik-Rijeka one (CBS, 2022b). The research results show that, under current conditions, fuel costs for transporting the same cargo on the Tovarnik-Solin route are 3.6 times higher. In addition to the higher costs of diesel fuel on the section from Ogulin to Solin, compared to the costs of electricity on the entire Tovarnik-Ogulin-Rijeka route, the total distance traveled by all individual driving engines also contributes to an enormous fuel cost difference on compared sections. On the Tovarnik-Rijeka section, the distance covered is three times greater than the actual distance (because three locomotives are used). On the Tovarnik-Solin section, it is 4.8 times greater (five locomotives). If the route from Ogulin to Solin were only electrified, without other modernization measures, then the transport costs would be 2.2 times higher than in the sample section. If the condition of the infrastructure on both routes were the same, then higher fuel costs for transport to Solin would be in line with the actual, longer transport route.

Despite the neglected infrastructure and rolling stock, the high costs of diesel fuel transportation, and an uninterested public, a heavy increase in traffic on the Ogulin-Knin-Split section, especially in gross ton-kilometers, has been recorded in the period from 2015 to 2020 (Ministry of the Sea, Transport, and Infrastructure, 2020) when the Split freight port recorded an annual turnover of 2.5-3 million tons. In the same period, the port of Ploče, having the status of one of the two strategic ports for the transshipment of cargo in the Republic of Croatia and is connected by an electric railway, recorded approximately equal amounts. The justification, acceptability, and profitability study of the Lika railway electrification, including connections to Zadar, Šibenik, and Split, with a positive assessment for sections toward Šibenik and Split, has existed since 1985 (Mandić, 2022). In current conditions, after the modernization of the port of Gaženica, the Knin-Zadar section would be equally justified and acceptable.

Until the economic crisis of 2008, rail freight transport was an indicator of economic growth. After that, there is an increase in the demand for road transport, and rail freight transport ceases to be an important economic indicator. However, under the pressure of environmental awareness and the principle of sustainability, it is changing again, as rail transport is rated as the most environmentally friendly form of transport (Pupavac et al., 2019). The dependence of port development on high-quality rail transport is a logical conclusion of the scientific and sectoral community, but the circumstances in Croatian ports show a specific dependency. Not only are the correlation factors and regression coefficients almost maximal, but also the quantitative values of transported cargo in rail and sea transport are almost the same in the examined period of four years. This dependence is the reason more in the decision-making process to start with the railway routes modernization toward Croatian ports.

Based on the principles of sustainable development, supported by the policy of the European Union, significant funds to invest in the revitalization of freight transportation by rail are expected (HŽ Cargo, 2014). Although only 11% of the total cargo has been transported by rail (The Government of the Republic of Croatia, 2022), maritime and rail transport are closely by infrastructure, capacity, and environmental impacts. According to the European Green Plan, by 2050, 75% of cargo should be transported by rail. Despite the plan to invest 5.7 billion Euros in railway modernization in Croatia, the Lika railway and connections to Dalmatian ports are not a priority After the recent Regulation on the classification of railways in the Republic of Croatia adoption, the funds will invest mainly in corridors RH1 and RH2 (CCE, 2022; The Government of the Republic of Croatia, 2021; Croatian Parliament, 2022).

Adopting the Croatian strategy for hydrogen until 2050, the Republic of Croatia has made a big turn towards sustainable development and achieving the high requirements for decarbonization by the EU (Dokoza and Schmidt, 2020). The hydrogen introduction as a fuel requires a systematic approach that must include production, distribution, storage, and the appropriate drive machinery procurement. The profitability of hydrogen-powered rail transport on routes longer than 100 km has been proven, which could rule out the need for electrification of the Lika railway with links to Dalmatian ports (HŽ Cargo, 2014; The Government of the Republic of Croatia, 2022). Unfortunately, the technological solutions of the hydrogen railway are currently reserved only for passenger transport, and commercial hydrogen-powered freight rail transport is still expected. Fuel costs of a freight train with a net weight of 1,600 t on hydrogen propulsion with a 2 MW power engine, with a consumption of 0.9 kg/km (The Government of the Republic of Croatia, 2022; Barbir, 2022) and the current price of hydrogen from renewable energy sources (RES) of €2.5-5.5 /kg (Dokoza and Schmidt, 2020), on the Ogulin-Solin route according to the current transport model (2263 km(rt)) would be €5091.75-11201.85 (€3.18-7/t). These costs are roughly at the level of electric railway fuel costs. In case of the announced consensus on the control of hydrogen from RES price at 1-3 €/kg (Dokoza and Schmidt, 2020), the transportation fuel costs in the mentioned section would fall to 2036.70-6110.19 € (1.27-3.82 €/t), which is half as much as with electric railway transport. These data indicate the competitiveness of freight transportation by hydrogen-powered railways compared to electric railways even without the modernization of the Lika railway with links to Dalmatian ports. According to current offers and projects being implemented in the Republic of Croatia, the costs of electrifying the railway in Croatia currently amount to 1-10 million €/km, depending on the level of the planned reconstruction of the railway, availability of the electric power and possibility of the electrical network and facilities. Following the climate neutrality scenario, investments planned in the production and distribution of hydrogen until 2050 amount to around €3 billion, which is at the electrification costs of the Lika railway to the Dalmatian ports level (Dokoza and Schmidt, 2020). Regardless of the strategic choice of drive on the Lika railway and the links in the future, electricity production for both propulsions is an essential item. A number of sunny and windy days and the water resources on the Croatian coast and the coast hinterland provide excellent conditions for electricity production from RES. The investment implementation plans from the strategy could promote this region as a leader in green hydrogen.

CONCLUSION

The research results clearly show a positive linear dependence of the size of the maritime on railway freight transport. Diesel-powered freight rail transport on the Lika railway and links from Knin to

Zadar, Šibenik, and Split are neither cost competitive nor sustainable compared to electric rail transport. Therefore, cargo is "running away" from Dalmatian ports, and the ports are stagnating. Without the electric railway, the development of regional cargo ports is not possible, nor is the contribution of this significant segment to regional development. The production of electricity from RES is an item in the sustainable development policy with no alternative. The railway electrification necessity is indisputable, and costs can be avoided or decreased using green hydrogen propulsion. By adopting green hydrogen production technology within the obligation to transfer cargo from road to rail and decarbonization according to the climate neutrality scenario, the Republic of Croatia could permanently solve the limitations of rail connections with Croatian ports.

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Advanced Construction and Technology Solutions for Heavy-Lift Vessels

Joško Dvornik, Srđan Dvornik

Transport of heavy loads by sea has resulted in the revolutionary modernisation of technologies dedicated for their carriage and handling. As the transport of out of gauge products in one piece is, from the standpoint of many producers, more favourable than assembling them at their destination, the demand for such shipping service has led to construction of special vessels. Due to specific cargoes they carry, the design of these vessels is quite different from the construction of standard merchant ships. Heavy-lift vessels are designed to load and carry various heavy out of gauge cargoes that cannot be otherwise transported by conventional cargo vessels. Their features include the very delicate stability, especially while loading and unloading heavy out of gauge cargo, and the dimensional accuracy of making and assembling the members forming the hull's structure, cargo hold structure, and hatch covers of the tween deck and main deck (Brodosplit d.d., 2008; Medić, 2021). The purpose of this paper is to examine the cutting-edge construction and technology solutions applied in building the heavy-lift vessel *Fairmaster*, operated by *Jumbo Shipping*, with special focus on her cargo handling system, cargo storage principles, and her stabilising system featuring two floating pontoons (Brodosplit d.d., 2008; Medić, 2021).

KEY WORDS

Construction, technology, transport, stability, tonnage, deck cranes, heavy cargo

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INTRODUCTION

Heavy-lift vessels are designed to carry extremely large and/or heavy items that cannot be transported in or on other vessels. The vessels transporting unusual, large and special out of gauge heavy cargoes, which are fitted with cranes dedicated for handling such cargoes, have exceptionally large cargo decks, ability to carry cargo on the double bottom tops, 'tween deck hatch covers and main deck hatch covers. Their features include unconventional configuration of other decks and the navigation bridge, as well as high-capacity on-deck cranes (Malvić, 2019; Medić, 2021).

Their size and length vary with the type of vessel and cargo. A large heavy lift vessel can measure 178,20 m in length and 42 m in width. There are different types of heavy-lift vessels built specifically for a certain task.

Heavy-lift vessels can carry high-value cargoes such as transformers, locomotives, rockets, crushers, semi-submersible rigs, jack-ups, oil platforms, bridge spans, TLPs (tension leg platforms), SPAR buoys, etc.

As most special heavy cargoes have unique, i.e. one-off characteristics, their management requires a very careful planning and coordination to the smallest detail. Detailed information on cargo and the location of loading and discharging are studied in the preparation phase, often before the transport contract is actually made.

Jumbo Shipping is a heavy-lift shipping and offshore transportation and installation contractor. The company has been engaged in sea-borne transport for over 50 years. It began to occupy a special position on the market in 2003, introducing a series of self-loading heavy-lift vessels for versatile heavy cargoes. Today they operate a dozen different in-house designed heavy lift vessels with a lifting capacity from 650 up to 3000 t. The *Fairmaster* belongs to the strongest K3000 class. It is equipped with two mast cranes placed on the starboard side with a lifting capacity of 1500 t each, 3000 t in total. This capacity is considered as the highest in the world for that class of vessels (Dundović, 2001; Boskalis, 2022; Jumbo maritime, 2022).

CONSTRUCTION AND TECHNOLOGY SOLUTIONS

The main features of the Fairmaster

According to Lloyd's Register, the vessel falls into +100 A1 class, strengthened for heavy cargoes +LMC, UMS, CG, LI, IWS, Ice Class 1A. The total height of the Fairmaster from the keel to the top of the masts (with the crane boom lowered) is 51,6 m. The maximum height of the cargo hold is 12,6 m (maximum 5,6 m below the 'tween deck, 7,0 m above it). Its tonnage is 18099 GT, 6397 NT, depth to the freeboard deck 11,30 m, depth to the upper deck is 16,40 m (Arhiva Brodosplita, 2021; Jumbo maritime, 2022). The main features of the vessel are presented in table 1.

Name of the vessel	**Fairmaster**
Operator	Jumbo Shipping
Length over all L_{OA}	152,60 m
Length between perpendiculars L_{PP}	141,70 m
Beam *B*	27,40 m
Height of the main deck above keel	14,10 m
Draft *T*	7,0 / 8,10 m
Hold volume	21000 m^3

Lower hold dimensions	83,20 m · 17,0 m · 5,6 m
Upper hold dimensions	108,80 m · 17,0 m · 7,0 m
Hold: total height	12,60 m
Mast crane lifting capacity	2 · 1500 t
Free deck space	3183 m^2
Deadweight at draft 8.10 m	14000 t
Main engines	2 x 4500 kW at 750 ^{o}/min, CPP/ME MAK 9M32C, total of 9000 kW
Thruster	Bow thruster: Berg – 1500 kW
Speed	17,2 kn

Table 1. The main features of the Fairmaster (Source: Jumbo maritime, 2022)

Structure of the hull

The cargo space consists of one large hold extending from R.20 to R.156 with a width of 8500 mm to the left/right from the center line, divided in height into three levels by the hatch covers of the 'tween deck at 7800 mm from the base line and the hatch covers of the main deck at 14100 mm from the base line (Arhiva Brodosplita, 2021; Medić, 2021).

The lower hold extends from R.44 to R.148, and the upper hold extends from R.20 to R.156. The double bottom cover structure can withstand loads of up to 12 t/m^2. The structure of the hatch covers of the upper deck at 16400 mm from the base line can withstand a load of 12 t/m^2 from R.5 to R.156.

The six hatch covers of the main deck can handle a load of 8,7 t/m^2 while the remaining three can handle a load of 12 t/m^2. The hatch covers of the 'tween deck, 7800 mm from the base line, can withstand loads of up to 7 t/m^2. The 'tween deck covers can be positioned at 16 different height levels with the patented JUMBO locking system.

Cargo hold features the frames inside the double side. The double bottom structure is made with longitudinal girders and frames. Tanks in the double bottom, both central and side left/right tanks, are intended for liquid ballast, as are the spaces of the double hull – the lower and upper wing tanks (Arhiva Brodosplita, 2021; Medić, 2021).

The superstructure consists of three floors and a wheelhouse. It stretches from R.158 to R.175 located at the bow and is designed to accommodate 27 crew members in 26 cabins. The bow is a classic bulbous bow, designed as a transverse construction system with high frames and floors (Medić, 2021).

Next to the R.176 frame is a transverse 1500 kW thruster. The stern is designed as a transverse construction system. The engine room is located aft and is separated from the cargo space by an impermeable bulkhead. A construction system with transverse frames is applied.

The ship's structure, i.e. its special design of the double-bottom structure, features the combination of longitudinal and transverse girders with small tolerances of mounting clearance. The clearance of the longitudinal girders to the openings on the transverse girders is 2 mm (there are no standard passages in the frames for the passage of longitudinal girders), see figure 1. (Malvić, 2019; Arhiva Brodosplita, 2021).

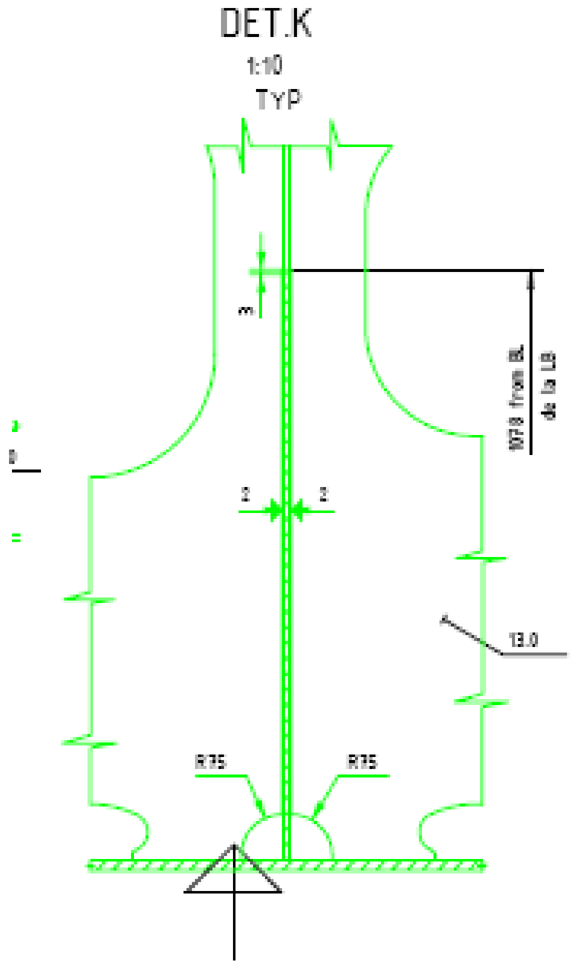

Figure 1. Structure of the vessel's hull (Source: Malvić, 2019; Medić, 2021)

The structure of the cargo hold is designed with the maximum permitted deviation tolerances of +/- 10 mm for the hold's width of 17,0 m and +/- 75 mm for the entire length of the hold (the lower hold is 83,20 m long, while the upper hold is 108,80 m long). The accuracy of the construction of the cargo hold structure is strictly observed in order not to jeopardize the system of smooth functioning of hatch covers at all levels. The above deviations must not compromise the system of uninterrupted functioning of hatch covers.

The structural elements of the ship's hull and superstructure are made of standard shipbuilding steel and high-tensile steel (Brodosplit d.d., 2008; Malvić, 2019; Arhiva Brodosplita, 2021).

Hatch cover system

The nine panels of the watertight hatch covers on the main deck, figure 2. and the thirteen panels of the hatch covers of the 'tween deck are able to be positioned in the longitudinal direction fore-aft and vice versa.

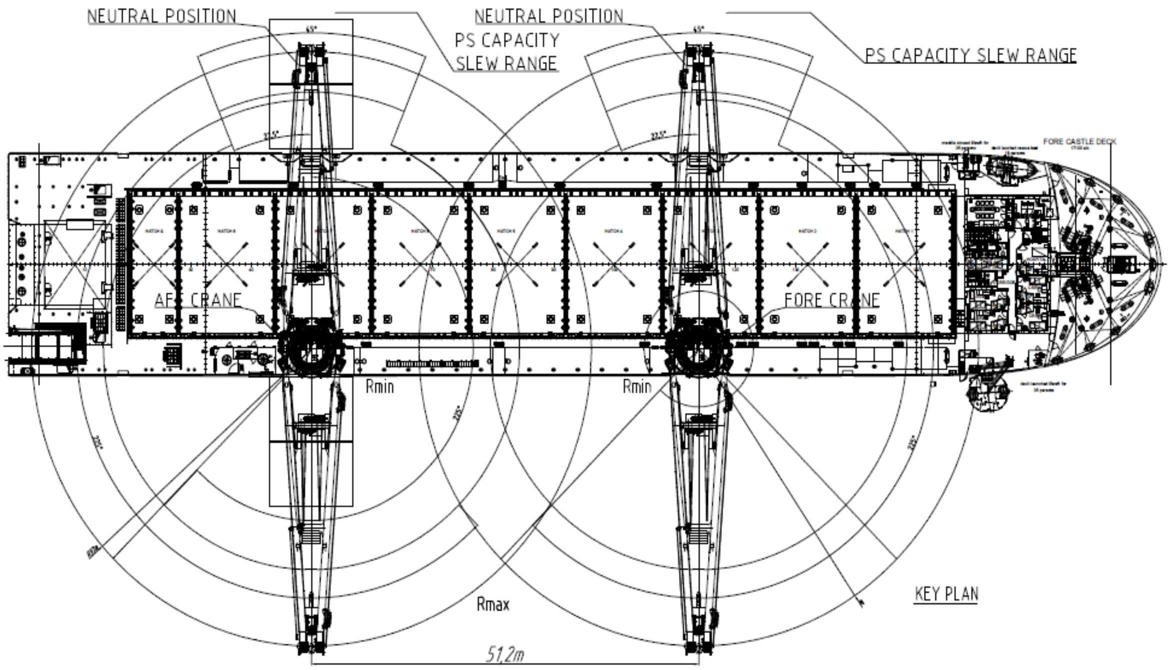

Figure 2. System of the main deck hatch covers (Source: Arhiva Brodosplita, 2021; Medić, 2021)

The hatch covers of the ‘tween deck are positioned and locked with the special JUMBO locking system, which consists of cast guides and pins that enter the ports on the guides. They can be locked at 16 height positions.

Special cast guides are welded into the longitudinal hold bulkheads at 8500 mm left/right from the center line on every other frame. The mutual longitudinal distance, and thus the permitted required tolerance of deviation of the guides, amounts to 3200 mm +/- 1 mm (Brodosplit d.d., 2008; Malvić, 2019; Arhiva Brodosplita, 2021).

The pairs of the ‘tween deck hatch covers have the same dimensions as the watertight hatch cover above on the main deck, so that their mutual connections are aligned vertically. The spacing of the frames they contain is the same as the spacing of the r in the double bottom. They are located at a height of 7800 mm from the base line.

The longitudinal tolerance of the designed hatch covers is +/- 2 mm, and the transverse tolerance of the designed hatch covers is +5 mm / 0 mm.

Usually, the cargo being loaded and transported is so large that there is no place on shore to store hatch covers. Therefore, the ‘tween deck and main deck hatch covers designed as watertight pontoons that can float. This means that during cargo handling they can simply be moored alongships on the seaward side until they are needed again, see figure 3.

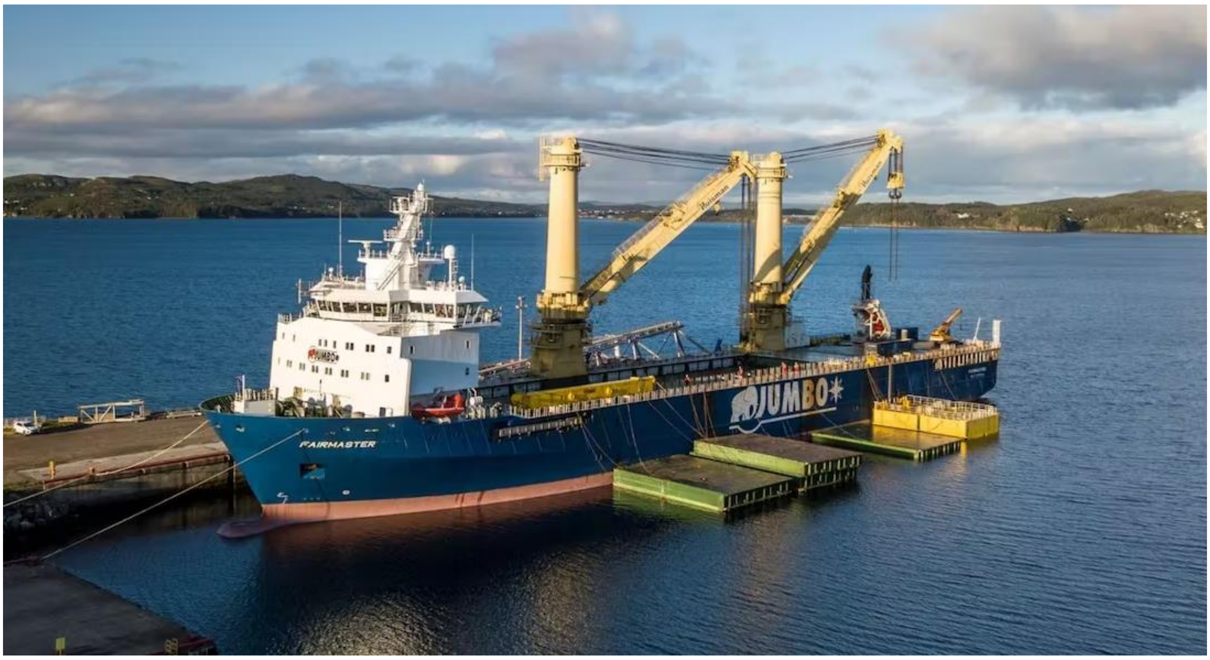

Figure 3. Hatch covers secured alongships on the seaward side (Source: Jumbo maritime - Fairmaster, 2022)

The vessel is certified for sailing without hatch cover. In such case, the maximum draught allowed is reduced from 8,10 m to 7,50 m (Brodosplit d.d., 2008; Malvić, 2019; Medić, 2021).

Vessel's stabilisation system

Hydrostatic stability has always been one of the most important parameters in the design of heavy lift vessels and over the years countless interesting and innovative concepts have been designed and tested to optimize the stability of these vessels. One way of obtaining this stability is by using a stabilization pontoon. In addition to the stability, the operation performance of a vessel is also very important (Dvornik J. and Dvornik S, 2021).

Along with the standard stability criteria for vessels, the stability of a heavy lift vessel must also take into account the scenario when there is a heavy piece of cargo hanging in the cranes. This drastically reduces the stability of the vessel and, if it is not sufficiently stable, the vessel may capsize (Medić, 2021; Ship technology, 2022).

To increase the stability of the Jumbo Shipping's Fairmaster, stabilisation pontoons can be connected to the seaward side of the vessel, along the outer shell of the hull during loading / unloading. This makes the vessel able to lift heavier loads or to increase the outreach of the crane, see figure 4.

Figure 4. Stabilisation pontoons (Source: Jumbo maritime - Fairmaster, 2022)

The stabilization system can function by securing one or both stabilising pontoons to the outer hull plating, side by side. The pontoons can be tied to the outer hull at twelve different height positions, depending on changes in the ship's draft during cargo loading. The lowest position of attaching the pontoon to the ship's outer hull is at the position of the ship's draft of 5,50 m, and the highest is at the position of the ship's draft of 8,50 m. Stabilization pontoons can only be used in the harbour or in calm waters, they cannot be used in rough sea conditions (Wartsila, 2022; Captain voyage, 2022).

Positions for attaching the pontoon to the vessel's hull in height are located every 300 mm. For securing the pontoon(s) to the port / starboard side of the vessel, there are welded guides in the vessel's outer shell, each with connection rods measuring 210 · 340 mm.

Wedging guides are located on R.46 and R.54, see figure 5. Pontoons can be semi-submersible or half-filled with sea. The pontoons are designed so that they can be stacked on the main deck and can float along the ship's hull (Brodosplit d.d., 2008; Malvić, 2019; Medić, 2021).

Figure 5. Wedging guides (Source: Jumbo maritime – Fairmaster, 2022)

When stacking on the aft part of the main deck, 16400 mm from the base line, pontoon No. 1 is stacked on top of pontoon No. 2. The dimensions of the stabilising pontoons are shown in table 2.

	Pontoon 1	**Pontoon 2**
Length	11 m	11 m
Width	8 m	8 m
Height	4,70 m	4,70 m
Weight	87 t	49 t

Table 2. Dimensions of the stabilising pontoons (Source: Jumbo maritime, 2022)

CONCLUSION

The basic technological requirement in the construction of the heavy lift vessel's hull is the dimensional accuracy of the manufacturing and assembly of the vessel’s hull structure, cargo space structure, hatch covers of the ‘tween deck and the main deck in all stages of manufacturing and assembly. It is essential to achieve the accuracy of cutting openings in all longitudinal and transverse elements of the vessel's hull structure, especially in the elements that form the cargo space, and to achieve the required vertical feature of the longitudinal and transverse elements of the structure (Brodosplit d.d., 2008; Malvić, 2019; Arhiva Brodosplita, 2021).

The hatch cover locking system should be created in stages with continuous monitoring of the condition of guides, pins and stoppers, while strictly observing the required deviations. Along with the formation of the guide system with pins, hatch covers should be made in strict compliance with the required accuracy conditions, and the same precision should be achieved on the hatch cover system of the main deck.

Today's modern vessels for loading and transporting special heavy out of gauge cargoes require professional and qualified crew. To work on such vessels, it is not enough to be familiar with the navigation systems – a wide range of knowledge and skills is required, including commercial affairs, shipbuilding and structural analysis, meteorology, hydrography, hydrodynamics and other scientific disciplines.

Precisely because of these facts, in addition to the vessel's crew, a large number of people ashore are involved in the transportation and loading of heavy cargoes, in order to ensure the safe and successful performance of a navigation venture (Brodosplit d.d., 2008; Arhiva Brodosplita, 2021; Medić, 2021).

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Cemex Croatia Rail Transport in Period 2011-2021

Ana Macura[1], Ante Bubić[1], Roko Glavinović[2]

Cement plants Sv. Juraj and Sv. Kajo has produced cement since the beginning of the 20th century. Both plants are based in the Dalmatian area with direct connection to the rail transport grid. Rail transport connects CEMEX Croatia plants with CEMEX Croatia terminals in the northern part of Croatia and Bosnia and Herzegovina. This research paper analyzes the 2011-2021 total cargo quantities moved by rail transport and managed by CEMEX Croatia. There is also an overview of the technology used for loading and unloading cement, available storage capacities at terminals, and rail technology used for cement transport. Furthermore, based on actual data, this paper gives an overview of possible development tendencies considering the possible market approaches.

KEY WORDS
Sv. Juraj Plant, Sv. Kajo Plant, CEMEX, Rail Transport, Cement

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INTRODUCTION

The utilization of the railway system in transportation plays a crucial role in ensuring sustainability, efficiency, and cost-effectiveness in the movement of goods. This mode of transport has a significant impact on shaping the economic and social development of numerous countries, by connecting communities, promoting trade and commerce, and reducing greenhouse gas emissions through its comparatively cleaner and more energy-efficient nature (Dundović et al., 2010). The Croatian railway system, being a vital aspect of the country's transportation infrastructure, serves as a crucial link between different stakeholders by connecting their operational hubs. The Croatian railway system is facing several challenges, including outdated infrastructure, limited capacity, and insufficient investment. Despite these challenges, there is significant potential for the development and improvement of the Croatian railway system, and the adoption of innovative technologies and best practices can help to address these challenges and improve the efficiency and effectiveness of the railway system in the country (Čagalj, 2018; HŽ Infrastruktura d.o.o., 2019).

CEMEX Croatia, one of the largest regional producers of building materials, relies on the railway system for the transportation of cement to its terminals and customers. The company operates multiple production facilities, including cement plants and concrete plants. Two producing plants are located in the Kaštela bay along the Croatian coast. These plants, Sv. Juraj and Sv. Kajo, are directly connected to the nearby railway network - Solin cargo rail station (Figure 1). Rail transportation provides an efficient mode of transportation for CEMEX Croatia's products, particularly bulk cement, which is transported from the production plants to various demand regions located far from the plants. Sustainable means of transports are in line with the business narrative of the company (CEMEX Croatia, 2023) and the European strategies, such as the European Green Deal (ECSA, 2020). The company's advanced technologies for loading and unloading cement, storage, and handling at terminals ensure damage-free and efficient transit (CEMEX Croatia, 2022).

Figure 1. Position of Sv. Juraj (1), Sv. Kajo (2) cements plants, and railway system (3) (Source: CEMEX Croatia, 2022)

This research paper aims to analyze the impact of rail transport on the operations of CEMEX Croatia, with a specific focus on the distribution network of cement. The Sv. Juraj and Sv. Kajo plants, both of which have a long history of producing cement, are located in the Dalmatian area and have a direct connection to the railway transport grid, allowing for efficient transportation to CEMEX Croatia's terminals (terminals Podsused, Maksimir and Bakar) in northern Croatia and Bosnia and Herzegovina (CEMEX Croatia, 2022). The paper provides a comprehensive analysis of the quantities of cement transported by rail and managed by CEMEX Croatia over the period of 2011-2021. It also examines the technology utilized for loading and unloading cement, the available storage capacities at terminals, and the rail technology used for transportation. By analyzing actual data, this research seeks to identify potential market tendencies and approaches that may be taken by CEMEX Croatia. The authors of this paper aim to offer an overview of the interplay between CEMEX Croatia, the Croatian railway system and its component - Lika railway, emphasizing the significance of rail transport for the efficient operation of cement production and distribution in the region. The findings of this research are expected to provide valuable insights for industry professionals, policy makers, and academics interested in the relationship between the railway system, business operations, and market trends.

The paper is structured into four sections, beginning with an Introduction. The second section presents the data on the quantities of cement cargo transported from the cement plants and terminals to the railway network. The third section provides an analysis of railway constraints and identifies potential areas for optimization in the context of companies that rely on rail transport, such as CEMEX. Finally, the fourth section, "Discussion and Conclusion", summarizes the key findings of the study, contextualizes them within the existing literature, and identifies the limitations of the research.

CARGO QUANTITY AND TERMINALS

The Sv. Kajo plant is the main loading point for railroad wagons of CEMEX Croatia. Most of the cargo transported by rail is bulk cement, with sporadic deliveries of bagged cement. Sporadic deliveries of bagged cement are loaded at the Sv. Juraj plant. Two shunting locomotives are used for internal movement of wagons within the plant premises (Figure 2). The transport company delivers empty wagons and collects loaded wagons at the entrance to the plant. The rail transport service provider is HŽ Cargo, the only rail transport service provider that transports goods on the Lika line towards hubs in other parts of Croatia.

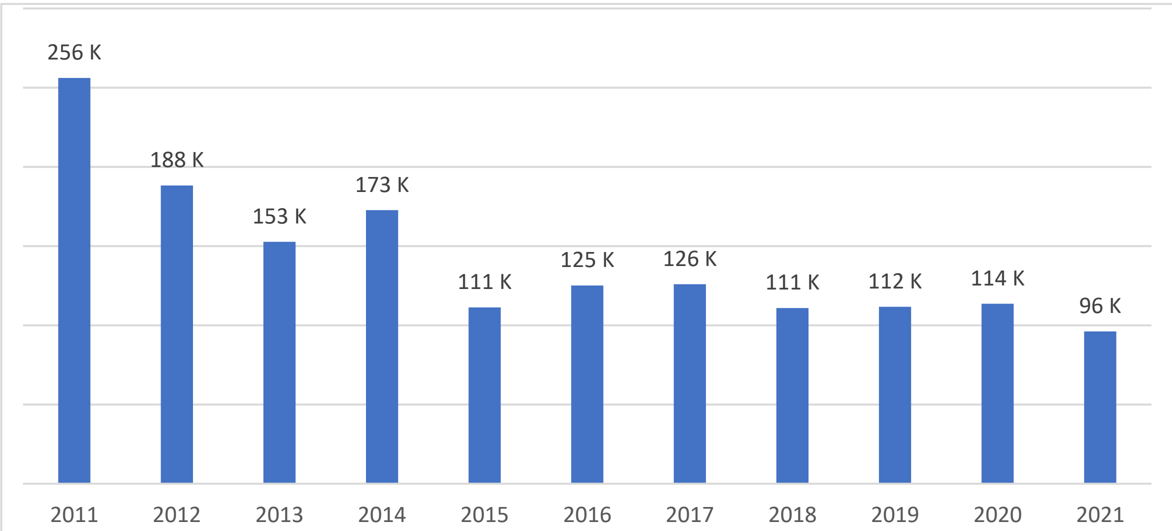

Figure 2. Two locomotives used at the Sv. Juraj plant (Source: CEMEX Croatia, 2022)

Wagon types UAC and UACNS are used for the transport of bulk cement. These wagon types have a net loading capacity of 50-55 tons. In the past, UCK wagon types were also used (with a net loading capacity of about 20 t of bulk cement), but the rail transport provider has not used them for several years. The total number of UAC and UACNS wagons used by CEMEX Croatia is about 100. Optimization of wagon turnover is the priority of CEMEX Croatia and the rail provider, delivery of the loaded wagons to the final destinations and return of the empty, unloaded wagons. For example, in December 2022, a total of 90 different wagons were loaded and transported to the terminals.

The rail provider transports loaded wagons in train compositions of 12 to 16 wagons (HŽ Cargo started using train compositions of 16 wagons in the second half of 2022), with the number of wagons in the train composition limited by the constraints of the infrastructure of the lower part of the Lika line.

Figure 3. Wagons in Sv. Kajo plant (Source: CEMEX Croatia, 2022)

The Figure 4. shows the total volume loaded in CEMEX Croatia plants and transported by rail to final destinations.



The record year of the decade was 2011, with a total of 256,000 tons of cement transported by rail. The second half of the decade shows stability in total freight volumes transported, all in a range just above the 100,000-ton mark, with the lowest volume in 2021 (the average for the period 2016-2021 is 112,00 tons).

In the period 2011 to 2021, there were seven final destinations for cement transported by rail, as follows:

- Podsused, Maksimir (Sesvete), Bakar, Gospić, and Knin in Croatia, and
- Prijedor, Blatna in Bosnia and Herzegovina.

The main demand region in the last decade and the destination for most volumes transported by rail is located in the northern part of Croatia and is internally referred to as "CRO North". Three terminals supplied by rail transport are located in the CRO North region: Podsused, Maksimir, and Bakar. The Podsused and Maksimir terminals are located in the Zagreb area and can be supplied by rail and trucks.

Terminal Podsused

The Podsused terminal (Figure 5) has 3 siloses with total capacity of 10.500 t and it is equipped with one locomotive which is used for shunting the wagons inside the terminal area.

Figure 5. Terminal Podsused location (Source: CEMEX Croatia, 2022)

The Podsused terminal can be considered as the main terminal of CEMEX Croatia due to the total volume transported to the terminal by rail. The fluctuation of the volume in the ten-year period was considerable, as shown in Figure 6, but the cement deliveries by rail to the terminal were regular. The record year in the studied period was 2011 with over 100 kt of cement delivered to the terminal. In 2014, the total volume was close to the record value. In the last 3 years, after the record minimum in 2018, the total volume of bulk cement deliveries to the terminal was around 70 kt.

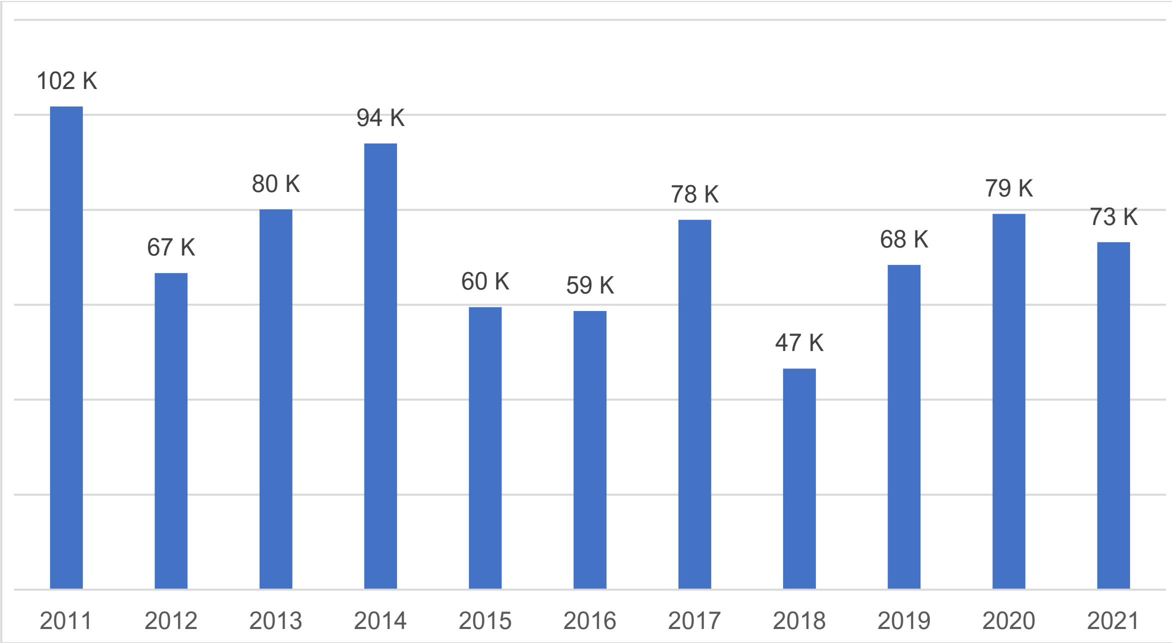


Figure 6. Terminal Podsused – cargo rail delivery (Source: CEMEX Croatia, 2022)

Terminal Maksimir

The Maksimir terminal (Figure 7) has two silos with a total capacity of 3,000 tons and is equipped with a UNIMOG vehicle that is used to maneuver the wagons within the terminal premises. The Terminal is located in Sesvete in the Zagreb region and was named after the Maksimir company located there.

Figure 7. Terminal Maksimir - UNIMOG vehicle shunting the (Source: CEMEX Croatia, 2022)

Over the past decade, total volumes delivered to this terminal have declined (Figure 8), from the record year of 2011 with 106 kt to an average of 20 kt of cement delivered per year in the second half of the decade. The decline in volumes is due to changes in demand and the location of customers.

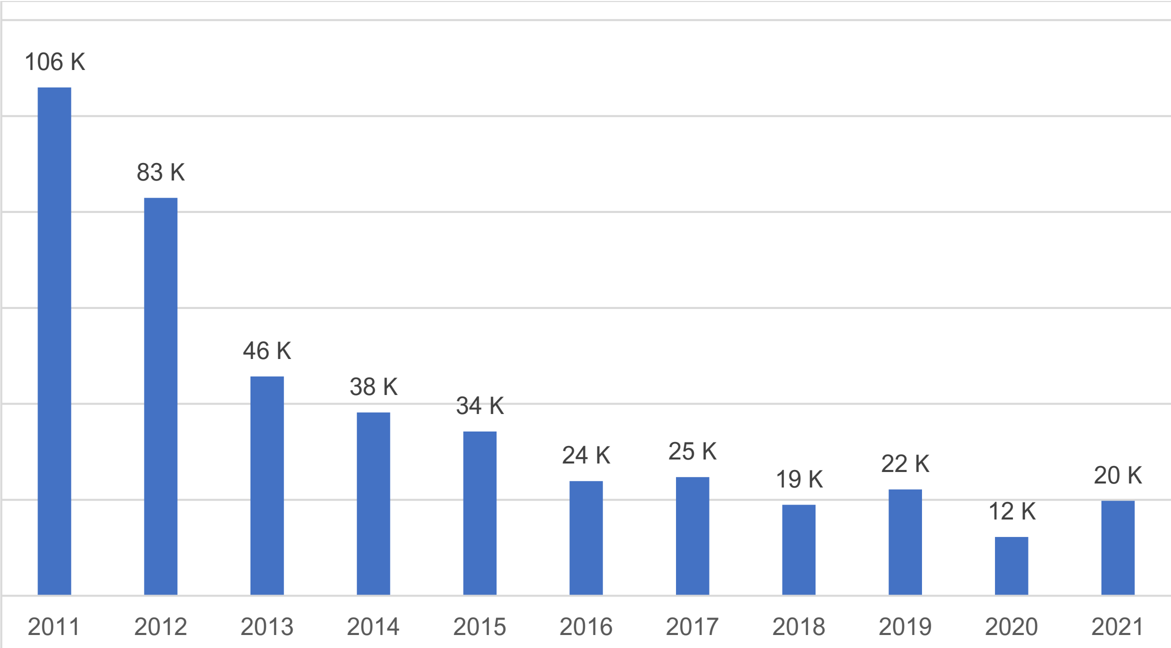


Figure 8. Terminal Maksimir – cargo rail delivery (Source: CEMEX Croatia, 2022)

Terminal Bakar

The Terminal Bakar is located in the Rijeka area and can be supplied by rail, ship and trucks (Figure 9). The Terminal is located in the port area and has a silo capacity of 500 tonnes.

Figure 9. Terminal Bakar unloading UCK type of wagons (Source: CEMEX Croatia, 2022)

Rail transport is used as the main supply route for the Bakar area only until 2021. Figure 10 shows the fluctuation of cargo delivery to the Bakar terminal. In 2021, construction work was carried out in the port where the silo is located, so that the supply by rail was limited. As a result, the rail operator informed CEMEX Croatia of its limited capacity to supply the terminal by rail, so rail is no longer the primary source of supply for the terminal.

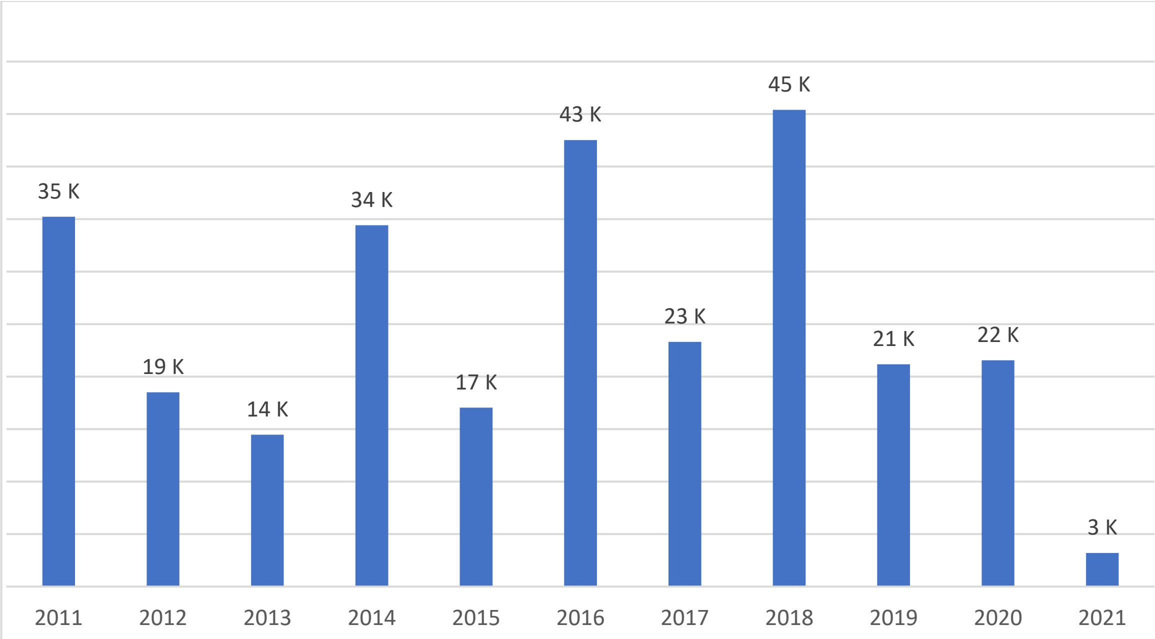


Figure 10. Terminal Bakar – cargo rail delivery (Source: CEMEX Croatia, 2022)

Other destinations

Other destinations (Figure 11) were used depending on market demand and the capacity of rail carriers and rail infrastructure. Until 2015, CEMEX Croatia used rail transport for the delivery of bulk cement to terminals in Bosnia and Herzegovina: Prijedor and Blatna. Delivery by rail to these areas was abandoned due to logistical constraints. However, there was an exception in 2020 when rail was used again due to supply chain constraints caused by the pandemic (CEMEX Croatia, 2022).

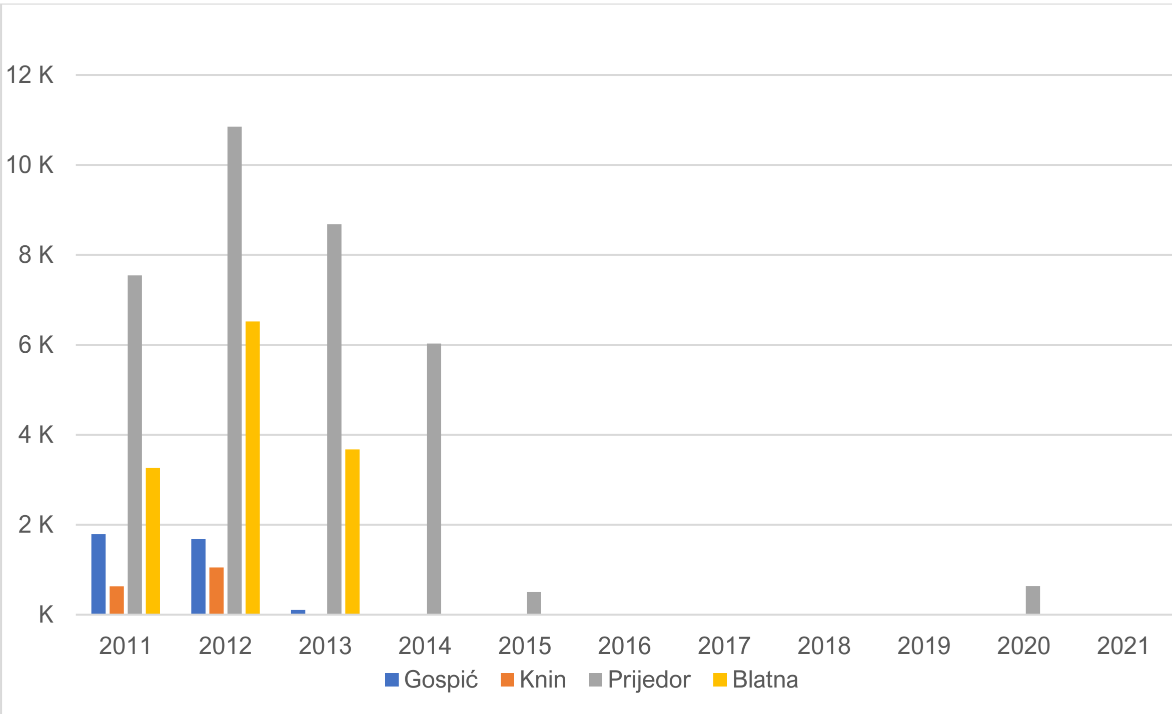


Figure 11. Cargo rail delivery – other destinations (Source: CEMEX Croatia, 2022)

LIKA RAILWAY – CARGO CAPACITY CONSTRAINTS

The Croatian railway network (Figure 12) is a critical component of the country's transportation infrastructure, providing essential connectivity to cities and various stakeholders. However, the current railway system is facing significant challenges, including outdated infrastructure, limited capacity, and insufficient investment. Despite these hurdles, there is significant potential for the improvement and development of the railway network through the implementation of innovative technologies and best practices. The Croatian government has recently taken steps to modernize the railway system by investing in infrastructure upgrades, with the aim of ensuring its continued role as a vital part of the country's transportation infrastructure, supporting the economic and social growth of the nation, particularly in its industrial regions (HŽ Infrastruktura d.o.o., 2019; (Čagalj, 2018).

Figure 12. Croatian railway system (Source: Find-Croatia, 2023)

The Lika railway (Figure 13), connecting Ogulin to Knin, was established in the 20th century and provides a crucial railway connection between Dalmatia and mainland Croatia (Leksikografski zavod Miroslav Krleža, 2023). Despite its importance, the inadequate state of the railway infrastructure and limited capacity on the Lika railway line have caused difficulties for the business activities of companies in the Split-Dalmatia County. This has had a detrimental impact on the competitiveness and sustainability of the Dalmatian economy, making it challenging to ship materials to the north and putting financial pressure on companies delivering goods to the terminals in the south. This situation is particularly affecting companies such as CEMEX which form the industrial backbone of the Split-Dalmatia County. The stability of the transport route is crucial to the competitiveness and sustainability of both the Dalmatian and Croatian economies, particularly given the European Union's focus on intermodal transport (European Commission, 2023) and the conception of railway system according to the White paper (European Commission, 1996). Therefore, it is imperative to address the challenges faced by the Croatian railway system and implement measures to enhance its efficiency and effectiveness (Petranović, 2022; Čagalj, 2018; Bunijevac, 2009; HŽ Infrastruktura d.o.o., 2019).

Figure 13. Lika railway (Source: Arbalete, 2023)

DISCUSSION AND CONCLUSION

The transportation of goods, including cement, via the rail system, is crucial in promoting a sustainable, and efficient movement of goods. This research analyzed the impact of rail transportation on the operations of CEMEX Croatia, one of the largest regional producers of building materials. The study focused on the cement distribution network from two cement plants, Sv. Juraj and Sv. Kajo, to terminals in northern Croatia, Gospić, Knin, Prijedor and Blatna in Bosnia and Herzegovina.

The research found that CEMEX Croatia heavily relies on the railway system for transporting bulk cement and sporadically bagged cement to its terminals and customers. The data analysis showed that the company's cement transport has been consistent over the past ten years, with occasional fluctuations, indicating a stable market trend. The paper identified some potential areas for optimization, such as the use of innovative technologies, that can help address some of the challenges faced by the Croatian railway system, including outdated infrastructure, limited capacity, and insufficient investment. Furthermore, the study emphasized the significance of the railway system for the efficient operation of cement production and distribution in the region.

Transportation to Bakar by rail was discontinued by Hrvatske željeznice (HŽ) due to capacity constraints and logistical limitations. The railroad network used to serve Blatna and Prijedor. However, this option became impracticable due to the complications arising from traversing two countries, namely Croatia and Bosnia and Herzegovina. Moreover, the Una railroad, which could have possibly solved some of the logistical problems, was not utilized. It is important to mention that market fluctuations also contributed to this decision.

Given the limited capacity of the Lika railway, it is challenging to formulate development strategies. Both HŽ Cargo and the rail network itself are constrained by capacity limitations. Regrettably, there is no alternative rail operator that can provide freight transport services on the Lika railway, with the exception of a private operator operating in Gospić.

The research findings have significant implications for industry professionals, policymakers, and academics interested in the relationship between the railway system, business operations, and market trends. By analyzing actual data, this research paper has provided valuable insights to help stakeholders make informed decisions regarding using rail transport for cement and other building materials, and other different industries as whole.

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Predictive Diagnostics Applied To Naval Equipment

David Boullosa-Falces[1]; Egoitz Urtaran Lavín[1]; D.S. Sanz [2]; Sergio García [2]; Miguel Angel Gomez-Solaetxe[1]

Due to the high competitiveness between shipping lines in achieving the required levels of operability, it is necessary to apply an appropriate maintenance strategy to the ship's propulsion and auxiliary equipment in order to achieve the highest availability and reliability at the lowest possible cost. The monitoring of equipment has taken on a dimension in which manufacturers have developed very powerful data acquisition systems, which has resulted in a growing computerisation of processes and monitoring, allowing a large number of variables to be recorded in real time with frequencies of up to milliseconds. However, the large number of monitored variables makes it difficult to visualise the evolution of the process quickly and effectively. In addition, current systems generate an alarm when a failure has occurred, leading to erroneous actions by the user, poor maintenance planning and generating unscheduled stops. In view of this problem, the objectives of the present work were: (1) To present a novel tool for maintenance monitoring; (2) To optimise and facilitate predictive maintenance of the vessel; (3) To reduce the costs produced by unscheduled shutdowns. This paper presents a predictive maintenance methodology based on a statistical algorithm, which provides ship managers with appropriate information well in advance to make a correct decision before a real failure in the process. On a 284 m length ship, an auxiliary installation was selected and monitored using statistical control techniques. Data acquisition was carried out by means of the ship's integrated IAS (Integrated Automation System). The results showed that the developed algorithm can detect very early deviations of the process from its optimal operating condition and thus help in the selection and timing of maintenance, reducing peration and maintenance costs due to unplanned downtime.Therefore, it can be concluded that the tool for maintenance monitoring optimized and facilitated the maintenance of the vessel and reduced the costs caused by unscheduled downtime.

KEY WORDS

Maintenance, Predictive, Monitoring, Naval

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INTRODUCTION

The need to adapt and use new technologies made the industry evolve into a new era. Connectivity, amount of data, new devices, inventory reduction, customization, and controlled production gave rise to the so-called Industry 4.0.(Zonta, Da Costa et al. 2020).

This has meant that the monitoring of the equipment has acquired a dimension in which the manufacturers have developed very powerful data acquisition systems, which allow the recording in real time with frequencies up to milliseconds of a large number of variables. Current monitoring systems monitor process variables individually (González, Sánchez 2010), this can lead to erroneous actions by the user, due to the difficulty in interpreting a large number of monitored signals at the same time.

The challenge now facing process monitoring is how to manage the large amount of correlated information that can be recorded, reducing the number of variables monitored without losing process information is a way of optimising the process, maximising its efficiency, as well as reducing measurement costs.

In view of this problem, the objectives of the present work were: (1) To present a novel tool for maintenance monitoring; (2) To optimise and facilitate predictive maintenance of the vessel; (3) To reduce the costs produced by unscheduled shutdowns.

The maintenance of engineering facilities includes a broad spectrum of repairs and services implemented to enable the systems and equipment to perform their intended functions. This helps achieve the desired level of reliability and operational safety and improves the availability of the equipment, which will enhance the capability and productivity of the facilities. (Bhandari, Arzaghi et al. 2016).

Predictive Maintenance (PdM) is historic data-based, models, and domain knowledge. It can predict trends, behavior patterns, and correlations by statistical or machine learning models for anticipating pending failures in advance to improve the decision-making process for the maintenance activity avoiding mainly the downtime (Sezer, Romero et al. 2018).

By a multivariable control chart, it is possible to monitor a group of variables in a single signal (Sabahno, Castagliola et al. 2020, Ershadi, Niaki et al. 2021), moreover, this type of chart is predictive in nature so that it is possible to anticipate a change in the process relative to its normal mode of operation (Boullosa, Larrabe et al. 2017).

This paper responds to this need on board a ship, we implement multivariable monitoring of the boiler-turbine process installed on a 284 m LNG tanker, through Hotelling T2 control charts for specific operating conditions.

MATERIAL AND METHODS

The process flow of the boiler-turbine installed on a 284 m LNG tanker is shown in figure 1.

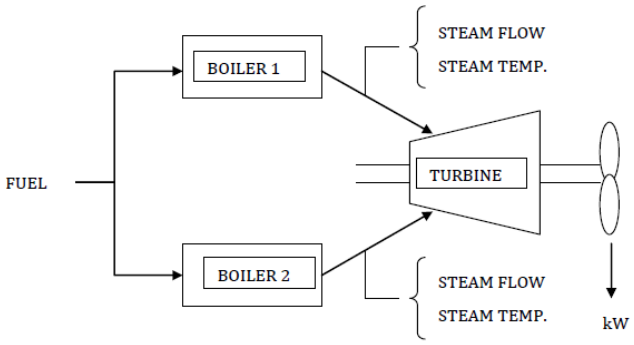

Figure 1. Process monitored

The variables analysed were as follows:

- Power generated by the shaft (kW),
- Boiler superheated steam production 1 (Tn/h),
- Boiler superheated steam production 2 (Tn/h),
- Superheated steam outlet temperature of the boiler 1 (ºC),
- Superheated steam outlet temperature of the boiler 2 (ºC),
- Consumption (m3/dĺa)

A total of 77 samples were taken through the vessel's monitoring systems, over a period of 2 voyages from Malta to Trinidad with a duration of 12 days each voyage, under the following conditions: vessel speed between 10 - 13.5, average engine room temperature of 27-32°C and average ambient temperature of 16 - 32°C.

Phase I Purging process

To build the historical database (HDS), the *n*=77 samples estimated for the multivariate process were monitored using Hotelling's T^2 chart (Tiryaki, Aydin 2022), following the expression (1).

$$\mathrm{T}^2 = (X_i - \overline{\mathrm{X}})' \ \mathrm{S}^{-1}(X_i - \overline{\mathrm{X}}) \quad (1)$$

Where:

X_i = ($X_{i1;}X_{i2}; \dots; X_{iP}$) preliminary data, $\bar{X}$, is the vector of sample means y S^{-1}, the inverse of the covariance matrix.

Depending on the circunstances, the T2 statistic can be described by three different probability functions: the Beta, the F and the chi-square distributions.When *μ,σ* are estimated, the Beta distribution is used in the purging process of a Phase I operation, whereas the F distribution is used in the development of the control process in a Phase II operation. When *μ,σ* are known, the chi-square has applications in both Phase I and Phase II operations (Mason, Chou et al. 2003).

In this case, with a mean and standard deviation *μ,σ* estimated, for the calculation of the UCL (Upper Control Limit), the *β* distribution of *α*=0.05, was used in the process of purging outliers from those observations that were outliers in the process. The level of α is typical value for this type of process.

The UCL has determined by the following expression:

$$\mathrm{UCL} = \left\{\frac{(n-1)^2}{n}\right\} \beta_{\left\{\alpha;\frac{p}{2};(n-p-1)/2\right\}} \tag{2}$$

Where:

n: Is the size of the data set, p: Number of variables, $\beta\{\alpha; p/2; (n-p-1)/2\}$, is the αth, quantile of the beta distribution, $\beta\{p/2; (n-p-1)/2\}$

If the value of T^2, which was monitored for an observation, exceeded the UCL, the observation was removed from the preliminary database.

With the remaining observations, we calculated a new vector of means and covariance matrix and again, outliers, produced by errors in the measurements, were detected and eliminated, this process was repeated, until a homogeneous set of observations was obtained. The final data set was the (HDS), from the normal operation mode of the process, consisting of 54 samples as shown in table 1.

Obs. No.	Var1 (*kW*)	Var2 (*Tn/h*)	Var3 (*Tn/h*)	Var4 (ºC)	Var5 (ºC)	Var6 (m^3/day)
1	6896	24,5	24	506	502	145
2	6940	24	24	506	502	145
3	6925	24	24	506	502	145
4	6876	23,6	23,7	505	499	144
5	6902	24	23,8	505	499	144
6	6820	23,5	23,3	505	499	144
7	6804	23,3	23,2	505	499	144
8	6800	23,9	23,7	503	496	142
9	7508	26	26,2	510	504	155
10	7551	25,5	25,5	510	504	155
11	7134	26,5	26,5	510	504	155
12	7108	26,3	26,4	510	504	155
13	7125	26,2	26,3	510	504	155
14	7217	26,7	26,7	510	504	155
15	7006	24,3	24,2	503	497	148
16	6774	24,7	24,8	503	497	148
17	6789	24,8	24,6	503	497	148
18	6884	24,8	24,8	504	498	144
19	6731	24,6	24,7	504	498	144
20	6881	24,4	24,4	504	498	144

Table 1. Part of the HDS

Phase II Process control

In this second phase, it was checked whether a new data input generated any deviation from the normal operating mode of the process (HDS).

The new data input corresponded to 14 valid samples acquired after analysing them according to the criteria of the vessel's normal operating conditions.

The T^2 values, for the new data input, were calculated, following the expression (3).

$$T^2 = (X_i - \overline{X})'\ S^{-1}(X_i - \overline{X}) \tag{3}$$

Where:

$\bar{X}\ y\ S^{-1}$, are the vector of sample means and the inverse of the covariance matrix, obtained from the HDS and X_i, the new data entry. $X_i = (X_{i1;} X_{i2}; \ldots; X_{ip})'$

For the calculation of the UCL (Upper Control Limit), the F distribution of α=0.05, for type II errors, was used (Mason, Tracy et al. 1997). The level of α can be variable, making more or less strict the method. The chosen alpha level is normally used in industrial processes.

The UCL was determined by the following expression (4):

$$\mathrm{UCL} = \left\{\frac{p(n+1)(n-1)}{n(n-p)}\right\} F_{\{\alpha;p;(n-p)\}} \tag{4}$$

Where p, is the number of variables, *n*, is the size of the HDS and $F\{\alpha; p; (n-p)\}$, is the αth, quantile of $F\{p; (n-p)\}$.

Values of T^2 that exceeded the UCL were declared as signals and it was concluded that the observation was out of range with respect to the normal operating performance of the process.

RESULTS

Through Hotelling´s T^2 control chart were monitored five variables of the caldera - turbina process to detect changes significant in the normal operation condition. The UCL for the chart was 15,48, with α=0.05. Considering the data listed in Table 1 as the HDS, T^2 values were calculated according (3), for the 14 new incoming observations, and they were monitored in a T^2 control chart according to Fig. 2.

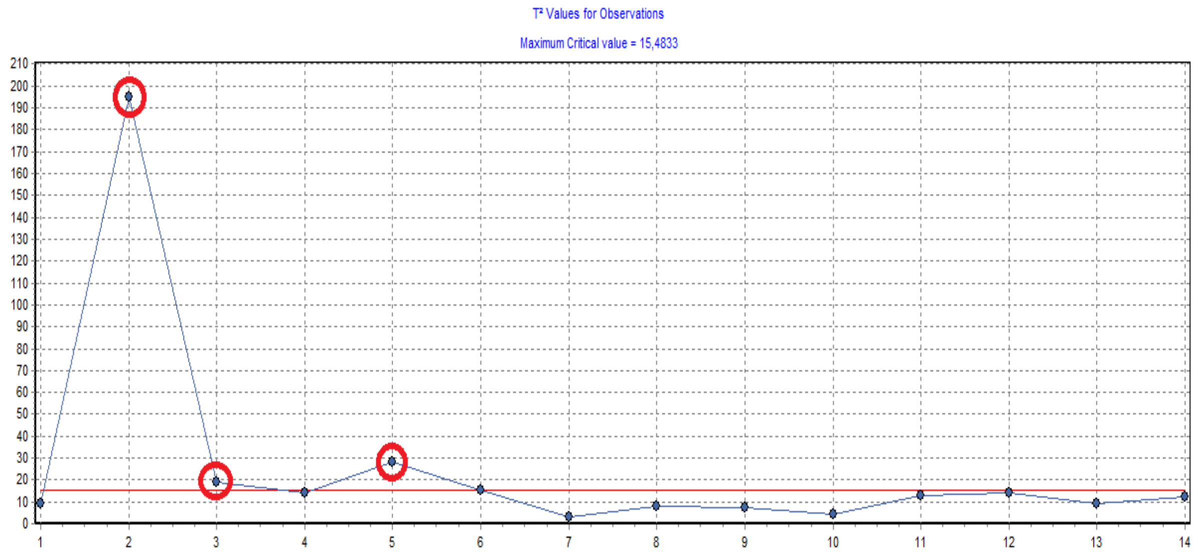

Figure 2. Control Chart

In figure 2, corresponding to the control chart, T^2 values above the UCL were observed, indicating that, in that time interval, the process suffered a deviation. That is, It was not working under the normal operating conditions of the process.

This situation does not mean that the process was failing, but that at that moment it deviated from its normal operating conditions. But if such a negative trend is repeated over time, it would be an indication of the need to take corrective maintenance action to restore process operability.

Figure 2 shows the 3 samples that caused the deviation of the process, where the UCL value was 15.48, and the T^2 values corresponding to the deviating samples were:

- Observation 1. T^2 = 34,54
- Observation 2. T^2 = 194,81
- Observation 3. T^2 = 19,05
- Observation 5. T^2 = 28,01

Therefore, by simply viewing the graph, we realise that during the course of the trip, there was a deviation in the monitored process in the engine room.

CONCLUSIONS

Current monitoring systems implemented in marine engines monitor process variables individually and generate an alarm when the value exceeds a set threshold, making preventive actions difficult. Without early detection of process deviations, it would be necessary to wait until the deviating variable(s) had risen above its set point and triggered a high or low alarm, sometimes leading to a failure.

The results showed that the algorithm developed, detected prematurely the deviation of the process with respect to its optimal operating condition, helping in the choice and timing of maintenance, reducing operation and maintenance costs due to unscheduled shutdowns. Therefore, it can be concluded that the tool for maintenance monitoring optimized and facilitated the maintenance of the vessel and reduced the costs caused by unscheduled downtime.

For the ship's engineers, knowing that the process was out of range could help them to be alert to significant changes in the process and try to correct the deviation in anticipation of failure.

This type of monitoring could be implemented in the ship's engine room, as a complement to the current monitoring system, or at headquarters as part of the predictive maintenance protocol.

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Fuel Exergy Based on the Chemical Equilibrium of Combustion Gases

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The evaluation of the energy efficiency of ships is becoming increasingly important, not only because of the reduction of the operating costs of ships, but also because of the regulations on exhaust emissions from ships. Energy analysis does not consider the quality of the available energy, but only the energy conversion, regardless of the possibility that the process takes place. Exergy efficiency, which considers the quality (availability) of energy achieved by burning fuel, is increasingly used, but unfortunately not in commercial applications. In this paper, the standard chemical exergy and exergy efficiency of the methane combustion process are analyzed in terms of the combustion products formed at complete combustion and the combustion products formed at chemical equilibrium. The calculation of the lower and higher heating values of the fuel and the chemical energy of the gaseous methane is based on the complete combustion of the fuel, considering nitrogen as an internal gas and the water in the combustion gases leaving the system either as a liquid or as a vapor.

KEY WORDS

Fuel exergy, Exergy efficiency, Combustion, Chemical equilibrium composition

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INTRODUCTION

Exergy analysis of a plant is increasingly used to evaluate its efficiency. When energy analysis was used exclusively, there was the possibility of a wrong choice or additional analysis of the system to select a more favorable solution. Also, the increasingly stringent requirements to reduce air pollution from ships force the use of fuels with lower emissions of harmful exhaust gases (greenhouse gases, stratospheric ozone depletion, acid precipitation and smog) - alternative fuels such as natural gas, methanol, ammonia and so on. The paper analyses the exergy of the combustion products produced during the combustion of gaseous methane in terms of: i) complete combustion, ii) the combustion products resulting from the chemical equilibrium composition in combustion products.

The definition of standard chemical exergy of fuels with reference to technical fuels is given in Kotas (Kotas, 1995), Szargut (Szargut, et al., 1988), Bejan (Bejan, 2006), Ghannadzadeh (Ghannadzadeh, et al., 2011). Methane combustion efficiency, total exergy, temperatures of combustion products and exergy destruction are discussed in Dunbar (Dunbar & Lior, 1994), Silva (Silva & Rouboa, 2011; Silva, et al., 2013) and Arnaiz del Pozo (Arnaiz del Pozo, et al., 2019). The results obtained in this work are consistent with the results in the aforementioned papers.

CALORIFIC VALUE AND EXERGY OF THE FUEL

To determine the lower and higher heating value of the fuel, the difference of the enthalpy of formation (of the products and the reactants) is used (Moran, et al., 2014):

$$\hat{h}_{RP} = HV = \sum_{P=1}^{i} n_P \cdot \left(\hat{h}_f^o + \Delta\hat{h}\right)_P - \sum_{R=1}^{j} n_R \cdot \left(\hat{h}_f^o + \Delta\hat{h}\right)_R \quad \left[\frac{J}{kmol_F}\right] \quad (1)$$

where is n_P and n_R number of moles of combustion products and reactants, respectively, $\hat{h}_f^o$ molar specific enthalpy of formation of the element in the standard reference state (T_{ref} = 25 °C and p_{ref} = 101325 Pa), $\Delta\hat{h}$ specific molar enthalpy difference between the standard reference state and the state of interest. The terms in parentheses is total enthalpy at state T and p. Indexes P, R, and F refer to the combustion products, reactants, and fuel, respectively. This equation is used to determine the temperature of the combustion products (adiabatic flame temperature, for case when is $\hat{h}_{RP} = 0$) and the enthalpy of combustion (for case when the temperatures of the reactants and the combustion product are equal). The calculated lower heating value (LHV) and higher heating value (HHV) of gaseous methane for one kmol of fuel is 802301 kJ/kmol$_F$ and 890309 kJ/kmol$_F$, respectively. The real heating value depends on the molar fraction of water (partial pressure of the water) in the combustion products and it is 878030.67 kJ/kmol$_F$ for a stoichiometric ratio, i.e., 823155.44 kJ/kmol$_F$ for an equivalence ratio of 500%.

Using Second Law analysis for a chemically reacting system (combustion), the entropy change must be calculated. For the control volume (combustion chamber), the molar specific entropy change can be calculated (Annamalai & Puri, 2001):

$$s_{comb.} = s_P - s_R = \sum_{P=1}^{i} n_P \cdot \left[\hat{s}_P^0(T_P, p_{ref}) - R \cdot \ln\left(\frac{y_P \cdot p_{prod}}{p_{ref}}\right)\right] - \sum_{R=1}^{i} n_R \cdot \left[\hat{s}_R^0(T_R, p_{ref}) - R \cdot \ln\left(\frac{y_R \cdot p_{rea}}{p_{ref}}\right)\right] + \frac{q}{T} \quad \left[\frac{J}{kmol_F \cdot K}\right] \quad (2)$$

where is $\hat{s}^0$ – the absolute entropy of the component at temperature T and standard reference pressure $p_{ref.}$, y_P and y_R mole fraction of each combustion product and reactant component, p_{rea} and

p_{prod} pressure of the reactants and combustion product, respectively, *q* – exchanged heat to achieve the temperature products of interest, T_P. The terms in square brackets represent the absolute entropy of the combustion products and reactants at temperature *T* and pressure *p*.

The exergy balance for the system under consideration can be written as follows (Dincer & Rosen, 2020):

$$E_{w,Q} + \sum_{in=1}^{m} n_{in} \cdot e_{x,in} = \sum_{out=1}^{n} n_{out} \cdot e_{x,out} + E_{x,W} + E_{x,D} \qquad (3)$$

where is $\dot{E}_{w,Q} = Q_{comb} \cdot \left(1 - \frac{T_0}{T}\right)$ rate of exergy transferred by heat, ex,in and ex,out exergy of stream substance at inlet and outlet of observed system, respectively, $\dot{E}_{x,W}$ rate of exergy associated with work and $\dot{E}_{x,D}$ irreversibility i.e. exergy destruction. The exergy of substance can be divided into following (specific) components: kinetic, ex,k, potential, ex,p, physical, ex,ph, and chemical, ex,ch, exergy. The kinetic and potential exergy can be neglected (Dincer & Rosen, 2020), so the physical (or thermomechanical, according to (Bejan, 2006)) and chemical exergy form the total exergy of stream substance (according to (Bejan, 2006)), i.e., the thermal exergy according to Szargut (Szargut, et al., 1988).

Now, the exergy of the reactants and the combustion products must be determined to calculate the exergy of the fuel. Kotas described exergy (Kotas, 1995) by definition: “Exergy of a steady stream of matter is equal to the maximum amount of work obtainable when the stream is brought from its initial state to the dead state by processes during which the stream may interact only with the environment”. “Physical (or thermomechanical) exergy is equal to the maximum amount of work obtainable when the stream of substance is brought from its initial state to the environmental state defined by p0 and T0, by physical processes involving only thermal interaction with the environment” (Kotas, 1995). Assuming that the substance stream is a mixture of ideal gasses, the physical exergy (of the reactants or the combustion products) related to 1 kmol of fuel can be described as:

$$\hat{e}_{x,k}^{ph} = \sum_{k=1}^{i} n_k \cdot \left(\hat{h} - \hat{h}_0\right)_k - T_0 \cdot \sum_{k=1}^{i} n_k \cdot (\hat{s} - \hat{s}_0)_k \qquad (4)$$

and using the equation (2), follows:

$$\hat{e}_{x,k}^{ph} = \sum_{k=1}^{i} n_k \cdot \left(\Delta\hat{h}\right)_k - T_0 \cdot \sum_{k=1}^{i} n_k \cdot \left[\hat{s}_k^0(T, p_{ref}) - \hat{s}_P^0(T_0, p_{ref}) - R \cdot \ln\left(\frac{y_k \cdot p}{y_k \cdot p_0}\right)\right]_{T,p} \left[\frac{J}{kmol_F}\right] \qquad (6)$$

where is $\hat{h}$, $\hat{s}$ specific molar absolute enthalpy and absolute entropy of the substance, yi – mole fractions of the i-th component of the stream substance. Index 0 refers to the standard reference state, and the index ref. refers to the standard reference pressure, pref. = 101325 Pa. When initial and final pressures are equal (e.g., during the combustion process in the combustion chamber), p0 = p (= pref.), term $\ln\left(\frac{y_i \cdot p}{y_i \cdot p_0}\right)$ is equal to 0. To calculate the physical exergy of the combustion products, the initial temperature is set to the adiabatic flame temperature and the final temperature is set to the standard reference temperature, T0 = Tref. Moreover, the physical exergy of a substance stream can be divided into two components, the pressure dependence and the temperature dependence, which is described in (Kotas, 1995)].

The observed substance, the products of combustion, is now in equilibrium with the environment, strictly separated from the environment (e.g. by means of cylinder and piston), i.e. in restricted equilibrium. What would happen if this substance were released into the environment, would it be possible to make any work? Using the definition for chemical exergy: "Chemical exergy is equal to the maximum amount of work obtainable when the substance under consideration is brought from the environmental state to the dead state by processes involving heat transfer and exchange of substances only with the environment" (Kotas, 1995) or "Maximum amount of useful work that can be obtained when the system under consideration is brought from its restricted dead state to the complete dead state where the system is in complete thermodynamic equilibrium with the environment" (Pal, 2019) there is the possibility of achieving additional work to reach the dead state, i.e., unconstrained equilibrium. This can be achieved by a reversible isothermal process in which each substance component reversibly leaves the system at its environmental partial pressure through a semipermeable membrane (Pal, 2019). Now, besides mechanical and thermal restricted equilibrium, chemical equilibrium is achieved. The part of the exergy related to the chemical exergy can be determined as follows:

$$\hat{e}_k^{ch} = \sum_{k=1}^{i} n_k \cdot \left(\hat{h}_{T_0} - \hat{h}_{T_e}\right)_k - T_0 \cdot \sum_{k=1}^{i} n_k \cdot \left(\hat{s}_{T_0} - \hat{s}_{T_e}\right) =$$

$$\sum_{k=1}^{i} n_k \cdot \left(\hat{h}_{T_0} - \hat{h}_{T_e}\right)_k - T_0 \cdot \sum_{k=1}^{i} n_k \cdot \left[\hat{s}_{T_0,p_{ref}} - R \cdot \ln \frac{y_k \cdot p_0}{p_{ref}} - \left(\hat{s}_{T_e,p_{ref}} - R \cdot \ln \frac{y_{k,e} \cdot p_0}{p_{ref}}\right)\right]. \quad (7)$$

Due to $T_0 = T_e$, terms $\left(\hat{h}_{T_0} - \hat{h}_{T_e}\right)$ and $\left(\hat{s}_{T_0,p_{ref}} - \hat{s}_{T_e,p_{ref}}\right)$ are equal to 0 for each individual substance, so the chemical exergy can be determined by:

$$\hat{e}_{x,k}^{ch} = -T_0 \cdot R \cdot \sum_{k=1}^{i} n_P \cdot \ln \frac{y_{k,e}}{y_k} = T_0 \cdot R \cdot \sum_{k=1}^{i} n_k \cdot \ln(y_k) - T_0 \cdot R \cdot \sum_{k=1}^{i} n_k \cdot \ln\left(y_{k,e}\right) \quad (8)$$

where is $y_{k,e}$ the mole fraction of substance *k* at the conventional mean concentration of the reference species in the environment. These concentrations may vary from author to author, e.g., (Szargut, et al., 1988), (Moran, et al., 2014), and (Bejan, 2006). The last term on the right side of the equation represents the standard chemical exergy, $\hat{e}_k^{ch,0}$ of pure substance *k*. If the substance is not a component of air, the calculation of the standard chemical exergy can refer to reactions for which the standard chemical energy is known (Dincer & Rosen, 2020). In this way, the standard chemical exergy of the fuel, when the fuel enters the system in restricted equilibrium, can be determined as follows:

$$\hat{e}_{x,F}^{ch,0} = \sum_{P=1}^{n} n_P \cdot \hat{e}_{x,P} - \sum_{A=1}^{n} n_A \cdot \hat{e}_{x,A} + \hat{e}_{x,W} - \hat{e}_{x,Q} - \hat{e}_{x,F}^{ph,0} + \hat{e}_{x,D} \quad (9)$$

The first term on the right-hand side of the equation, $\sum_{P=1}^{n} n_P \cdot \hat{e}_{x,P}$, refers to the exergy (chemical and physical) of the combustion products when the initial temperature is equal to the adiabatic flame temperature and the pressure is equal to the pressure of the standard reference state. The term $\sum_{A=1}^{n} n_A \cdot \hat{e}_{x,A}$ refers to the exergy of the air at the inlet of the observed system (combustion chamber). The exergy of work, $\hat{e}_{x,W}$, and the exergy of heat, $\hat{e}_{x,Q}$, are neglected. The physical exergy of fuel, $\hat{e}_{x,F}^{ph,0}$, is equal to 0 because the fuel is in equilibrium with the standard reference state at the inlet. The exergy destruction of combustion can be calculated based on the entropy generation:

$$\hat{e}_{x,D} = T_0 \cdot s_{comb.} \left[\frac{J}{kmol_F}\right] \quad (10)$$

To compare the results obtained with the above calculation, the following equation can be used to calculate the standard chemical exergy of the fuel (at complete combustion and stoichiometric ratio) according to (Moran, 1989) and rearranged for 1 kmol of fuel:

$$\hat{e}^{ch,0}_{x,F} = \left[n_R \cdot \sum_{R=1}^{n} y_R \cdot \hat{g}^{o}_{f,R} - \sum_{P=1}^{n} n_P \cdot \hat{g}^{o}_{f,P}\right]_{T_0,p_0} + \sum_{P=1}^{n} n_P \cdot \hat{e}^{0}_{x,P} - \sum_{R=1}^{n} n_R \cdot \hat{e}^{0}_{x,R} \quad \left[\frac{J}{kmol_F}\right] \qquad (11)$$

where is $\hat{g}^{o}_{f}$ Gibbs energy of formation at the standard reference condition.

Several authors have given formulas for calculating the standard chemical exergy (Table 1.).

Author	Equation	Chemical exergy [kJ/kmol]**	Reference
Szargut	$LHV \cdot \left(1.0334 + 0.0118 \cdot \frac{H}{C} - 0.0694 \frac{1}{N^{*}_{C}}\right)$ mean accuracy: $\pm 0{,}27$ %	831650	(Szargut, et al., 1988)
Moran	$LHV \cdot \left(1.033 + 0.0169 \cdot \frac{H}{C} - 0.0698 \frac{1}{C}\right)$	831650	(Moran, 1989; Moran, et al., 2014)
Kotas	$LHV \cdot \varphi$; where is $\varphi = 1.04 \cdot (1 \pm 5\%)$ for natural gas	836510	(Kotas, 1995)

*mean number of carbon atoms in the molecule

** from table in appendix, not calculated

Table 1. Equations and values for standard chemical exergy of gaseous fuels

The calculated standard chemical exergy (based on thermodynamic properties from the literature (Moran, et al., 2014) and (Moran, 1989)) of gaseous methane for complete combustion and a stoichiometric ratio, using the above equations, is 831670 kJ/kmol$_F$. This standard chemical exergy will be noted as Case A. However, complete combustion in internal combustion engines or in a boiler cannot be achieved with a typical excess air (the typical excess air for natural gas is between 5% and 10%). In view of this, it is expected that the standard chemical exergy of the fuel will be smaller in relation to the composition of the combustion product determined by the chemical equilibrium, will be smaller. In this work, the data of chemical equilibrium composition in combustion products produced by the combustion of gaseous methane with different excess air are obtained using the Cantera software (Goodwin, et al., 2022). When this fact is taken into account, the calculated standard chemical exergy of gaseous methane and stoichiometric ratio is 825067 kJ/kmol$_F$. This standard chemical exergy will be noted as Case B.

RESULTS

In this paper, calculation of the exergy (of reactants, combustion products and destruction), adiabatic flame temperature and exergy efficiency for complete combustion and the exergy, equilibrium flame temperature (Moran, 1989), and exergy efficiency based on the combustion products composition determined by the chemical reaction equilibrium is made.

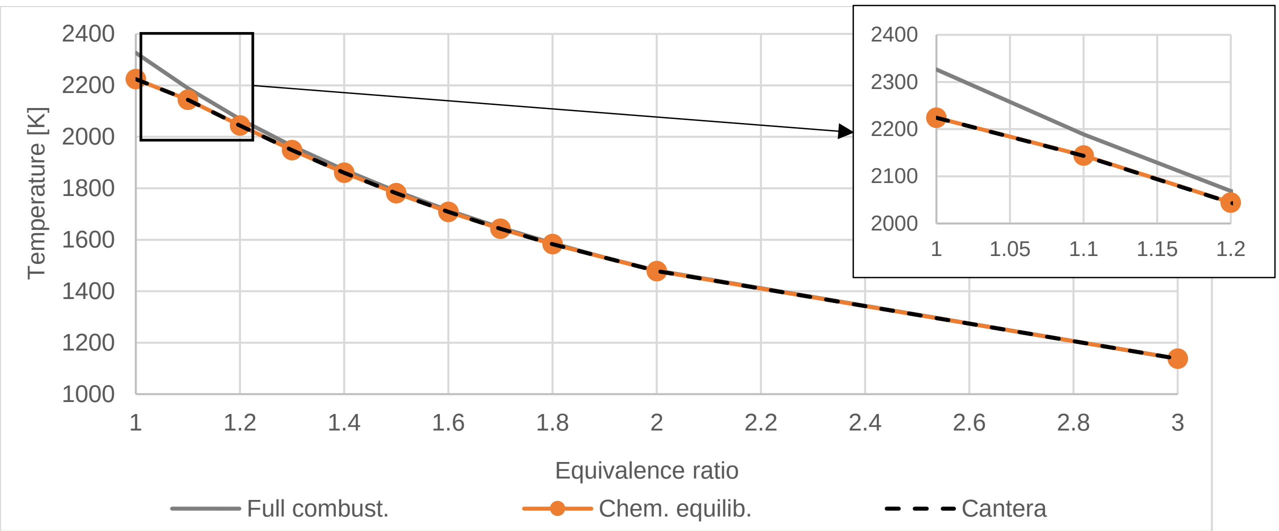

Figure 1. Adiabatic flame temperature and equilibrium flame temperature

Figure 1 shows the adiabatic flame temperature at complete combustion, equilibrium flame temperature determined by the Cantera and calculated adiabatic flame temperature based on the chemical equilibrium in combustion products. The last two temperatures coincide (with deviations between 0.09 K and 0.25 K). The value of the adiabatic flame temperature at complete combustion deviates most (with respect to the equilibrium flame temperature) for the stoichiometric ratio (by 102.31 K), i.e., for typical excess air values for natural gas (from 5% to 10%). As excess air increases, the difference between adiabatic flame temperature and equilibrium flame temperature decreases. Temperature differences (in areas of typical excess air) can affect the calculation of the formation of nitrogen oxides, which by their formation affect the greenhouse effect (N_2O), stratospheric ozone depletion (N_20, NO, and NO_2), acid precipitation, and smog (NO and NO_2).

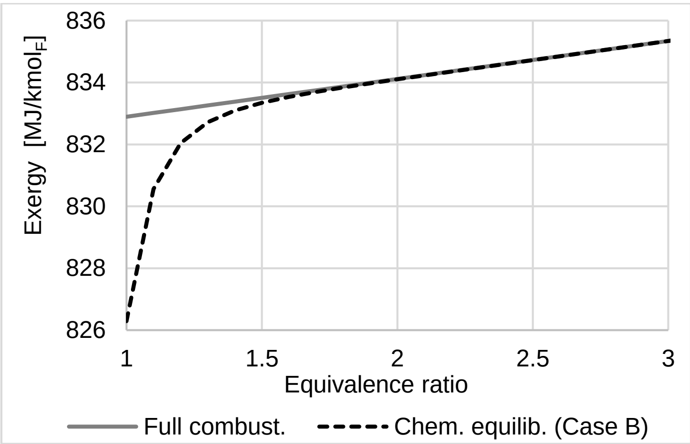

Figure 2. Reactants (fuel + air) exergy

Figure 2 shows the total exergy of the reactants: i) calculated with respect to the combustion products at complete combustion (solid line, Case A) and ii) calculated when the composition of the combustion gases is obtained by their chemical equilibrium (dashed line, Case B). The exergy of the reactants increases in both cases with the increase of the excess air. The maximum difference in the exergy of the reactants occurs at the stoichiometric ratio. Increasing the excess air decreases the difference between the above exergies.

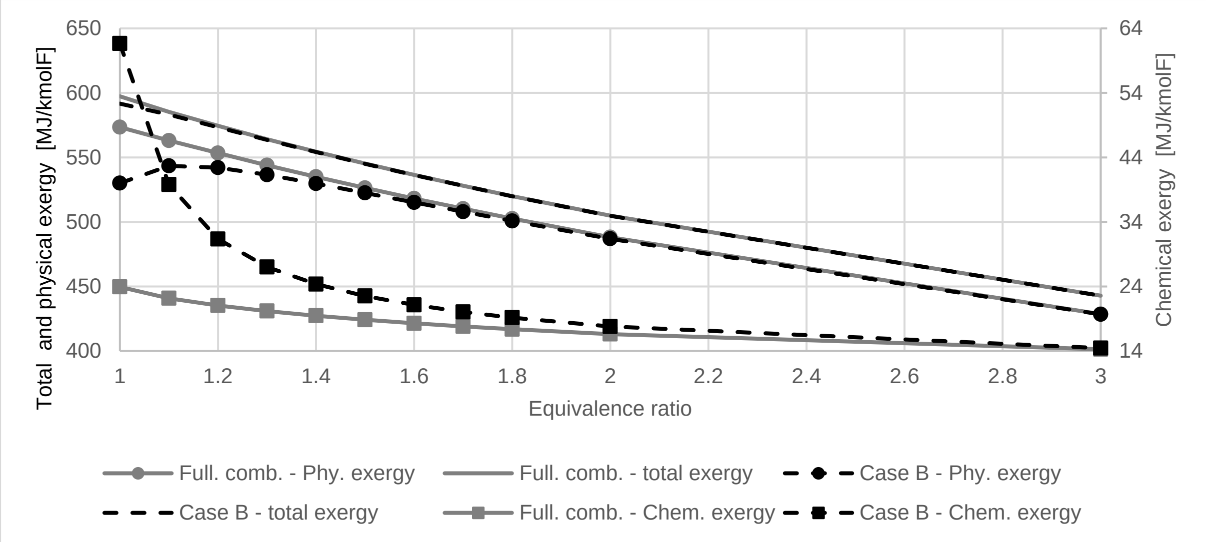

Figure 3. Combustion products exergy

Figure 3 shows the exergies of the combustion products, total, and their components (chemical and physical) for Case A and Case B. The largest deviations for these cases occur for the physical and chemical components of the exergy at the stoichiometric ratio (with a deviation of 8.2% for physical and 61.2% for chemical). Increasing the excess air for Case A result in decrease of the total exergy and its components. For Case B, increasing the excess air total and chemical exergy decrease. However, in the case of physical exergy, increasing the excess air up to 13.6% results in an increase in physical exergy, where it reaches its maximum value. Further increases in the excess air the physical exergy decreases. This fact may be a justification for increasing the excess air for natural gas to 13% (instead of the current 10%).

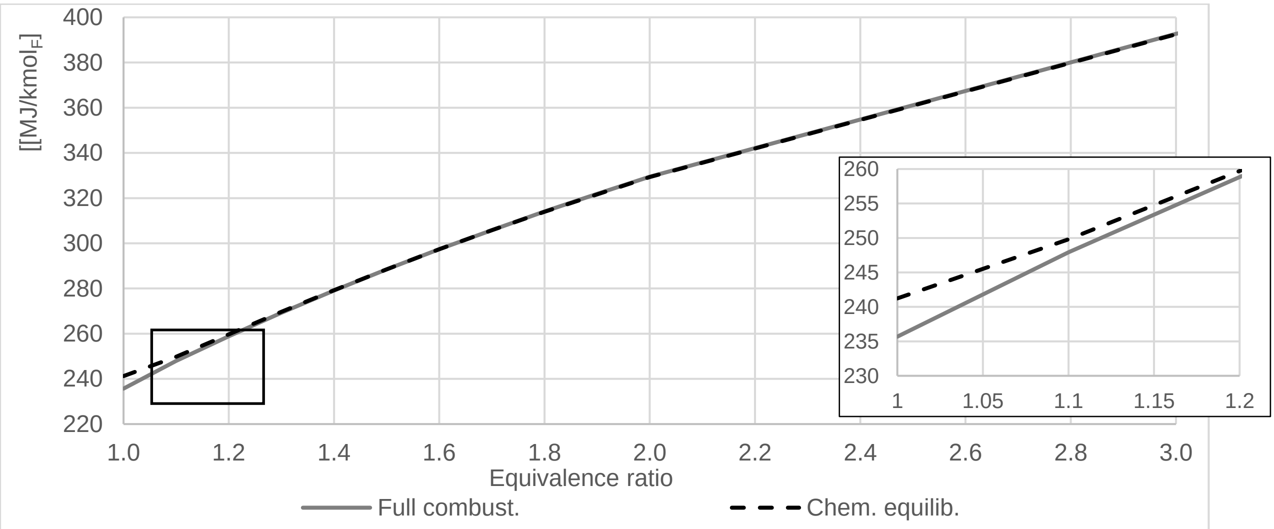

Figure 4. Exergy destruction

Figure 4 shows the total exergy destruction due to the mixing of reactants, the combustion process, the mixing of combustion products, and the internal thermal energy exchange. The exergy destruction increases as the excess air increases. The difference between exergy destruction at complete combustion and for chemical equilibrium composition in the combustion product is higher at stoichiometric air ratio, while this difference decreases as excess air increases.

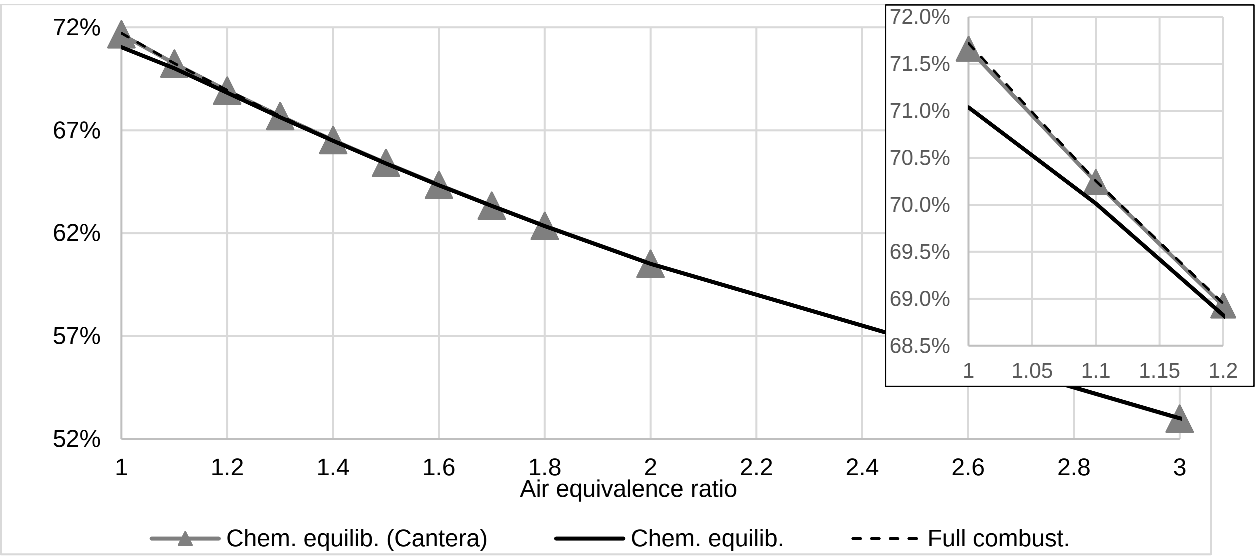

Figure 5. Exergy efficeincy

Figure 5 shows the exergy efficiency of the combustion process as a function of excess air for the Case A, Case B and results obtained by Cantera. As the excess air increases, the exergy efficiency of gaseous methane combustion decreases. The highest exergy efficiency is for complete combustion, followed by case iii) and the lowest for case ii).

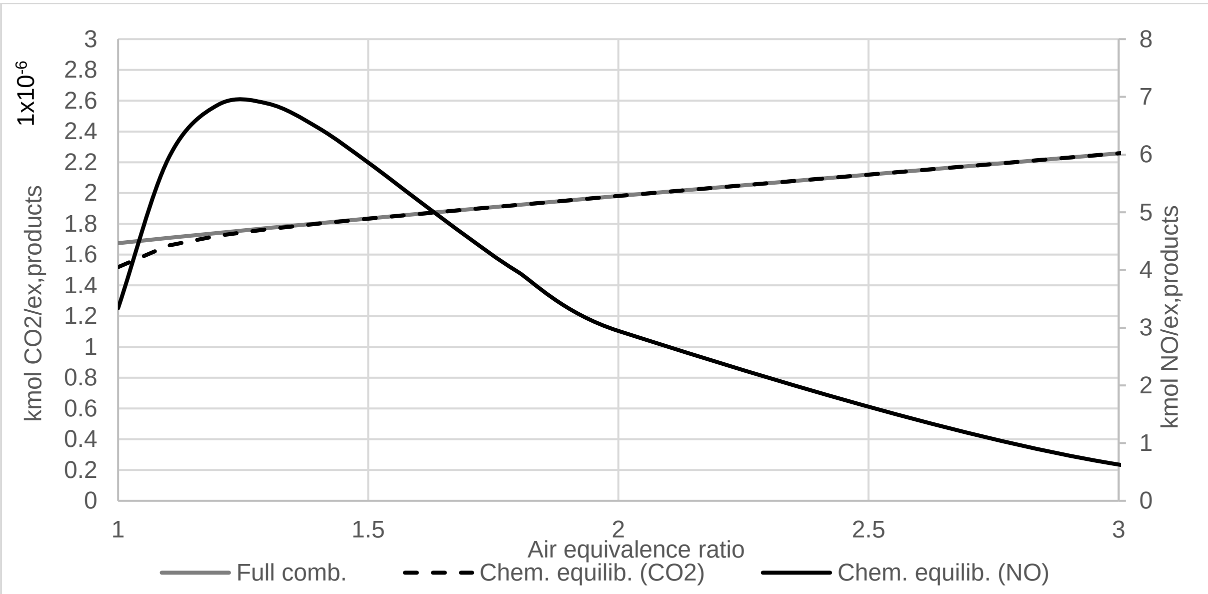

Figure 6. CO_2 and NO emission

The area of navigation and the requirements for reducing air pollution from ships determine the type of fuel used on ships. For the natural gas considered in this work, the dimensionless conversion factor between fuel consumption and CO_2 emissions prescribed by IMO [15] is 2.75 t_{CO2}/t_F (which is the mass of CO_2 in the combustion product for 1 kg of CH_4 for complete combustion). The ratio of CO_2 emissions in the combustion products and the exergy ratio of the combustion products [kmol CO_2/(kJ/kmol$_F$)] as a function of excess air at complete combustion and chemical equilibrium composition in the combustion products is shown in Figure 6. As excess air increases, the ratio of $CO_2/e_{x,products}$ for Case A and Case B increases. The ratio of $CO_2/e_{x,prod.}$ at stoichiometric ratio is larger at complete combustion than at chemical equilibrium composition. This is attributed to the fact that at stoichiometric ratio CO_2 has a greater influence on the exergy of the exhaust gases compare than at higher excess air.

The ratio of NO emission in the combustion products and the exergy molar ratio of the combustion products [kmol NO /(kJ/kmolF)] as a function of excess air are also shown in Figure 6. As for the NO emission, its contribution to the exhaust exergy is highest at an equivalence ratio of about 1.25. In the range of excess air typical for natural gas, the ratio NO/ex,product increases. NO_2 emission and the exergy of the combustion products increases from 6.11×10^{-12} (for the stoichiometric ratio) to a maximum of 1.17×10^{-10} (for 200% excess air).

CONCLUSION

The standard chemical exergy of the fuel or the available energy of the combustion products (produced during combustion) is determined based on the reaction(s) using the content chemical elements for which the standard chemical exergy is known. In this work, the reaction of gaseous methane and air was used. Methane was chosen because its fraction in natural gas is the highest, up to 96%. In this work the physical and the chemical exergy (as components of the total exergy) of the combustion products is compared for complete combustion of the fuel and for chemical equilibrium composition in combustion products. The results show the highest values (temperature and exergy of the combustion products, standard chemical exergy of the fuel and exergy efficiency) for the case of complete combustion, which is a way to calculate the standard chemical exergy of the fuel. The results for the above properties obtained for the chemical equilibrium composition of the combustion products (incomplete combustion) for the stoichiometric ratio are lower. Moreover, a higher deviation is observed for the amount of excess air typical for natural gas. With the increase of excess air, the mentioned differences decrease, with other elements of the combustion products assuming a dominant role in the mentioned values. With the increase of excess air, the exergy of reactants increases, while the exergy of combustion products decreases. The only properties in which an exergy increase was observed by increasing excess air is physical exergy. It increases as excess air is increased from the stoichiometric ratio to 13.6%. However, by further increasing the excess air, it also decreases. The difference in the slope of the exergy of the combustion products and the exergy destruction leads to a decrease in the exergy efficiency of the fuel combustion (expressed by the exergy of the combustion products).

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Principles of Torque Measurement in the PFST Instrumented Sliding Bearings Test Rig

Igor Pavlović, Karlo Bratić, Nenad Vulić, Liane Roldo

The sliding bearings instrumented test rig has recently started its service in the TEMPO Lab of the Faculty of Maritime Studies of the University of Split and is an essential part of the laboratory and the research itself. The main objective of the tests is to validate their energy efficiency with respect to the frictional power losses. In the context of the numerous possibilities for testing bearings, this paper will present a method that has been developed and applied in the test rig to measure the frictional torque originating from the lubricant. The method comprises the explanation of the concept for the application of hydrostatic bearings to eliminate dry friction torque between the bearing housing and its seating in the two main configuration settings: intermediate shaft bearings and aft stern tube bearings, the measurement principles, as well as the input data and output values relevant in these measurements. The results contain the presentation of the torque and power losses values obtained by the actual measurements for the aft stern tube water lubricated polyether PU bearing of 300 mm in diameter with its 2:1 ratio within the range of shaft journal rotational speeds and vertical loading values. The application of hydrostatic bearings in the test rig for hydrodynamic sliding bearings provides a reliable background to determine the actual torque loading of the shaft journal in the test bearing of the rig and consequentially its power loss function due to friction, thus directly influencing the energy efficiency of the tested bearing in the tested configuration.

KEY WORDS

Marine propulsion system, Intermediate shaft and stern tube bearings, Hydrodynamic lubrication, Hydrostatic bearings, Frictional torque and power loss, Validation measurements.

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INTRODUCTION

Marine propulsion system and its individual elements represent interesting research topics involving various aspects (safety, ecology, economy, etc.). Such a system can be designed in different configurations and with different elements, but is usually configured in such a way that the prime mover (usually a diesel engine) is directly coupled with the propeller through a shaft line. Plain bearings are most commonly used to hold the shafts and allow them to rotate. In addition, they have the task of transmitting reaction forces to the ship's structural parts through the lubricant layer in the bearing. With respect to this a distinction is made between radial and axial sliding bearings.

Under normal operating conditions, the shaft journals rest on the lubricant layer, which also separates the shaft journals and the bearing sleeves from direct contact. Hydrodynamic lubrication occurs due to relative velocity between the shaft journal and bearing sleeve, the viscosity of the fluid, and the relative inclination (Vulić, Komar, 2022.). This type of lubrication is also known as full film lubrication and it acts as a mechanism that provides for the automatic formation of a lubricant layer. Under hydrodynamic lubrication, frictional losses are very small. They are generated in the lubricant layer by relative motion of one layer against neighboring one, with insufficient friction in the innermost layer to cause surface deformation. The study of the behavior of sliding bearings is necessary to determine their energy efficiency in terms of frictional power losses. For this reason, the frictional torque emanating from the lubricant must be measured. Measurement of applied torque is essential in all rotating bodies to ensure that the design of the rotating element is adequate to prevent failure under shear stress. Torque measurement is also a necessary part of measuring the power transmitted by rotating shafts. The four methods of measuring torque consist of measuring the strain generated in a rotating body due to an applied torque, an optical method, measuring the reaction force in cradled shaft bearings, and using equipment known as the Prony brake. (Morris, Langari, 2012.).

The results of this study include the presentation of torque and power loss values obtained by actual measurements for the water-lubricated aft stern tube bearing under vertical loading represented only by its dead weight. In the article (Pelic et al., 2022.), water-lubricated stern tube bearings are studied and analyzed with respect to technical and environmental aspects. The main advantages and disadvantages of oil and water lubricated bearings are discussed. The research work (Wodtke and Litwin, 2021.) investigated the thermal effects during the operation of a water-lubricated stern tube bearing. Their goal was to understand the key factors affecting the origin and progression of the thermal effects, including the influence of forced axial flow through the bearing. A three-layer water-lubricated bearing design with five axial grooves in the upper part of the sleeve was used in their analysis. Theoretical studies indicated a relationship between the structure and the direction of water flow in the grooves, while experimental studies showed that the axial water flow had a significant effect on the recorded bearing temperature. In another study, rotatory lip seals were investigated for stern tube seal application (Borras et al., 2021). A dynamic setup was used to mimic stern tube seal operating conditions. Measurements of frictional torque, operating temperature, and lubricant migration through the seal were made at various shaft speeds and pressure differentials.

In this paper, experimental data are obtained using a sliding bearings test rig. It is equipped with tension-compression load cells using the method of strain measurement. The measurement of the force by a single tension-compression test probe installed under one of the supports is sufficient to determine the reactive torque when the hydrostatic bearing lifts the housing of the test module by a small amount. In their study, the authors measured the instantaneous torque in the real engine. It has been suggested that such results can provide guidance for diagnosing mechanical and combustion faults in the cylinder (Palomo Guerrero and Jiménez-Espadafor, 2019, Jiménez Espadafor et al., 2014). In this paper, a measurement method (Chen et al. 2020.) is proposed concerning the torque and the rotational speed of the rotating shaft. The method consists of two resistance strain gauges and a capacitive grating, which is also used for non-contact signal transmission. It was found that the proposed method is proven by simulation and experimental measurements.

The aim of this paper is to present the developed and applied method for measuring the frictional torque originating from the lubricant. The method involves explaining the concept of using hydrostatic bearings to eliminate the dry friction torque between the bearing housing and its seat in the two main configurations: Intermediate shaft bearing and aft stern tube bearing, the measurement principles, as well as the input data and the output values relevant to these measurements.

TEST RIG DESCRIPTION

The test rig enables researchers to validate the actual behavior of sliding bearings in their various arrangement configurations, dimensions, bearing and lubricant materials, as well as their service loading. It is a modular device that can be used to test bearings with different nominal diameters and different relative lengths λ. The module currently installed consists of a water-lubricated polymer radial plain bearing with a nominal diameter of 300 mm and a relative length of λ=2, designed as an aft stern tube bearing. The prime mover, i.e. the drive module, is an electric motor with a frequency controller allowing arbitrary speeds. Neither brake nor propeller are installed on the test rig, so that the total torque load on the system comes only from the friction in the bearings and the hydraulic cylinders applying load to the shaft (Vulić, Komar, 2022.).

The test rig is designed as an assembly consisting of the following modules (Figure 1):

- drive module;
- thrust module;
- shaft;
- radial module;
- test module;
- load module;
- lubrication module;
- cooling module;
- control module.

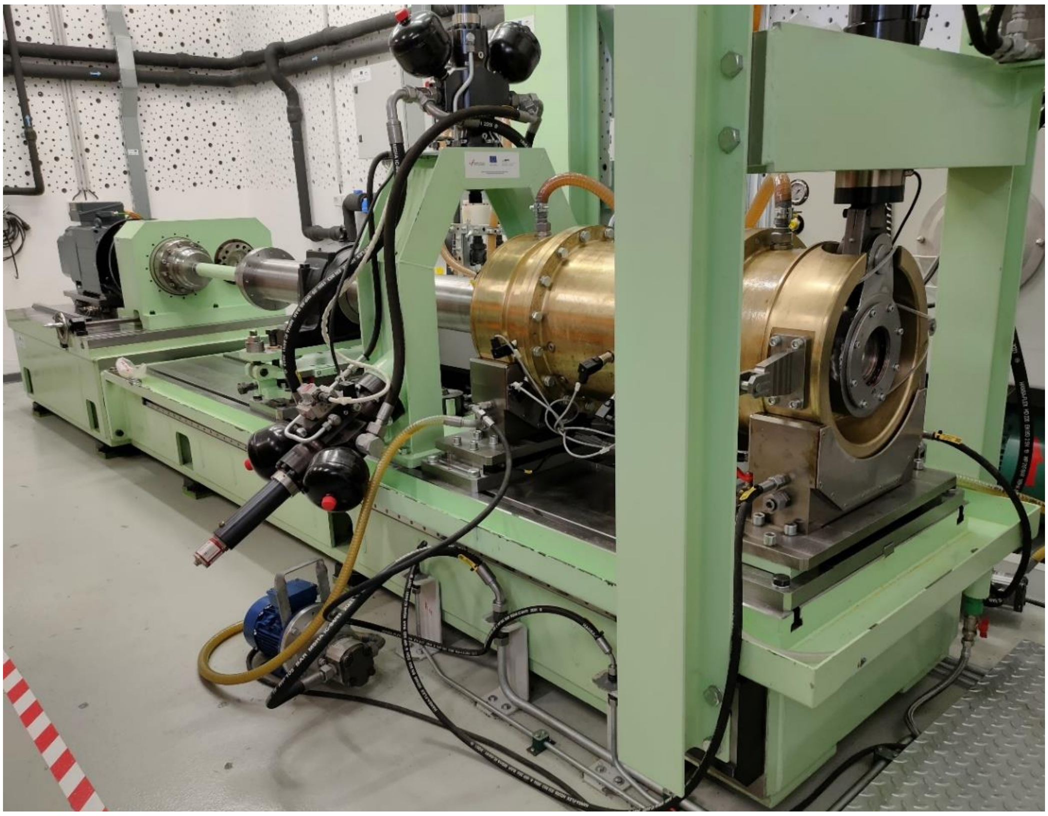

Figure 1. Test rig (Source: photo taken by I.Pavlović)

The main focus of this paper will be on the test and lubrication module. The test module is affected by friction reactive torque of the bearing, which is measured directly, which means that the torque can be accurately determined in relation to the frictional torque of other bearings (Vulić, Komar, 2022.). All measurement data of the test rig are recorded in the test module. In the lubrication module, fresh water circulates to and from the test module via the fresh water circulating pump. The fresh water serves simultaneously as a lubricant and coolant for the bearings in the module.

The test module rests on two supports (L1 and L2) that are part of the hydrostatic lubrication system. The two supports are connected to the hydraulic power unit via high-pressure hoses. The purpose of the hydrostatic lubrication system is to use hydraulic oil to lift the test module off the supports and allow it to "float" on a thin film of oil, eliminating friction between the test module and its supports. The HPU has two fixed electric motors each coupled with two supply pumps and two portable electric motors each coupled with one extraction pump (Figure 2).

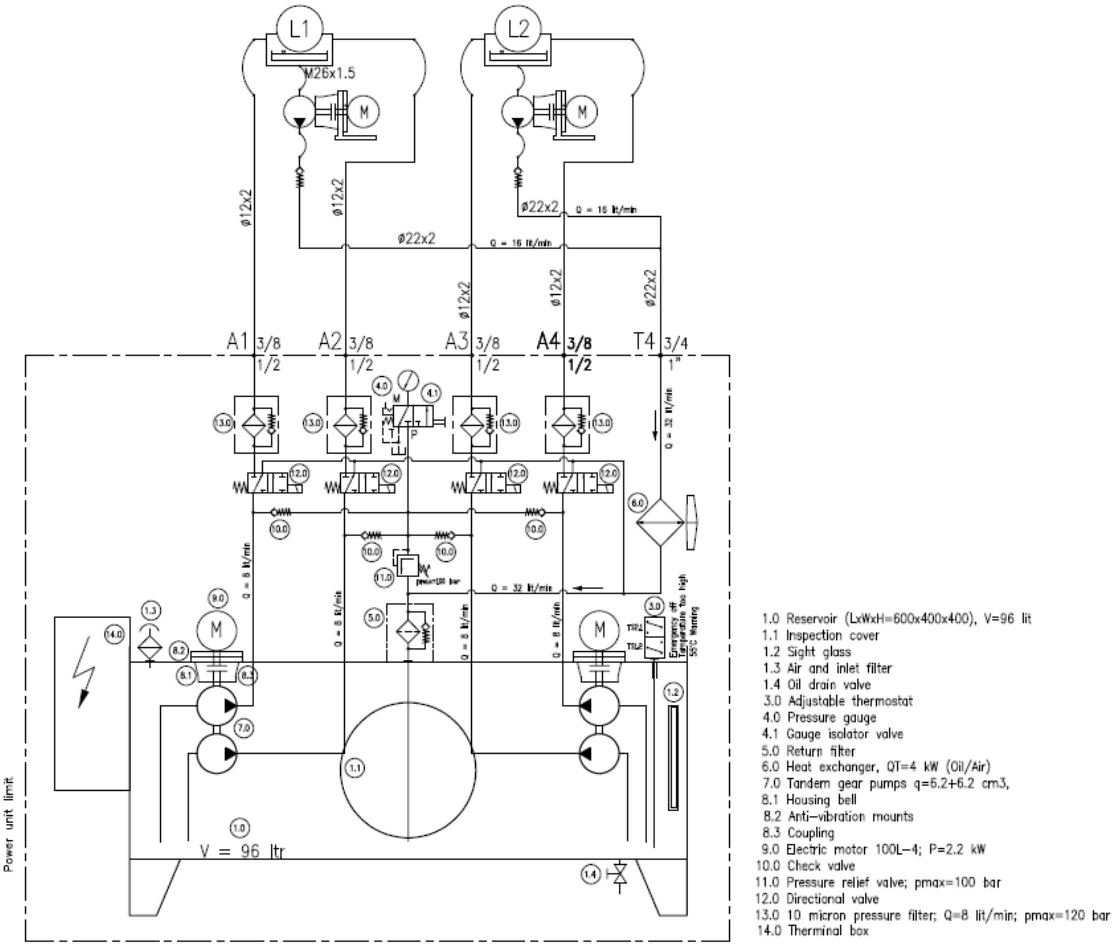

Figure 2. HPU for hydrostatic lubrication (Source: Etra.d.o.o.)

Each hydrostatic lubrication support has two inlet, two outlet, and two overflow ports (Figure 3). High-pressure oil enters the hydrostatic lubrication support through both inlet ports (No.1), lifts the test module resting on the supports through the overflow ports (No.3), and is then pumped out through one of the outlet ports (No.2).

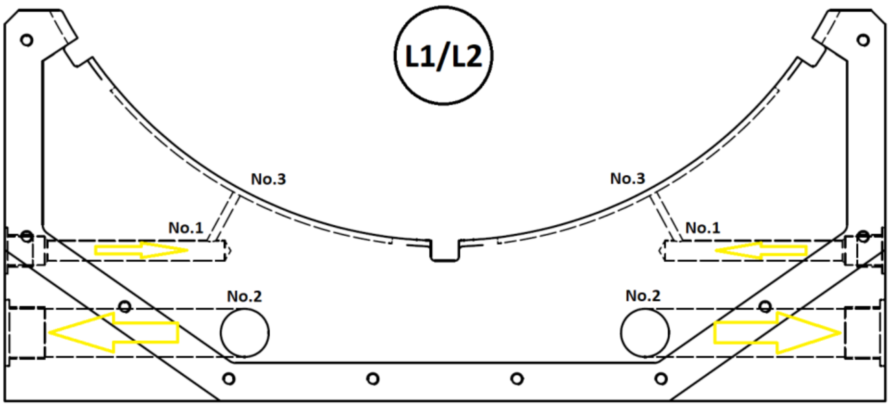

Figure 3. Hydrostatic lubrication system supports (Source: Etra.d.o.o.)

To prevent the entire test module from rotating while "floating" on the oil, it is important that the module is anchored. This was achieved by connecting the module via connecting arm to the tension-compression load cell, which is fixed to the base plate of the test rig to measure both tension and compression forces along a single axis (Figure 4.).

Figure 4. Test module anchored to the tension-compression load cell (Source: photo taken by I.Pavlović)

Measuring the force by means of a single installed tension-compression test probe is sufficient to determine the reactive torque when the hydrostatic bearing lifts the test module housing by a small amount. Tension-compression load cells are essentially transducers that convert force or weight into an electrical signal. They do this by implementing strain gauges attached to the body of the load cell. When under load, the body of the load cell deforms slightly. This is detected by the strain gauges which deform in unison with the body, resulting in a change of voltage for compression and change of electrical resistance for tension (Flintec, 2023). This generates a voltage signal proportional to the initial force or weight and can thus be used to calculate it.

RESULTS AND DISCUSSION

In order to adequately measure the frictional torque originating from the lubricant, a method had to be devised. The method comprises of certain conditions which had to be met. The first condition was to establish lubrication and cooling of the sliding bearings by turning on the circulating water pump to provide a continuous flow of water through the test module. The second condition was to establish the initial measurement condition by turning on the hydrostatic lubrication system to raise the test module so that it "floats" on a thin film of hydraulic oil while the test rig is stationary (not rotating). The third condition was to confirm that all sensor values were "nullified", i.e. set to 0, which is the starting point of the measurement. If all conditions are met, the test rig can be started at the preset point rpm.

Two different shaft speeds were selected for this paper. The first selection was 70 rpm, to simulate slow-speed, long-stroke, crosshead marine diesel engines driving the propeller shaft directly, while the second selection was 200 rpm, to simulate medium-speed marine diesel engines driving the propeller shaft through a gearbox.

In the first condition, the test rig was started at a preset clockwise speed of 70 rpm and allowed to run at that speed for approximately 10 minutes. The highest recorded friction torque was 220,4 Nm, which then slowly settled to a stable average value of 17,1 Nm (Figure 5), while the friction dissipation varied between 110 W and 150 W. When the test rig started to rotate, the lubrication between the contact surfaces was insufficient, i.e. the entire load was transmitted by solid to solid contact. This type of lubrication is referred to as boundary lubrication. As the test rig increased in speed, the lubricant film began to separate the surfaces. In such case, the total friction is a combination of the solid to solid contact friction and the friction of the lubricant layers, which is referred to as mixed lubrication. Once the lubricant film has fully formed, the only friction developed is by viscous shear of the lubricant layers, which is referred to as full film lubrication (Stachowiak, G., Batchelor, A. W., 2014).

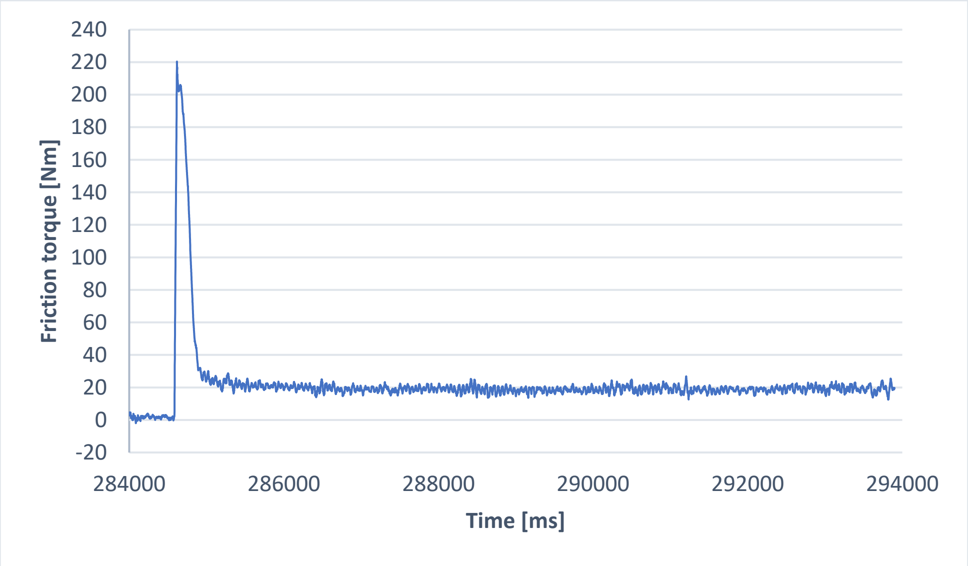

Figure 5. Recorded measurement at 70 rpm clockwise direction (Source: I Pavlović)

For the second condition, the direction of rotation was changed from clockwise to counterclockwise with same shaft speed of 70 rpm, and the results were recorded. When tested counterclockwise at 70 rpm, the peak friction torque of -188,3 Nm was measured, which then settled to a stable average value of -14,1 Nm (Figure 6), while the friction dissipation varied between -90 W and -110 W. The tension-compression cell measures the clockwise direction as compression (negative value) and the counterclockwise direction as tension (positive value).

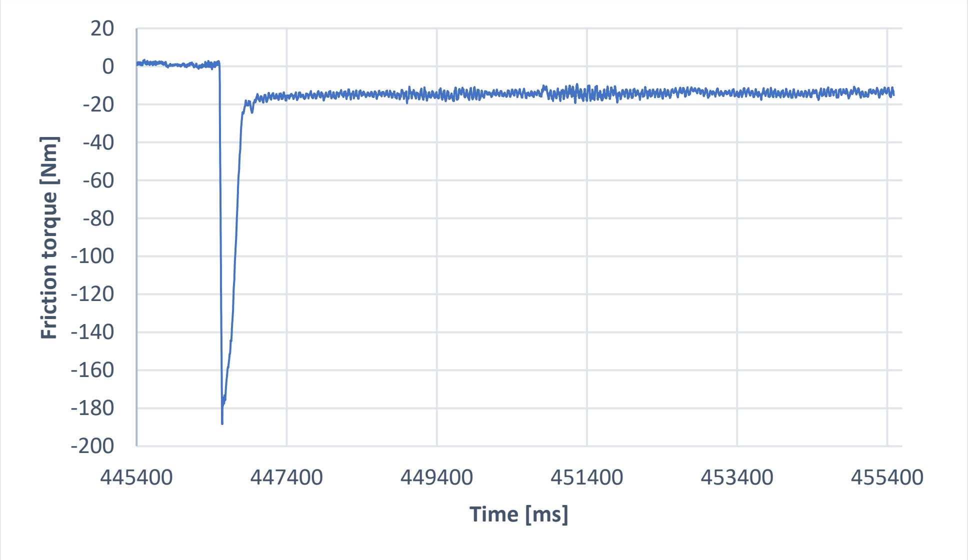

Figure 6. Recorded measurement at 70 rpm counterclockwise direction (Source: I Pavlović)

For the third condition, the direction of rotation and shaft speed was changed to clockwise at 200 rpm, and the results were recorded. The friction torque peak was 222,1 Nm until it settled to a stable average value of 15,2 Nm (Figure 7), while the friction dissipation varied between 300 W and 350 W.

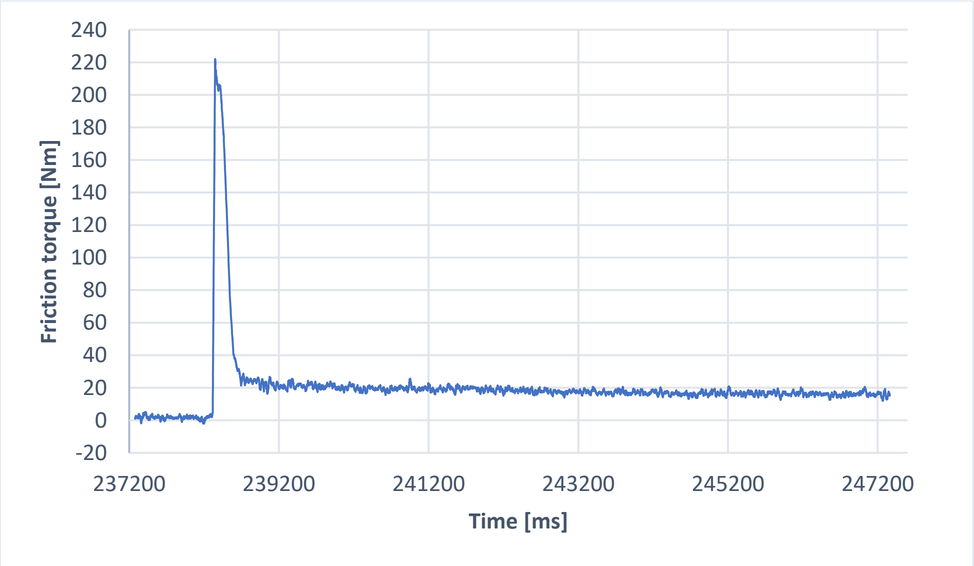

Figure 7. Recorded measurement at 200 rpm clockwise direction (Source: I Pavlović)

For the fourth condition, the direction of rotation was changed to counterclockwise at 200 rpm, and the results were recorded. Friction torque peak was -185,4 Nm until it settled to a stable average value of -12,7 Nm (Figure 8), while the friction dissipation varied between -270 W and -320 W.

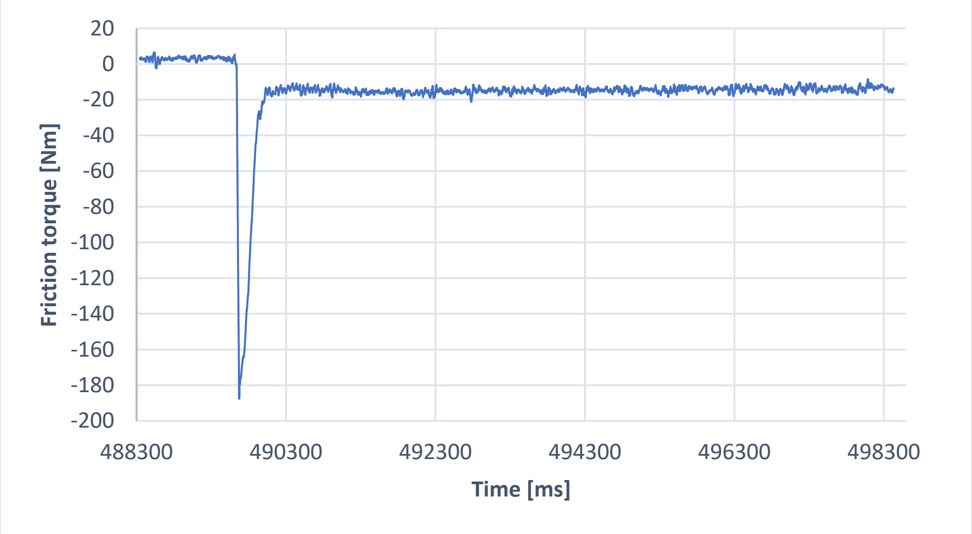

Figure 8. Recorded measurement at 200 rpm counterclockwise direction (Source: I Pavlović)

All tests were performed several times for each condition, and in all cases the results were repeated with equal values. The most important factor that appeared in all the tests, validating the applied method, was that as soon as the test rig received the stop command, as it was slowing down, all the curves returned to the starting position, i.e. 0 Nm (Figure 9, Figure 10).

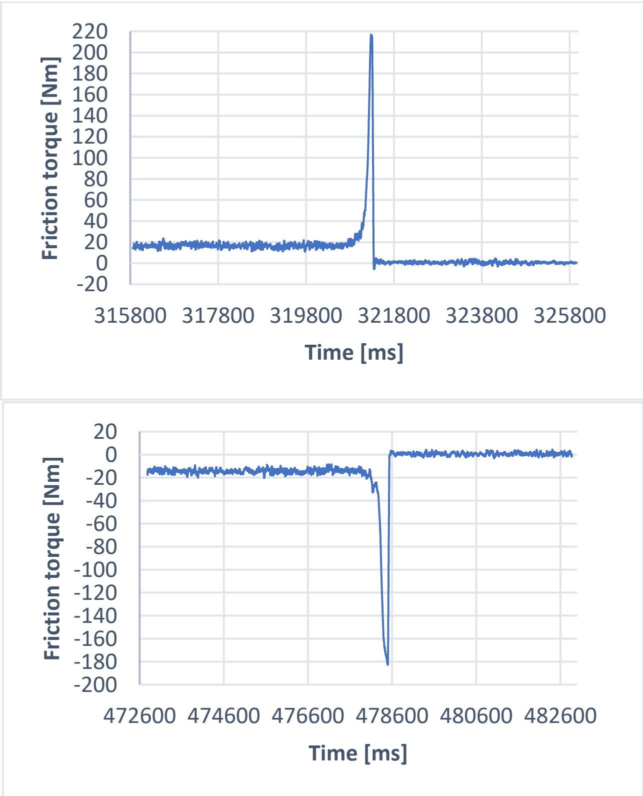

Figure 9. Recorded measurement of test rig stopping from 70 rpm clockwise and counterclockwise direction (Source: I. Pavlović)

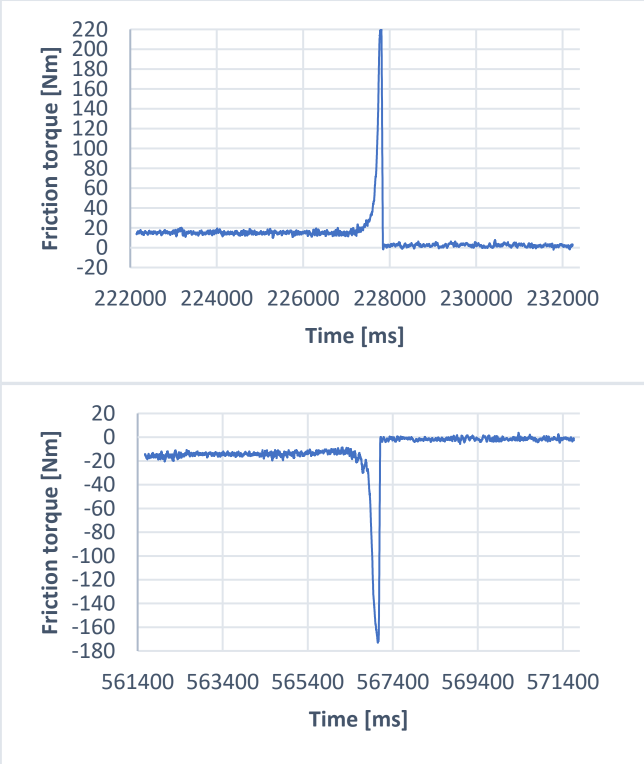

Figure 10. Recorded measurement of test rig stopping from 200 rpm clockwise and counterclockwise direction (Source: I. Pavlović)

CONCLUSION

The main aim of this research was to present the developed and applied method for measuring the frictional torque originating from the lubricant. The method consisted in finding the proper measurement conditions that would provide reliable results. Initially, the method provided with the test rig installation was applied without thinking that it could be wrong. However, when the same tests were repeated several times, each test gave different results, and the values never returned to the initial condition once the test rig was stopped. Upon investigation, it was suspected that the method used to determine the test rig start-up sequence might be incorrect. After the new method described in this paper was developed and thoroughly tested, it was clear that the suspicion was well founded. With the new method, the same tests were performed several times, and in all cases the results were repeated with the same values, and most importantly, the values returned to the initial state as soon as the test rig was stopped. All tests were performed without subjecting the stern tube bearing to any additional vertical load, except for its own dead weight.

Based on the experimental data presented, it can be concluded that the application of hydrostatic bearings in the instrumented test rig for hydrodynamic sliding bearings provides a valid basis for determining the actual torque load of the shaft journal in the test rig bearing and its power losses due to friction, which directly affects the energy efficiency of the tested bearing. In this way, the researcher can predict the torque load and power losses that can be expected in the bearing of an actual marine propulsion system.

With a reliable method, future research can be conducted with different test rig configurations which include: different shaft speeds, different lubricant types, different bearing materials and sizes, different temperatures, and different vertical loads. Such research can provide valuable information that can lead to cost savings and the use of environmentally friendly materials and lubricants.

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Using Drones to Monitor Illegal Dumping Sites: A Contribution to Marine Engineers Education

Liane Roldo, Dario Medić

Illegal dumping continues to be a major problem worldwide, as it is well known that garbage, waste and recyclable materials lead to soil and water pollution, endangering flora, fauna and human health. Much of the trash and waste ends up in the seas and oceans, creating a vicious cycle that continues to worsen. Ultimately, it is a matter of educating society and changing its behavior, which may take several generations. The aim of this article is to communicate the practical experience shared with fifth year students of the Faculty of Marine Engineering in Split on the use of drones, monitoring of illegal waste sites, selection of recyclable finds and characterization of materials. To carry out the study, action research, case studies, and unstructured interviews were used as qualitative research methods in conjunction with on-site and photography, as well as drone photography from 50 to 10 m altitudes. The results showed that the students were satisfied with the experience, as they could see the quality of the image captured by the drone in action, see an illegal dumping area with their own eyes, became aware of a real unacceptable situation, and discuss possible solutions to recycling polymers, metals, electronic devices (WEEE waste), ceramics, glass, textiles and wood. The use of drone on surveilling illegal dumps, as well as identifying the type of materials is proven to be simple, reliable and fast.

KEY WORDS
Illegal dumping, Drone monitoring, Recycling of materials, Education

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INTRODUCTION

The impact of economic development and increasing human population on planet Earth's ecosystems is undeniably large and, in many ways, environmentally destructive. However, people, communities, and entire societies can contribute constructively in many ways to mitigate the harmful effects. In general, the good will of every citizen to properly separate household waste on a daily basis is already a big step. However, being able to pick up trash on the beach or remove trash around the building where one lives cannot hurt either. On the other hand, public policies to protect the environment and natural resources seem to be dissolving into bureaucracy, losing much of their effectiveness. That is, it seems easy, but it is still difficult for the government to coordinate, monitor, and control compliance with environmental laws and policies. Apart from environmental groups or associations and committed citizens, the general population has difficulty understanding and exercising its role in the community in protecting the earth and its resources.

The Turnovac road near the licensed Karepovac landfill in Split, Croatia, was selected as the site for the drone's use in mapping illegal waste dumping. This area was not chosen at random. Although nearby recycling centers such as Karepovac (since 2011) and Orišac in the city of Split, as well as recycling centers in the cities of Kaštela and Solin, became operational in 2021 and 2022 (some of which offer a free service), the Turnovac area, as local newspapers have repeatedly reported, is an unfortunate and inconspicuous location for illegal waste dumping. (Giovanelli, 2021; Ilić, 2022).

Construction debris, cardboard boxes, PET bottles, frames or furniture made of wood or chipboard, wooden cable reels, low carbon steel frames, vehicle parts made of PVC or PP, ABS appliance parts, tires made of vulcanized rubber, PVC pipes, waste from electrical and electronic equipment (WEEE) are examples of solid waste found along Turnovac street. These are the waste types considered for reuse, recovery, repurpose and recycling in this study. They comply with EU directives and are as follows: packaging waste (polymers and metals) and recyclable household waste such as electrical and electronic equipment, furniture, vehicle parts and batteries (Black Sea-CBC, 2020) and glass, paper and textiles (European Environmental Bureau, 2020).

To discuss the characteristics and properties of all industrial materials (metals, ceramics, polymers, and composites) and even natural materials in one article would be an extensive task. Therefore, in order to get an idea of what causes indiscriminate disposal and poor waste management, some data on the global pollution problem caused by polymeric materials are relevant. According to Schmidt et al. (2017), of the 10 river basins that discharge the largest amounts of plastic pollution into the oceans, 8 are in Asia, and a 50% reduction in plastic pollution in the top 10 rivers would reduce total ocean pollution from rivers by 45%. Microplastics are plastic debris, fragments, particles, or fibers ranging in size from 1 μm to 5 mm. The estimated extent of global plastic pollution is about 75% macroplastic (> 200 mm), 11% mesoplastic (4.75 - 200 mm) and 11 to 3% microplastic. It is estimated that the accumulation of plastics in the natural environment will be between 155 and 265 million tons by 2060, and 13.2% of this weight could be microplastics (Eriksen et al., 2014; Sobhani et al., 2020).

According to the European Environmental Bureau - EEB (2020), waste separation is a prerequisite for high-quality recycling and reuse. It also prevents hazardous substances from polluting waterways, the environment and inhabited areas. The basis of EU waste management is the five-level waste hierarchy (Figure 1), which establishes a hierarchy for the management and disposal of waste. It requires that waste be managed in specific ways, such as without endangering human health or harming the environment; without harming water, air, soil, plants, or animals; without disturbing or causing a nuisance through noise or odor; and without adversely affecting the landscape or places of special interest. It explains when waste ceases to be waste and becomes a secondary raw material, and how to distinguish between waste and by-products. The directive also speaks of the polluter pays principle and extended producer responsibility (EU Waste Framework Directive, 2008).

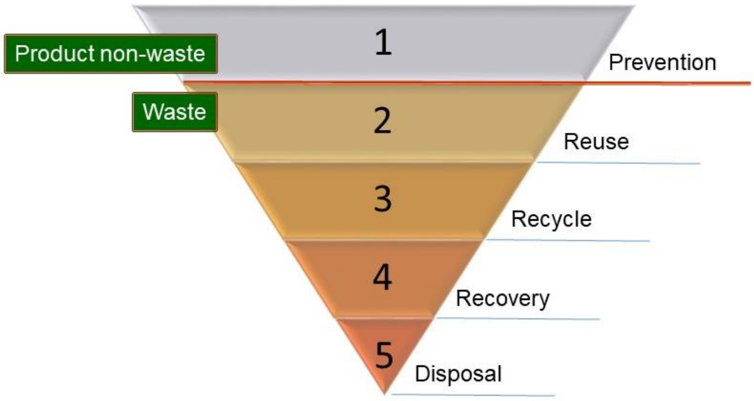

Figure 1: EU five-level waste hierarchy. Modified from EEB (2020).

Drones are also used in a variety of civilian applications, including search and rescue, surveillance, traffic monitoring, weather observation, agriculture, delivery services, etc. To fly, drones require rotors, propellers, a frame, and a power source such as a battery or fuel. The airframe of a drone is usually made of lightweight composite materials to improve maneuverability and reduce weight. To assist in meeting waste management regulations, the use of drones (unmanned aerial vehicle - *UAV*), a robot or a type of aircraft without a pilot controlled by a person on the ground can be used (Lutkevich, 2021). In this case, the drone could be used to monitor illegal landfills and map an area already at risk. Cities in the United Kingdom, Ireland, and Japan regularly use UAV or admit to using it in trials to patrol sites that are frequently used as illegal dumping sites. In addition to the large number of complaints, the constant cleaning of the sites proved to be very costly (Crumley, 2022; Staines, 2022).

This study, using qualitative research methods, was conducted as a way to raise awareness and as a complementary component in education. It was carried out by the authors and two students of the fifth year of Marine Engineering as part of their assignments in the subject Project at the Faculty of Maritime Studies of the University of Split during the summer semester 2022. The goal was to use high-tech equipment, in this case a drone, to identify the problem of illegal waste dumping in the Turnovac area and the nature of the materials found on site.

METHODOLOGIAL PROCEDURES

The methods of qualitative case study, action research, and unstructured interviews were used to conduct the study, which consists of five coordinated and interconnected steps (Figure 2). The steps consist of:

- Identification of the selected area - Turnovac Street in Split, Croatia - using Google Earth;
- Mapping of the selected area using a drone (Phantom 4 RTK model by DJI) at an altitude of 50 to 10 meters. The drone is equipped with a 20-megapixel CMOS sensor, can reach a ground scanning distance of 2.74 cm at 100 m flight altitude, and has a remote control with a built-in screen;
- Investigating the site and photographically capturing the illegal dumpsite using a cell phone and a Sony DSC-RX100 camera. Compact camera with a 20MP 1" CMOS sensor. It has a lens of

28-100mm (equivalent) with an aperture range of F1.8-4.9. Photos and objects were measured using the free and open-source vector graphics editor Inkscape;

- Identification of waste, garbage and materials;
- Report of the experience of the two students who participated in the project.

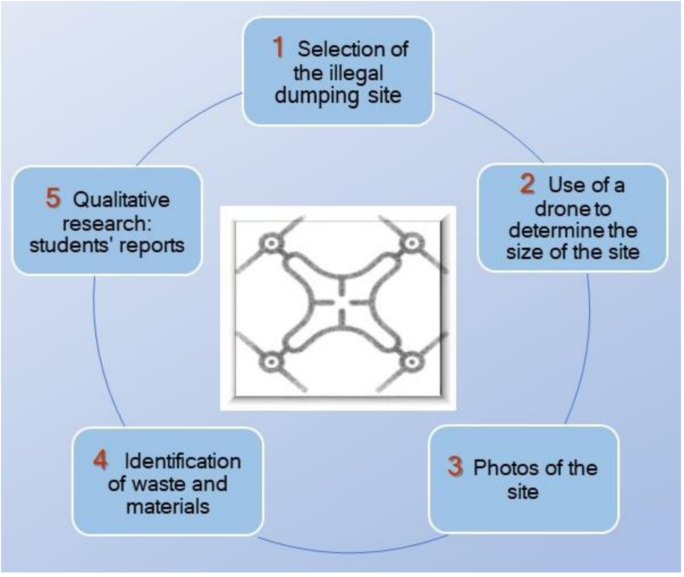

Figure 2. Flowchart of the experimental procedure showing the 5 phases of the study.

RESULTS AND DISCUSSION

Turnovac area: localization and site survey by image

As mentioned above, Turnovac road and the surrounding area were chosen as the object of investigation for the drone's use, as this is an illegal landfill site that has been referred to several times in the local news. Figure 3 shows the location of Turnovac street in the city of Split, Croatia, provided by Google Earth.

Figure 3. Localization of the street Turnovac (yellow line) near the landfill Karepovac of the municipality Split provided by Google Earth.

Figure 4 shows the image taken by the drone at an altitude of about 47 m (at this distance above the ground, it appears to be a pretty field). As can be noted, there are no utility or street lighting poles along this part of Turnovac road. Therefore, in areas where light poles are not available for installation of surveillance cameras, the use of a drone to monitor illegal waste disposal is an option that should really be considered.

Figure 4. Photo taken by the drone at about 47 m altitude (photo taken in June 2022).

Figure 5a shows a photo taken by the drone at 19 m altitude, while in Figure 5b the photo was taken at 10 m above the ground. Both photos taken by the drone show construction debris, pallets and wooden boards, framed glass plates, mattresses, and plastic bags.

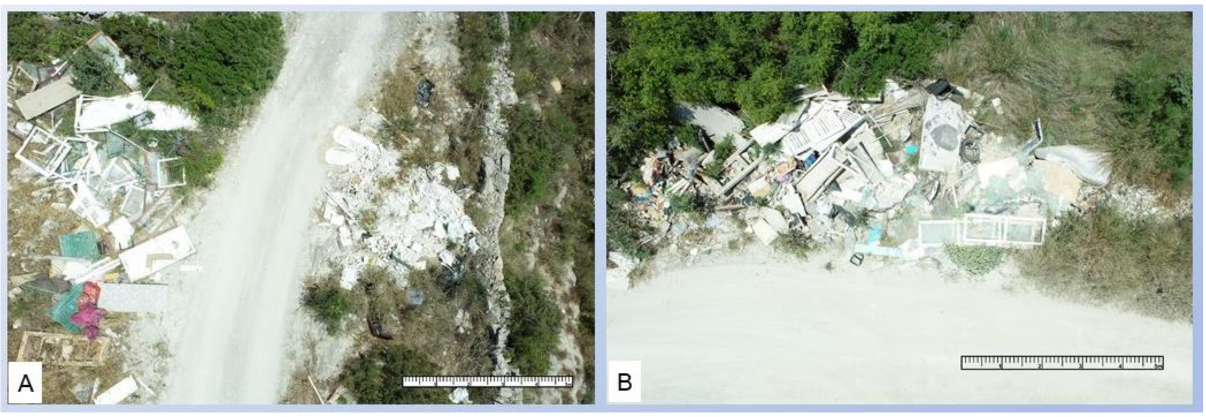

Figure 5: (a) photo taken by drone at 19 m altitude, and (b) example of image provided by drone at 10 m. The photos were taken in June 2022.

The photos taken by the UAV have a high resolution. Therefore, when viewing Figures 5a and 5b in full-screen mode (e.g., 1920 x 1200 pixels) or, more accurately, considering the actual size of the image (5472 x 3648 pixels), the waste objects were easily identified, also the zoom tool helps to identify smaller objects, their texture, the presence of holes or layers. By opening the image with a particular software (e.g. Inkscape) or application, the dimensions and thus the area of the dumped waste can be calculated. The area visible in Figure 5b has approximately 12x5 m or 60 m^2. The height of the pile of debris seen on the right side of Turnovac Street in Figure 5a is estimated at 80 to 100 cm.

To illustrate some of the uses of the photographs taken by the drone and the quality of the image, Table 1 shows the size of the selected objects (residuals) measured in centimeters and in pixels in Figures 5b.

Selected objects	At 10 m altitude	
	Item dimension (cm)	Item dimension (pixels)
Tire	57,5	220
Wooden door frames	70x210	254x764
Mattress	90x190	345x690
Couch	68x200	245x740
PVC chair	46x76	175x290

Table 1. Examples of objects found at the site and their dimensions.

As for the photos taken on site, furniture, sofas and mattresses (made of various natural and synthetic (polymeric) textiles such as cotton, leather, hemp, polyester, polypropylene, viscose, and polyamide), building materials, wood panels, shipboards, WEEE waste, debris and plastic boxes are examples of illegally disposed products shown in Figure 6 a, b and c.

Figure 6. Among the different dumped products, (a) furniture and sofas, (b) PET containers, PVC pipes, tires are very much present along the road, and (c) glass wood or asbestos blocks. Photos taken in Feb. 2023.

An example that looks unremarkable but is quite telling: at least two dozen as new nickel-plated L-shaped cabinet brackets were found still attached to kitchen cabinets that had been tossed to the side of the rode. Each bracket costs between 0.38 - 0.52 cents of Euro (price from January 2023). Figure 6b shows product debris dumped on the side of the road, such as PVC or PET containers, dismantled furniture, appliance parts, tires, and PVC pipes. Figure 6c shows leftover building materials, including glass wool and possibly asbestos. These building materials have been shown to be hazardous to living things and the environment.

Environmental problems encountered

To get a more accurate picture of the delicate balance (or already unbalanced situation) in the Turnovac area, it is important to point out the presence of waste disposed of on the road side, where there are vine and olive trees nearby (Figure 7a). Another important and aggravating example of an environmental problem is caused by PE plastic bags along the way (Figure 7b).

Figure 7. (a) illegal waste dumping on Turnovac road near an olive plantation (photo of February 2023), and (b) PE plastic bags hanging from fences and vegetation on Turnovac Road (photo taken in April 2022).

Identifying the materials from which products are made is an important step in determining whether a discarded product can be reused, repurposed, or should be recycled. To illustrate Phase 4 of this study, plastic bags made of polyethylene (PE) were selected, a thermoplastic polymer considered the most inert of the polyolefins with repeating structure $(-CH_2-CH_2)_n$ (Chamas et al., 2020; Harper, 2002; Lajeunesse, 2004). PE is a very versatile material. Depending on the application and product properties, they are made from different types of PE, i.e., with different arrangements of their macromolecules, such as linear, branched, or unbranched chains. Thus, plastic bags are generally made from one of three basic types: HDPE, LDPE or LLDPE. They nominally have the same chemical composition, but have very different degrees of crystallinity (Chamas et al., 2020). The thick glossy bags are made of LLDPE, grocery bags are made of HDPE, while dry cleaning bags are made of LDPE. The explanation is that branching in polymers affects various physical and mechanical properties such as crystallinity and tensile strength. The more branched a molecule is, the lower its tensile strength and crystallinity. This is why laundry bags are so weak and fragile. They are made of highly branched LDPE (Lajeunesse, 2004). Despite the lack of scientific evidence, estimates of the degradation time of plastic bags can be placed in one of two ranges depending on the degree of crystallization, oxidation of the polymer chain, the environment in which they are located, temperature, presence of sunlight, pH, and other factors: 10 to 20 years or 500 to 1,000 years (Chamas et al., 2020).

Polyethylene (PE) and also other polymers, which have a high recyclability, have not aroused any economic interest so far, leading to innumerable environmental problems (Figure 7b). Therefore, the degradation rate of polymers in marine and terrestrial environment became an important data. So, the first important information is that PE degradation rate strongly depends on the amorphous fraction of the polymer. Compared to Low Density Polyethylene (LDPE) or Linear Low Density Polyethylene (LLDPE), for example, a slightly branched and more crystalline polyethylene such as High Density Polyethylene (HDPE) degrades much more slowly. Due to their low density and open balloon shape, LDPE or LLDPE bags, especially on windy days, cover the vegetation around the Karepovac landfill and Turnovac road. However, the real problem is the ingestion of plastic waste, particles or microplastics by marine and terrestrial animals, as well as the contamination of soil, watercourses or groundwater by toxic sources (Galgani et al., 2015; Kühn et al., 2015).

Potential difficulties for using drones to monitor illegal waste sites at locations such as Turnovac road near the Karepovac landfill include birds and extremely windy days. Figure 8 shows a flock of seagulls feeding on the remains each time a truck unloads its contents at the landfill.

Figure 8. Karepovac landfill, the area on the site showing the presence of a flock of birds after unloading the garbage truck (photos taken in February 2023).

To curb the indiscriminate use of plastic bags, the EU Directive (1994) calls on its members to take measures to reduce the consumption of lightweight plastic carrier bags, which includes various types of PE bags. The directive states: "...the annual consumption level does not exceed 40 lightweight plastic carrier bags per person by 31 December 2025, or equivalent targets set in weight. Very lightweight plastic carrier bags may be excluded from national consumption objectives". Australians are taking the plastic bag problem much more seriously. In early February 2023, Hornsby Shire Council in New South Wales introduced a new soft plastic, hard plastic and Styrofoam recycling policy that limits residents to one standard soft plastic shopping bag (40 cm x 40 cm bag) per week, along with proof that they reside in the Local Government Area (Korycki, 2023).

Qualitative research: unstructured interviews

A worrisome global problem that was also mentioned by the students participating in the study was plastic bags (Figure 7b). In the words of student A:

"...the illegal dumping is localized and it could be remediated with ordinary methods of specialized companies. Problem comes with plastic bags, there is no bush or tree totally clean from plastic bags or other light weight plastics. These plastics are all over Turnovac road and covers very big area around. Since, Karepovac is the only licensed landfill of Split, it looks like a huge hill of garbage. The possible problem of plastic spreading to the surrounding area is probably from the countless seagulls that scatter it into the surrounding area. Probably by applying appropriate technical solutions, such as airport methods to repel birds, the number of plastic products in the environment can be reduced. There are also several small streams in the area, which are gray in colour and have an extremely bad smell, and unfortunately probably end up in the sea by underground paths. Monitoring the roads around Karepovac could reduce the number of illegal dumps."

The qualitative data collected from the students participating in the study show their concern about the amount of waste products and materials illegally dumped along Turnovac street, as well as the quality of water and soil. According to Student A, it was obvious that there was an environmental problem. In his words:

"The usage of drone surveillance in detecting waste significantly increased perception of the impact on the natural habitat as well as locating the previous one. There are many possibilities for action, among other things, all visible waste should first be extracted and let the environment to regenerate naturally, besides the problem of illegal dumping, there is also the proximity of a large landfill that is not adequately protected."

Student B explained that the drone was very useful to map the area around Turnovac street. He stated:

"Due to the difficult access at the terrain around Turnovac area, the use of a drone greatly helped in assessing the situation of the environment. In order to further determine the state and level of toxins for further research, it is necessary to take samples of the soil and water to carry out research to restore it to its original state, as well as ensuring a satisfactory level of life for plants, animals and people in the surrounding area."

CONCLUSIONS

The study conducted with the students of the fifth year of the Marine Engineering course at the Faculty of Maritime Studies in Split was quite interesting and useful from the point of view of education and information. On this occasion, the students had the opportunity to get acquainted with UAV technology, characteristics and properties of materials, and to learn about the problem of illegal dumping and jointly search for solutions.

Drone monitoring and mapping of illegal dumping sites on Turnovac road, as well as product identification, proved to be simple, effective, and fast. Another positive factor for using the technology is that there are no light poles in the area for installing surveillance cameras. Clearly, the municipality that uses drones would have to hire UAV services company to patrol or to acquire few units to monitor vulnerable areas remotely.

From what has been found in Turnovac area, the opportunity to reuse, repurpose and recycle products and materials is immense. There are literally heaps of money for discarded goods on the side of the road, so to speak! Among the products found in the Turnovac region, those made from polymers and wood and its derivatives stand out. In addition, there are also hazardous materials such as glass wool (possibly asbestos) and WEEE waste that pollute soil and water.

Social responsibility practices are becoming increasingly important for government organizations that need to conserve natural resources and promote social well-being. From this point of view, recycling is indispensable because it avoids the degradation of the environment by reducing the extraction of resources and reducing the amount of waste released into the environment. Solutions such as the recently established recycling centers in Split, Solin and Kaštela are already available (all within a radius of 600 to 5500 m) from the illegal dumpung site on Turnovac road. Therefore, without glossing over the issue, but addressing the problem directly, it is obvious that the core of the population's habits must be changed, i.e., the act of throwing away and buying new must change into a culture of rethinking, reusing, reusing and recycling products and materials in the direction of a circular economy and ecocentrism. One can envision a more constructive, wise and conscious economy and cooperate to effectively protect the environment, natural resources and wildlife and improve the quality of life!

Future studies should evaluate the integrity of the water and soil in the Turnovac area. In addition, more focused quantitative research could include the use of UAVs and on-site photography to calculate the volume of illegal dumping.

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Energy Efficiency Analysis of Variable Frequency Driven Centrifugal Pump in Merchant Vessel Cooling System

Goran Rilje, Nikola Račić, Đorđe Dobrota, Marko Katalinić

The seawater cooling system of diesel-powered merchant vessel is traditionally designed with centrifugal pumps driven by constant-speed electric motors. This arrangement provides constant pressure and flow in the system, regardless of sea water temperature and engine operating conditions. Whenever the vessel is underway in temperate to colder climates, during slow steaming, manoeuvring operations, or port and anchor stay, this flow exceeds demand, so the temperature in the fresh water system is maintained by a 3-way valve bypassing the central cooler. From the thermodynamic point of view, required flow reduction could be achieved on the sea water side instead, by reducing the pump speed. Considering that the shaft power of a centrifugal pump generally changes in a cubic relationship to its speed (a relatively small reduction in pump speed results in a significant reduction in the power required to operate the pump) and considering that there may be as many as three cooling sea water pumps per vessel running 24/7, it is clear that there is potential for energy savings. Speed reduction can be achieved by a variable frequency drive, which changes the speed of the electric motor driving the pump by changing its frequency. Previous works on this subject have assumed that the efficiency of the pump is either constant when the speed of the electric motor is reduced or have used somewhat arbitrary expressions to calculate it. While the assumption of constant efficiency is generally true when affinity laws are considered, it cannot be taken as fact without considering the pump as part of the system. The purpose of this paper is to analyse case study of ship's cooling seawater system and to determine whether the efficiency of the pump changes when its speed is reduced, and if so, to quantify that change. Analysis results will be obtained using Matlab software simulation.

KEY WORDS

Cooling sea water system, Centrifugal pump, Variable frequency drive, Energy efficiency

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INTRODUCTION

Over the past decade, Marine Environment Protection Committee (MEPC), as an internal branch of International Maritime Organisation (IMO) in charge of environmental issues, has brought various legislation and created mechanisms (EEDI & SEEMP in 2011, EEXI & CII in 2021) to reduce CO_2 emissions from merchant vessels, as part of the effort to decarbonize maritime industry. Despite of this, CO_2 emissions are gradually going up. In 2012, there were 962 million tonnes of CO_2 emissions from all shipping (international, domestic, and fishing), while in 2018 this amount increased by 9.3% to 1,056 million tonnes of CO_2 emissions. The share of shipping emissions in global anthropogenic emissions increased from 2.76% in 2012 to 2.89% in 2018. (Fourth IMO GHG study, 2020)t_t

By 2050., IMO's GHG strategy aims for a 50 perce$_{nt}$ reduction in total annual GHG emissions and a 70 percent reduction in CO_2 emissions per transport work compared to 2008, while continuing efforts towards phasing them out - as a point on a pathway of CO_2 emissions in line with the Paris Agreement temperature goal.

Though SOx, NOx and PM emissions are problems which certainly deserve equal concern, global attention has – prompted by global warming issue - focused on greenhouse gases, especially CO_2. To achieve IMO’s ambitious goals the effort from all industry segments (shipping companies, class societies, flag states, machinery manufacturers and scholars) will be required over the next decades. Since shipping companies, as actual vessel operators, might going to have the key role in this effort, it is a fortunate coincidence that CO_2 reduction from their angle means not only adherence to regulatory framework but also reduction in fuel costs and returns on CO_2-reduction investments, be it minor retrofits, such as the one which will be further analysed in this paper, or purchase of new vessels altogether.

A typical fresh water cooling system for merchant ships (in shipping parlance known as LT system as short for “low temperature fresh water system”) cools the main engine, auxiliary engines and all auxiliary machinery in the engine room. This system displaced direct seawater cooling, which had been used on merchant ships, but abandoned for several reasons: first and foremost being the corrosive properties of seawater. Normally, the LT temperature is maintained at 36˚C in LT system and that is being done by means of 3-way valve, which either drives water through the cooler, or bypasses the cooler, depending on the heat demand. It is worth mentioning that 36˚C has been chosen because IMO defines tropical conditions as the ones with the sea water temperature of 32°C, and 36°C for the LT system has been considered technically attainable under those conditions. Hence all the machinery has been designed to operate with 36˚C cooling water.

On the other side of the heat exchanger there is seawater. Both seawater and LT fresh water pumps are usually centrifugal pumps, for the reason of their high capacity, reliability and relatively low cost. Afore mentioned 3-way valve control in certain situations (low seawater temperature, low ME revolutions or port/anchor conditions) may signify waste of energy, as the cooling capacity required by the machinery could also be achieved by lowering the speed of the seawater pump and thus the flow of seawater through the heat exchanger.

Since according to the affinity laws, the energy required to drive the pump is related to the pump speed with exponent 3, that means that reducing pump speed reduces the pumping energy and ultimately, saves fuel. For illustration purposes, the mentioned relationship would mean that a 20% reduction in speed represents a nearly 50% reduction in power.

Speed reduction can be achieved by VFD (Variable Frequency Drive) which, in essence, takes over the role of the 3-way valve. In that case, 3-way valve is fully open (full flow through the cooler) and the LT system temperature is maintained by controlling the speed of the seawater pump. Only when the cooling demand of the machinery is low enough (at particular operating conditions) or sea water temperature is low enough, and provided that the seawater pump is already running at its minimum speed, the 3-way valve will start to change its position to maintain 36˚ C in the LT system.

Power reduction as defined by affinity laws represents an ideal case, so it remains to be seen what the savings will be in reality, given the efficiency of the VFD (as a new element in power transmission) and the efficiency of the electric motor and pump at low speeds.

It also remains to be calculated what is the minimum pump speed at which the energy savings can still offset all efficiency and system losses. VFD and induction motor efficiencies generally decrease with speed. Overall heat transfer coefficient of heat exchanger also decreases as flow is reduced, but on the other hand, system losses and thus required pumping power decrease as flow is reduced. This is essentially a modelling problem that requires close consideration for all mentioned parameters.

Centrifugal pumps in cooling systems have traditionally been driven at constant speed because this type of arrangement is simple and reliable; it has a proven track record, so why change it. However, nowadays could be economically and environmentally justified to consider installing VFD without sacrificing reliability. (Su, Chung and Yu, 2013; Durmusoglu and Yalcin, 2015; Theotokatos, Sfakianakis and Vassalos, 2016)

There have always been investments in the efficiency of the main and auxiliary engines and hull resistance in the shipping industry. However, considering that 70% of the electricity generated on board ship is spent on pumping systems (Su, Chung and Yu, 2013) and taking into account the order of magnitude, it is safe to conclude there is room for savings when it comes to auxiliary machinery too.

However, it is worth mentioning that this solution may not be feasible for ships sailing exclusively in warm seas, or for ships where the scavenge air is cooled directly by seawater, as well as for ships where the LT temperature is not fixed at 36 °C, but varies with seawater temperature. In both cases, the problem is the increase in scavenge air temperature and the resulting increase in specific fuel consumption, which could negate or exceed the fuel savings achieved with VFD (Pariotis, Zannis and Katsanis, 2019). For this type of cooling system, the analysis should be done on a case by case basis. Nevertheless, this is an arrangement which, as a retrofit or as a permanent design improvement, deserves closer examination.

Electric motor and VFD efficiency curves are usually given by the manufacturer and although they are changing with the speed, they do not depend on the system. It is different though with centrifugal pump. For this reason, the issue of centrifugal pump efficiency in sea water cooling system is relevant topic of research.

COOLING SEA WATER SYSTEM CASE STUDY

Vessel which is going to be assessed in this paper is Q-flex LNG tanker, built in 2008. Its deadweight is 106983 ton; it has 2 conventional slow speed diesel engines for propulsion and 5 auxiliary engines for electricity generation. Because of its 2 main engines (2 propellers), almost all components in the engine room are doubled. Same goes for cooling system. It has 2 cooling sea water pumps and 2 central coolers (plate heat exchanger, single-pass, counter-flow) per main engine plus 2 cooling sea water pumps for reliquification plant. Sea water system is an “open loop” in a sense that pumps take suction from sea chest and deliver sea water through central cooler overboard. Low temperature fresh water system is closed loop and except ME jackets (which too are cooled by LT system but indirectly through separate coolers) is cooling all other machinery in the engine room. This arrangement can be found, with possible minor alterations, on most of newbuilds too.

Under normal conditions there is one sea water pump operating per main engine, and one cooler in use. Both coolers and pumps are designed for 100% cooling capacity, so they are not designed for parallel operation. There are two on each side only for the sake of redundancy.

It is worth mentioning that some vessels have a combination of large and small centrifugal pumps in sea water system that can be combined to meet the demand of machinery. In that case, the system has to be designed to accommodate this arrangement.

Here however, pumps can be run in parallel, but it is not intended, because as it will be explained later, in systems where friction resistance predominates and which have a relatively steep characteristic curve, the difference in flow is minimal when two pumps operate in parallel.

Though pumps and coolers are connected in parallel, for the sake of simplicity Figure 1 shows only one pump and one cooler. Length of the pipeline from sea chest to overboard valve is 70 meters and pipe diameter is 350mm.

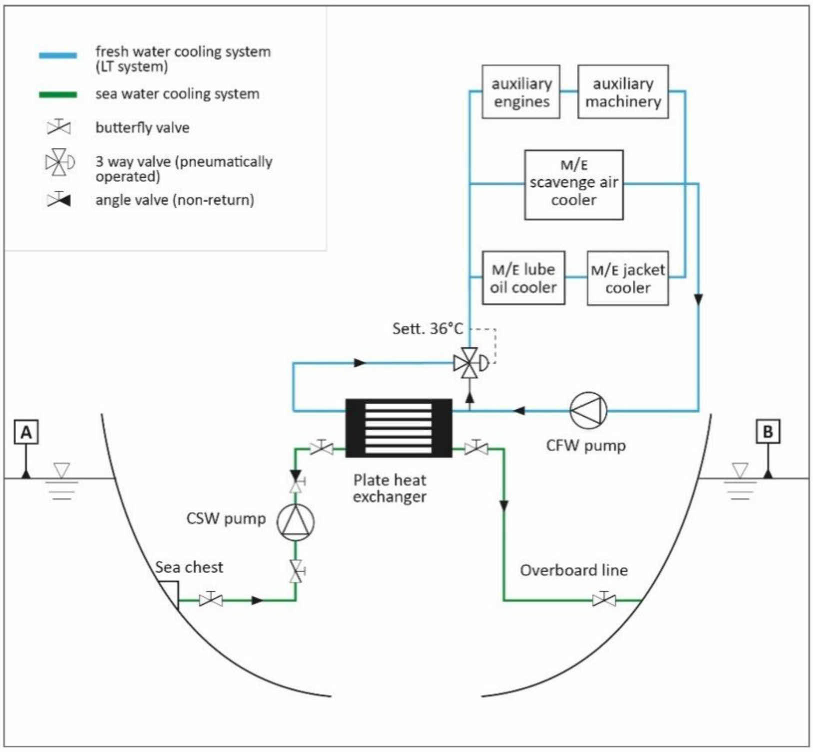

Figure 1. Typical ship’s cooling water system – simplified arrangement

SYSTEM CURVE CALCULATION

System curve can be acquired by taking into consideration all the elements in the system and their resistance to flow, as well as friction resistance of the pipeline and pressure drop through the cooler which is a function of flow velocity and multiple variables of geometry, and it has to be calculated separately.

Net head H_p is aquired by solving the energy equation (1) from point A to point B as shown in the Figure 1:

$$\frac{p_1}{\rho} + z_1 + \frac{v_1^2}{2g} + H_p = \frac{p_2}{\rho} + z_2 + \frac{v_2^2}{2g} + h_f + h_m + \frac{\Delta p_{PHE}}{\rho g} \quad \text{...(1)}$$

where p stands for pressure, z for elevation and v for fluid velocity. Δp_{PHE} represents the total presure drop of a heat exchanger which is calculated in the section 3.1 of this paper and h_f represents the value of friction losses:

$$h_f = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} \quad \text{...(2)}$$

Friction losses depend of several factors: length of the piping system L, pipe diameter D and friction factor f which was taken from the Moody's diagram based on JISG3454 (steel for pressure service) pipe roughness and Reynolds number.

The value of minor losses h_m is calculated using:

$$h_m = \sum k \cdot \frac{v^2}{2g} \quad \text{...(3)}$$

where the constants k (non-dimensional coefficient of pressure loss) are taken from “Working Guide to Pump and Pumping Stations” (Menon and Shashi, 2009) for every specific piping element except sea chest which was calculated separately. Table (1) shows all piping elements in the observed system and their respective constants.

Piping element	Qty	Factor k
entrance loss	1	0.5
elbow 90°	10	0.39
butterfly valve	6	0.35
angle valve	1	4.4
overboard line (exit loss)	1	1
suction side (entrance contraction)	1	0.5

Table 1. k coefficients used in calculation, (Menon, E. Shashi. 2009)

There is a variety of sea chest filters on the market, and manufacturers sometimes give pressure drop of a clean filter at particular flow. As this data was not available, pressure loss coefficient was calculated using equation (4) which is basically rearranged form of the equation (3) for a single piping element:

$$K = \frac{\Delta p \cdot 2}{\rho \cdot v^2} \quad \text{....................................(4)}$$

where Δp is pressure drop across sea chest which was calculated by subtracting pressure in the sea water main line (reading taken from standby sea water pump suction gauge) from the hydrostatic pressure at the elevation of the sea chest; ρ is density of sea water at 27°C (temperature at the moment of calculation) and v is velocity of sea water through the sea chest which was calculated as a ratio between total flowrate through the sea chest (flowrate of all pumps which were taking suction from sea water main line at the moment of calculation) and flow area of the sea chest which was calculated by projecting filter mesh over the diameter of main sea water line and calculating flow area which turned out to be 23.6% of the pipe cross section. Finally, calculated pressure loss coefficient for the sea chest was found to be 1.52.

By solving the energy equation, pressures, elevations and velocities cancel each other out. Basically, this case can be represented with the pumping of liquid between 2 large tanks which maintain the same levels throughout the process. In that case, pressures are equal on both sides (same as it is on both sides of the ship's hull), velocity is zero on both sides (or it can be neglected since the tanks are large) and elevation is zero (since the levels in the tanks are equal).

After rearranging energy equation (1) and using equations (2) and (3), required net head equals to:

$$H_p = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} + \sum k \cdot \frac{v^2}{2g} + \frac{\Delta p_{PHE}}{\rho g} \quad \text{......................(5)}$$

Plate Heat Exchanger

Calculation of pressure drop across plate heat exchanger (PHE) is complex; it is a function of flow velocity (it changes roughly with a square of velocity) and it depends heavily on plate geometry. A number of expressions were found experimentally such as Kumar's equations and constants (Bejan and Kraus, 2003) which were used in this paper. Pressure drop across PHE can be divided to pressure drop in the channel (Δp_{ch}) and pressure drop in the port (Δp_{port}) as per equations (6), (7) and (14). Manufacturer's data of the observed PHE which was used in the calculation is given in the Table 2 at the end of chapter 3.

$$\Delta p_{PHE} = \Delta p_{ch} + \Delta p_{port} \quad \text{..(6)}$$

Equation (6) shows channel pressure drop:

$$\Delta p_{ch} = \frac{4 \cdot f_{ch} \cdot N_p \cdot L_p \cdot G_c^2}{D_h \cdot 2\rho \cdot \Phi^{0.17}} \quad \text{.....................................(7)}$$

where N_p is the number of passes in PHE. In this case N_p equals to 1. L_p represents the measured length of the plate from port to port. Φ is viscosity correction factor i.e. the ratio between boundary layer and fully developed flow viscosity and in this paper it is assumed to be 1.

D_h stands for hydraulic diameter:

$$D_h \approx \frac{2b}{\Lambda} \quad \text{..(8)}$$

where Λ is an enlargement factor (developed over protracted length as shown in Figure 2 with values $1.1 \leq \Lambda \leq 1.25$, and b is the mean channel flow gap:

$b = p - t$ ....(9)

where p is the plate pitch (outside depth of the corrugated plate) i.e. the length of compressed plates divided by total number of plates N_t, and t is the thickness of a plate. (as shown in Figure 2)

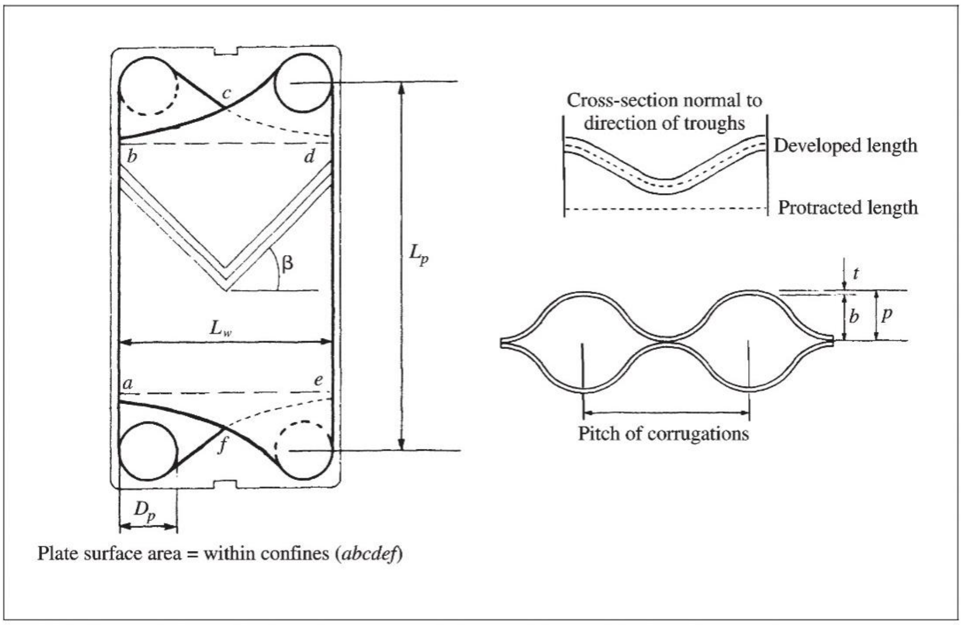

Figure 2. Heat exchanger plate with its most important measurements (A. Bejan, A. D. Kraus, 2003.)

Channel mass velocity G_c is calculated using following equation:

$$G_c = \frac{\dot{m}}{N_{cp} \cdot b \cdot L_w} \quad \text{...(10)}$$

where $\dot{m}$ is mass flow velocity, L_w is the measured useful plate width and N_{cp} is the number of channels per pass:

$$N_{cp} = \frac{N_t - 1}{2N_p} \quad \text{...(11)}$$

Friction factor f_{ch} is calculated using:

$$f_{ch} = \frac{K_p}{Re^z} \quad \text{..(12)}$$

where K_p and z are parameters taken from the table shown in Figure 3 below, based on the plate chevron angle β and the value of Reynolds number calculated with following equation:

$$Re = \frac{G_c \cdot D_h}{\mu} \quad \text{...(13)}$$

TABLE 11.5 Kumar's (1984) Constants for Single-Phase Heat Transfer and Pressure Loss in Plate and Frame Heat Exchangers

Chevron Angle (deg)	Reynolds Number	C_h	y	Reynolds Number	K_p	z
≤ 30	≤ 10	0.718	0.349	< 10	50.000	1.000
	> 10	0.348	0.663	10–100	19.400	0.589
				> 100	2.990	0.183
45	< 10	0.718	0.349	< 15	47.000	1.000
	10–100	0.400	0.598	15–300	18.290	0.652
	> 100	0.300	0.663	> 300	1.441	0.206
50	< 20	0.630	0.333	< 20	34.000	1.000
	20–300	0.291	0.591	20–300	11.250	0.631
	> 300	0.130	0.732	> 300	0.772	0.161
60	< 20	0.562	0.326	< 40	24.000	1.000
	20–400	0.306	0.529	40–400	3.240	0.457
	> 400	0.108	0.703	> 400	0.760	0.215
≥ 65	< 20	0.562	0.326	< 50	24.000	1.000
	20–500	0.331	0.503	50–500	2.800	0.451
	> 500	0.087	0.718	> 500	0.639	0.213

Figure 3. Kumar's constants for observed plate heat exchanger (A. Bejan, A. D. Kraus, 2003.)

Port pressure drop is calculated:

$$\Delta p_{port} = \frac{1.3 \cdot N_p \cdot G_p^2}{2\rho} \quad \text{.......................................(14)}$$

where G_p is the port mass velocity:

$$G_p = \frac{4\dot{m}}{\pi \cdot D_p^2} \quad \text{...(15)}$$

and D_p is the diameter of plate ports.

Finally, after entering all data and arranging the equation, system curve can be described with the equation (16):

$$H_p = 0.92614 \cdot V^2 + 0.7284 \cdot V^{1.794} \quad \text{.....................(16)}$$

Plate heat exchanger (manufacturer's data)	
No. of plates (N_t)	471
Plate thickness (t)	0.6 mm
Plate length (L_p)	1960 mm
Plate width(L_w)	450 mm
Chevron angle (β)	45°
Port diameter(D_p)	360 mm

Table 2. Manufacturer's data for the observed PHE

ANALYSIS OF PUMP EFFICIENCY AT REDUCED SPEED

Typical centrifugal pump curves

Figure 4 shows an example of centrifugal pump curves. The curves are usually shown on the same graph and are obtained by the manufacturer based on the experiments, and later provided to the customer for the reference when looking for the pump to match their system. The graph is usually made for single pump speed.

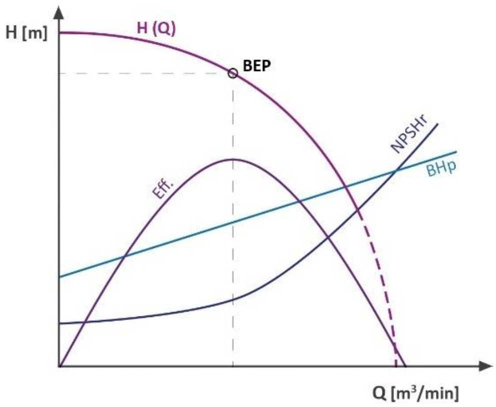

Figure 4. Typical centrifugal pump curves

The curves shown on the picture off course vary from one pump to another but generally they have similar characteristic. H(Q) curve is main pump performance curve and it should intersect system curve at BEP (best efficiency point), ideally. It stretches from shutoff head (H is max, Q is zero) to free delivery point (H is zero, Q is max.). Efficiency curve goes from zero to its maximum at BEP and back to zero. NPSHr (net positive suction head required) curve usually starts to go up after BEP and it signifies the minimum positive suction head on the pump which will prevent cavitation. Brake horse power (BHP) curve represents pumping power required and is gradually rising with flow; from some initial value required to maintain shut off head to some final value along the straight line.

Family curves are sometimes given by manufacturers but that usually means several different impeller diameters, rather than different pump speeds. However, if it is necessary to get the curves for different speed, affinity laws have to be used.

Affinity laws

“Affinity laws are dimensionless groups which are developed within fluid mechanics and are useful for relating any two pumps that are both geometrically and dynamically similar. It is convenient to summarize the similarity relationships as ratios. For any two homologous states A and B:

$$\frac{Q_B}{\ } = \frac{\omega_B}{\ } = \left(\frac{D_B}{\ }\right)^3$$ ....(17)

$$\frac{H_B}{H_A} = \left(\frac{\omega_B}{\omega_A}\right)^2 = \left(\frac{D_B}{D_A}\right)^2 \quad \text{....................................(18)}$$

$$\frac{bhp_B}{bhp_A} = \frac{\rho_B}{\rho_A} = \left(\frac{\omega_B}{\omega_A}\right)^3 = \left(\frac{D_B}{D_A}\right)^5 \quad \text{..........................(19)}$$

Equations (17), (18) and (19) apply to both pumps and turbines. States A & B can be any two homologous states between any two geometrically similar turbomachineries, or even between two homologous states of the same machine." (Cengel and Cimbala, 2013). In case that the same fluid is pumped and only pump speed is varied, equation (19) reduces to:

$$\frac{bhp_B}{bhp_A} = \left(\frac{\omega_B}{\omega_A}\right)^3 = \left(\frac{n_B}{n_A}\right)^3 \quad \text{...................................(20)}$$

Centrifugal pump efficiency

It is worth mentioning that centrifugal pump efficiency is ratio between pump hydraulic power and shaft power, or in other words a measure which says how much of the power which is delivered to the pump from its driver will be transferred to the liquid. When expressed by equation:

$$\eta_{pump} = \frac{P_{hyd}}{P_{shaft}} = \frac{Q[\frac{m^3}{s}] \cdot h[m] \cdot g[\frac{m}{s^2}] \cdot \rho[\frac{kg}{m^3}]}{P_{el} \cdot \eta_{el.motor}} \quad \text{.......(21)}$$

where g is gravitational acceleration of 9.81 m/s^2, ρ is liquid density, Q is flow, h is differential head, P_{el} is electric power consumed by the electric motor and $\eta_{el.motor}$ is efficiency of the electric motor.

As it was stated earlier, it is not possible to find the answer about pump efficiency at reduced speed without looking at the system and the pump together. As it is shown in Figure 5, in systems with high delivery head, the curve is relatively flat, and for this reason the application of VFD is usually not recommended, as even a small reduction in speed can drastically reduce the efficiency of the pump.

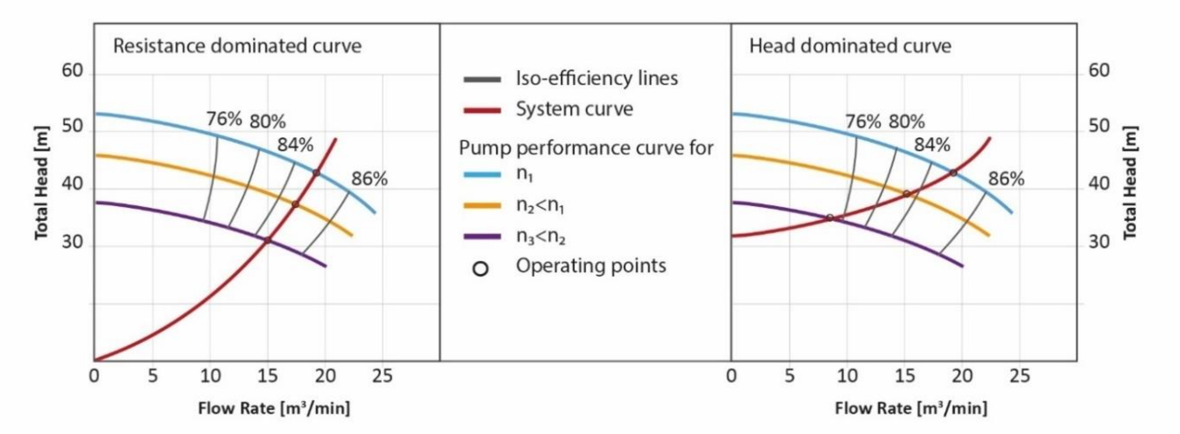

Figure 5. Centrifugal pump efficiency in resistance vs. delivery head dominated system curve

On the other hand, in systems where the pipe resistance dominates (as in the system considered in this paper), the curve is much steeper, so in the ideal case (when the system curve is parallel to the similarity curve) the efficiency remains unchanged. On the left side of the Figure 5, it is visible that efficiency stays approximately the same (around 84.5%) or it falls slightly as the speed is reduced from n_1 to n_3. On the right side though, there is more than 30 meters of delivery head, and efficiency drops below 76% when speed is reduced.

MATLAB simulation, case study

Previous papers which covered ship's cooling water system either did not analyse pump efficiency but rather covered potential energy savings (Kocak and Durmusoglu, 2017) or they used Sarbu and Borza (1998.) equation for calculating it (Pariotis, Zannis and Katsanis, 2019; Dere and Deniz, 2019). According to Sarbu & Borza, the equation (22) is valid for up to 33.3% reduction of speed and only for the bigger size pumps. Even though that might be good enough, it is still a rough estimate, and it too does not consider system curve:

$$\eta_2 = 1 - (1 - \eta_1) \cdot \left(\frac{n_1}{n_2}\right)^{0.1} \quad \text{.................................(22)}$$

This paper investigates the pump's efficiency by creating the sea water piping characteristic of the observed vessel, by simulating pump curves at lower speeds analytically in MATLAB software, and finally, by finding new intersections with system curve and giving results for the efficiency. All components of the system (minor losses as shown in Table 1), piping resistances and cooler resistances were considered. Minor and friction losses were calculated separately (Menon and Shashi, 2009), and the resistance of the cooler as a function of flow was calculated using Kumar's relations and geometry data for the plate cooler on the observed vessel as it was explained in chapter 3.1.

Initially, there were 12 points which were experimentally acquired by the manufacturer and used for the further calculation. Out of that, 6 points were combination of flow and head, while the remaining 6 were combination of the flow and efficiency. (As shown in Table 3).

It was decided to make the simulation for 5 different speeds starting from 90% of nominal speed (1044 RPM) to 50% of nominal speed (580 RPM). After all relevant data was loaded in Matlab (system curve equation, affinity laws equations, pipeline diameter etc), a code was made in a way that it finds similarity points of flow for reduced speeds based on affinity law equations. Then, it fits the pump head curve using least squares method (curve approximated with 2nd degree polynomial with 1000-point resolution) and finds intersection with the system curve (the one obtained in chapter 3).

Then, based on the fact that similar points have same efficiency, it finds new efficiency points for reduced speed, it fits efficiency curve using least squares method (approximated with 4th degree polynomial with 1000-point resolution) through the points and it plugs in previously obtained intersection coordinates of flow to get exact efficiency for the reduced speed. It turned out that the efficiency of pump in the considered system changes only insignificantly, i.e., it goes down 1.68% when speed is reduced by 50%. Table (4) shows efficiencies at all speed levels.

Experimental data shown in Table (3) was obtained from the pump manufacturer. This data applied to nominal speed of 1160 rpm. The motor was constant speed, 6 pole, 440V, 3 phase induction motor of 170 kW, with the efficiency of 94.5% at nominal speed. As everything was done analytically using Matlab, the graph was plotted and edited to visually represent the results as shown in the Figure 6.

Flow capacity Q[m³/min]	Total Head H[m]	Pump efficiency [%]
0	34.616	0
8.555	31.291	33.252
22.635	24.659	71.173
26.755	22.835	81.512
28.903	20.966	81.099
30.473	19.084	78.314

Table 3. Manufacturer's performance data for a pump operating at 1160 rpm.

Speed	n = 1160 rpm	n1 = 1044 rpm	n2 = 928 rpm	n3 = 812 rpm	n4 = 696 rpm	n5 = 580 rpm
Efficiency	73.67 %	73.44 %	73.23 %	72.65%	72.61 %	72.00 %

Table 4. Simulation results: efficiencies at reduced speeds

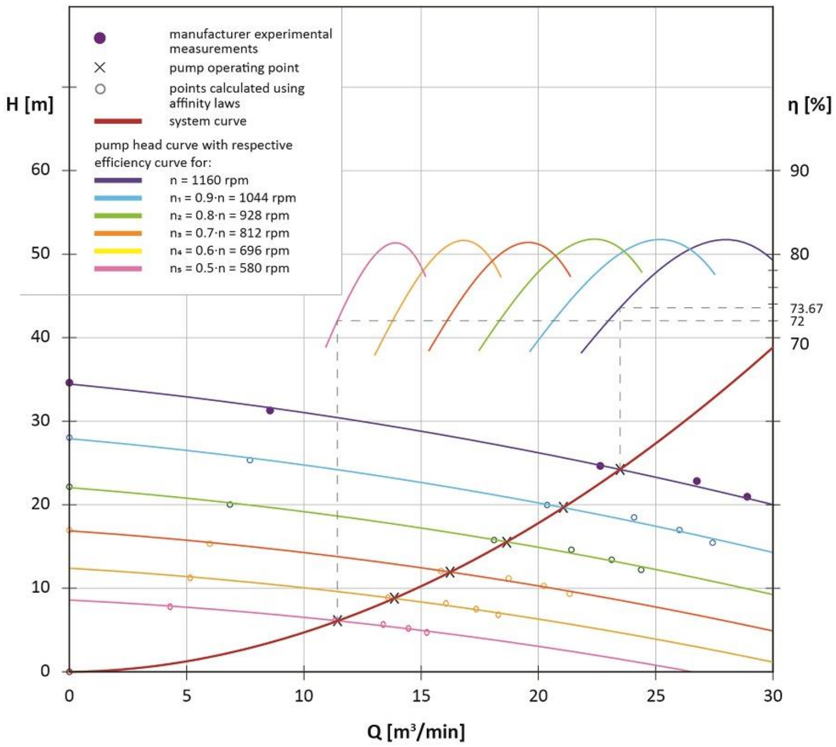

Figure 6. Graph with Matlab simulation results

CONCLUSION

In this paper, the efficiency of variable speed centrifugal pump in a typical ship's cooling seawater system has been analysed. System characteristic was obtained by calculation, i.e. by setting the energy equation between both sides of ship's hull while taking into consideration all losses. Next, pump head and efficiency curves for reduced speeds were found based on manufacturer's data for nominal speed using affinity laws. Finally, new intersections with system curves were found analytically in Matlab software and new efficiencies were found thereby. From the results of the Matlab simulation, the centrifugal pump in a typical seawater cooling system has an approximately constant efficiency at lower speeds. The efficiency has decreased from 73.67% at rated speed to 72.0% at 50% of rated speed. This is consistent with the general view that circulating systems (which are dominated by friction), with their steeper curve characteristics, are a good basis for the use of VFDs. The high range of speed reduction simulated in this paper (from 1160 rpm to 580 rpm) was made to cover all possible scenarios and is probably more than will ever be feasible in practice for several reasons. Hence, in future work it would be necessary to consider some of the following: efficiency of electric motors and VFDs which generally decreases with speed. Also, possible problems with cooling of the electric motor (as fan is driven by the motor, it spins at the same speed). At certain low speeds, there may be structural vibration problems (resonance conditions) that can affect the mechanical integrity of the pump, etc. All of these can offset energy savings achieved by using VFDs, so the extent of speed reduction should be calculated on a case-by-case basis. However, in this paper it is shown that for the typical ship's seawater cooling system energy balance analysis, the calculation can assume a constant efficiency of the centrifugal pump at reduced speeds.

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Developing Cyber Resilience in Naval Domain

Ante Gelo[1], Hrvoje Karna[2], Tomislav Kovačević[3]

Cyberspace has become a critical component of national security. This is confirmed by the fact that it has been defined as the fifth dimension of warfare. Contemporary military doctrines recognize the terminological shift from the concept of the “battlefield” to “battlespace”. The increased digitization of the Navy opens numerous opportunities. At the same time this threatens the security of its assets – the data, systems, and people. Previously the information and communication systems were isolated but with the emergence of the Internet they became increasingly interconnected and thus more vulnerable. As the importance of effective communication between different naval segments increases, it is necessary to adequately protect them. The paper provides an overview of the trends that have led to the increased importance of cyber security in the Naval Domain. Next, the position and role of cyber capabilities as well as the importance of their further development are pointed out. Authors note typical attack vectors over which systems can be compromised followed by categorization of cyber threats. Furthermore, an overview of recent naval cyber incidents is presented. The importance of protecting all components of cyber security is emphasized in order to develop a more resilient environment and reduce the consequences of potential attacks, stressing the importance of the human factor. As the digital age has also influenced modern warfare, the paper elaborates issues of national strategies and military doctrines with special reference to the protection of the national cyber space in the Republic of Croatia. Finally, authors provide their expectations about the development of the studied area with recommendations for improving the current state of affairs.

KEY WORDS

Cyberspace, Cyber Security, ICT Infrastructure, National Security, Naval Domain, Attack Vectors, Resilience

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INTRODUCTION

Digitization is an inevitable process that has led to transformation of all aspects of human existence (Bulgheroni et al., 2021). Driven by technological progress, digitalization enables individuals and societies to move beyond their current reach, thus creating conditions for innovation and creation of new added value (Lazzeretti et al., 2020). It has changed the ways we interact, work and live. Today, information exchange is faster, and if managed properly, more efficient (Bertagnolli, Gallotti and De Domenico, 2021). Automation driven by digital transformation has led to elimination of repetitive tasks and enhancement of processes. Digital technology is transforming society, this time from the informational perspective (Hilbert, 2020). However, digital dependency is creating a new area of vulnerability that needs to be adequately protected (WEF, 2022).

There is no formal definition of cyberspace. Partly so because it involves elements that are both abstract and concrete (Garvey, 2021). It has evolved on the wave of rapid advancement of computerization, its wide application in all domains, gradually reaching the position of being practically irreplaceable (Sawyer and Tapia, 2004). The spread of access to the Internet and availability of network services enabled exchange of information at a previously inconceivable level that today often determines the success or failure of any undertaking (Chałubińska-Jentkiewicz et al., 2022). For the purpose of this work, we denote it as a “global domain within the information environment consisting of the interdependent networks of information technology infrastructures and resident data, including the Internet, telecommunications networks, computer systems, and embedded processors and controllers” as in (DOD_DIR, 2021).

As cyberspace consists of computer networks, systems, services, and users which interact for numerous purposes, there is a need to adequately protect them. Cybersecurity therefore considers vulnerabilities, countermeasures, and security requirements of involved entities (Gunduz and Das, 2020). This implies the implementation of methods for detecting and preventing potential threats. So, it refers to the efforts aimed to prevent damage caused by disruption to, breakdowns in or misuse of information and communication technology (ICT) and to repair damage when it occurred. Such damage may consist of any or all the following: reduced reliability of ICT, limited availability, and violation of the confidentiality and/or integrity of information stored in the ICT system (NDL_DCS, 2012).

Related to the previous, and associated with national security, we must refer to the concept of cyber warfare. Despite the existing definitional ambiguity (Ashraf, 2021) it can be denoted as a form of a warfare that involves the actions by a nation-state or international organization to attack and attempt to damage another nation's computers or information networks through, for example, computer viruses or Denial-of-Service attacks (RAND, 2023). All the above indicates the need to work on the continuous improvement of cyber resilience that is a framework that consists of cyber resiliency goals, objectives, techniques, implementation approaches and principles similar as it is defined in (Ross et al., 2021).

As naval forces increasingly turn to digitalization, creating ever greater dependance on information and communication technology, their reliance on these technologies must be protected at all levels. The maritime environment has its own specificities in relation to other areas, which is also reflected in the cyber area. Cyber security is a real concern in the maritime sector and naval forces are therefore advised to develop cyber resilience capabilities (Thiele, 2018). Maritime cyber resilience entails resilient systems as well as operators (MAROFF-2, 2023). Croatia as a maritime and NATO member country must be prepared to meet the challenges in the naval domain.

The rest of the paper is organized as follows: first, we provide an overview of the research concerning the area of cyber security and issues of developing resilience in this domain. Next, in Section 2 the importance of cyber security in naval domain is discussed followed by a review of typical cyber threats and recent incidents. In Section 4 we stress the importance of national strategies and military doctrines in relation to cyber and the approach implemented in Croatia with reference to the Navy. Finally, the last section outlines the expected future developments and conclusions.

RELATED RESEARCH

Interaction with the cyber domain has become a regular part of our lives, thus we become exposed to a number of threats. These threats can be benign, posing no severe security risk but can also be highly malicious (Kaddoura, 2021). Cyber attacks carried out in a sophisticated manner target individuals, institutions, and nations (Spremić and Šimunic, 2018). They can be prevented, or their effects mitigated by rising awareness and building capacity to resist such threats by all participants in the digital domain (Collet, 2021). Cyber attacks attempt to steal, alter, disable, destroy, or otherwise exploit computers, networks, or any other digital asset (Quader and Janeja, 2021). Traditional security measures are not efficient enough in the era of Big Data, Internet of Things (IoT) and wide application of artificial Intelligence (AI) that shape the future of many sectors (Oseku-Afful, 2016) and new approaches are required to keep up with the challenges we are exposed to (Rawat, Doku and Garuba, 2019).

Cyberspace has been declared the fifth dimension of warfare, next to the air, land, maritime, and space (Kasapoglu, 2017) which is designated by many nations in their respective military doctrines (Biernacik, 2018). The Sea or Naval domain of warfighting comprises combat in and on seas, oceans or any other major bodies of water such as large lakes and wide rivers (Panwar, 2017). This has also been recognized in a terminological shift that, following the advancement in technology and increasingly greater dependance upon the digital sphere, turned to the concepts of “battlefield” to “battlespace” (Ethelston, 2015). As ICT systems are facing an increase of cyber security threats (Liu, 2018) it is necessary to develop cyber capabilities and achieve cyber security resilience which includes cyber and information security (Galinec, 2022).

The global maritime sector is increasingly reliant on digitalization, as modern ships are equipped with a fleet of sensors and systems that enable them to operate with a high degree of autonomy (Akpan, 2022). Cyber security approach in this field must consider various systems both on ships and in ports (Alcaide and Llave, 2020). Threats to cyber enabled ships are ever greater, especially attacks aiming on bridge and navigational systems, considering that it is necessary to ensure the safe and secure operation of the vessel (Kavallieratos, 2021). On the other hand, ports and onshore installation in general are centralized information hubs that provide data and service needs of various stakeholders and are typically composed of heterogeneous technical systems (Meyer-Larsena, Müllera and Zedela, 2020), which further complicates the situation. The mentioned issues reach a new level when they are applied to the environment of the Navy and the need for these systems to operate in a combat situation (Visscher, 2021).

DEVELOPING CYBER RESILIENCE

The following chapter focuses on cyber security issues related to the maritime sector and the concept of its organization. Furthermore, it justifies its importance by providing an overview of the systems on which attacks were typically carried out. This indicates cyber elements that need to be protected in order to build-up resilience.

Importance Of Cyber Security In Naval Domain

Cyber security is important because it can affect people, platforms, organization, and mission. Cyber incidents can affect operation of hardware and software systems that control devices and that are used for storing, processing, and exchanging data. There are numerous reasons why the maritime industry is vulnerable to cyber incidents, for example: use of legacy systems, the absence of antivirus protection, irregular patching, lack of training and discipline of the staff etc. (ICS, 2021). These and other risks can be avoided to a large extent by implementation of security procedures on board and ashore that include the personnel engaged in operations, technical measures thus raising the security culture in the organization.

Attackers in the cyber domain can try to take advantage of the shortcomings present at all levels. These potential vulnerabilities can exist at (Thiele, 2018; JCS_3-12, 2018; AFDP_3-12, 2023):

- Physical network layer - includes the hardware and infrastructure e.g., computing devices, storage devices, network devices, and wired and wireless links. This layer is made of information technology devices and infrastructure in the physical domain that provide storage, transport, and processing of information. Security measures here must ensure protection from physical damage or unauthorized physical access.
- Logical network layer - consists of elements that are not necessarily equal to the physical specification of the network as it is based on logical programming that organizes the network components in the desired topology. Elements of a network relate to one another in an abstracted form and different elements such as data and applications can be distributed but function as a single entity. Security at this level is about protection of devices and programs including hardware, firmware, and software.
- Cyber-persona layer – refers to the digital representation of an actor or entity in cyberspace. It consists of network or information technology accounts that are in certain relation, that are created by humans or otherwise. Typical representatives are phone numbers, email addresses, IP addresses, login data etc. Relation of a cyber and physical persona can be complex, this is the reason why the establishment of protection at this level is particularly demanding.

Naval operations heavily rely on communication technology and advanced electro-optical and infrared sensors used for intelligence, surveillance, and reconnaissance purposes all of which can prove vulnerable to disruption and exploitation. It is essential for an attacker to gather information about the target's weaknesses, i.e., details about its network, systems, and protection measures, in order to be able to carry out an attack effectively. That is why it is important to preserve integrity at all the mentioned levels.

Next, we briefly consider the potential targets of cyber-attacks that are specific to the maritime domain. Unlike other traditional systems, primarily land-based, naval systems differ in number of features, and this reflects to cyber security. Some of these relate to the fact that ships necessarily have a larger number of ICT systems that support automation, navigation, and office functions. Moreover, ships have a relatively long service life, which, combined with the amount of equipment they carry, complicates the maintenance of both hardware and software. Conceptually, we can differentiate two segments: on ship and in port (ashore) (Akpan, 2022; Meland et al., 2021). Conversion to the digitalized infrastructure and increased integration with modern technologies such as cloud, smart technologies, IoT and Big Data has made the issue of protection even more complicated (Farah et al., 2022).

Attack Vectors And Categorization Of Cyber Threats

An attack vector is a path by which a threat actor can gain access to a server, host, or network. Attack vectors originate from inside or outside the organizations. Internal threats also have the potential to cause greater damage than external threats, because internal users have direct access to the facilities and its infrastructure devices. External threats can exploit vulnerabilities in network or computing devices or use social engineering to gain access (Cisco, 2023). Attackers can generally be classified into amateurs, hackers, and organized hackers. Organized hackers possess highly sophisticated skills and use a range of tools to carry out network, wireless, malicious, and social attacks.

Common network attacks are Denial-of-Service (DoS), Distributed DoS, and Man In The Middle (MITM). For Wireless networks these are usually encryption cracking, fake Wi-Fi Access Points, Evil Twins, etc. Malware, short for malicious software, is the most common type of cyber attack which includes ransomware, trojans, spyware, viruses, worms, keyloggers, bots, crypto jacking, and many others. Social engineering is an access attack that attempts to manipulate individuals into performing actions or divulging confidential information (CIS_185, 2023). Most common methods are baiting, scareware, pretexting and phishing. Modern and powerful attacks use more complex techniques and hybrid methods to strike.

One way in which infiltration is achieved is through Advanced Persistent Threats (APTs). They consist of a multi-phase, long term, stealthy and advanced operation against a specific target. Due to its complexity and skill level required, an APT is usually well funded. An APT targets organizations or nations for business or political reasons, protection against them requires a multifaceted approach of administrators, service providers and users. Another way is a so-called blended attack, that uses several different techniques at once, attackers have malware that are a hybrid of worms, trojan horses, spyware, keyloggers, spam and phishing schemes. This way of hybrid attacks is complex malware and places user data at great risk (Cisco, 2023).

For an adequate defense against the mentioned threats, it is necessary to develop both human and technical resources and implement appropriate processes at all levels. But primarily, individuals are needed who are capable of recognizing the scale and direction of cyberattacks in order to counter them. Also, for advanced defense it is necessary to have at disposal a next generation routers, firewalls, IPS devices, IDS devices, web and email security appliances and other.

Overview Of Recent Cyber Incidents

The following excerpt of incidents in the maritime domain is based on data collected from the surveys (Akpan, 2022; Meland et al., 2021; Farah et al., 2022). The data provided in Table 1 categorizes incidents based on the following criteria: the year when the attack occurred, attacked entity, technique used, and the effect caused, it provides insight into the different characteristics of these events and includes incidents characterized as military conflicts.

	Incident		
Year	**Entity**	**Attack**	**Effect**
2010	drilling rig	control systems; malware	days of downtime
	shipping company	hacked via Wi-Fi	information was used to plan pirate attacks

2011	port	cargo tracking system	enabled smuggling
	ship-building groups	spear-phishing	espionage; collection of sensitive information
	shipping company	internal network	damaged data; financial and cargo loss
2012	border protection service	cargo handling system	compromised shipment information
	maritime authority	email	information stolen
2013	drilling rig	PC/USB virus infection	distributed system halted operation
	maritime company	fake AIS identification	smuggling, terrorism, military conflict
2014	shipping lines	email intercept	transactions; financial loss
	coastal admin body	AIS data	electronic espionage
2016	multiple ships	navigation systems	ships had to return to port
2017	ship broker	hacked; data stolen	sensitive information stolen
	logistics company	virus; ransomware	devastating attack (300M$ USD)
	navy/commercial ship	navigation system attack	collision between navy and container ship
	navy/commercial ship	navigation system attack	collision between navy ship and oil tanker
	navy/commercial ship	navigation system attack	collision between navy and fishing ship
2018	multiple ships	GPS spoofing	geolocation system showed wrong data
	shipbuilder company	stolen data	attempted to extort money
	navy contractors	ransomware attack	data stolen/unusable
2019	port	ransomware, phishing	access and process monitoring disabled
	pipeline operator	ransomware, phishing	information and operating systems impact
2020	cruise operator	virus	customers and employee’s data stolen
	shipping agency	intranet disabled	not disclosed
	cruise operator	IT systems crippled	systems unavailable

Table 1. Excerpt of cyber incidents in maritime domain.

The data about recent incidents is scarce or unavailable and therefore could not be included in this review. What is evident from the reports is that the frequency of cyber incidents is increasing, as well as their complexity. As expected, private companies and even state bodies are reluctant to publicly disclose specific, technical information about their cybersecurity systems. According to the author's knowledge, there have been no recorded cyber attacks against vessels sailing under the Croatian flag.

NATIONAL SECURITY, MILITARY DOCTRINES AND MODERN WARFARE

The chapter ahead provides an overview of the issues of modern warfare in the digital age with a special focus on the issues of national strategies and military doctrines which elaborate this further. After that, the approach to the protection of the national cyber space in the Republic of Croatia was presented, with special emphasis on the organizational structure and coordination of state bodies whose jurisdiction includes the prevention and response to such threats in general and therefore also in the naval segment.

Information Era And Change In National Security Strategies

Information technologies and reliance on computers and networks shifted conceptions of national security and introduced a new instance of warfare, Information Warfare, which can be defined as destroying and reducing information, as well as the reduction of content and denial of information.

Political and military security policymakers must recognize and point to digital threats and react through national and political relationships. It must be clear that reliance on computer technology has opened a new kind of vulnerability (Devost, 1995). For national security, marginalized groups of people have access to cyberspace and through it can alter national security. For modern warfare, emerging information technologies, artificial intelligence and machine learning will be decisive weapons of modern battlespace. As a conclusion, it can be stated that supremacy in cyberspace, both in peace and in war, is the challenge of the current century (Gordon, 2021).

Cyber In National Strategies And Military Doctrines

Based on previous considerations, nations along the globe created cyber national strategies and military cyber doctrines. National cyber security strategy is the main national document for setting strategic principles, guidelines and objectives and mitigation measures in the cyber domain (ENISA, 2023). For the United Kingdom, National Cyber Strategy can be viewed through short term outcomes: strengthening the cyber ecosystem, building a resilient and prosperous digital nation, taking the lead in the technologies vital to cyber power, advancing global leadership and influence for a more secure, prosperous, and open international order (UK_NCS, 2022). For Italy, national cyber strategy can be stated after defining most systematic risks and their effects: a) cyber-attack can influence states Gross Domestic Product and its reputation, b) products developed by large companies can be controlled by the host-country governments which can influence in the supply chain, availability and reliability and c) disinformation, fake news and misinformation through cyber domain can influence public (IT_SNC, 2023). Also, because the cyber environment is changing rapidly, cyber periods are given for a short-term, usually 3 to 5 years, after which the strategy must be reviewed.

Digital revolution influenced military organizations for their response through changes in military doctrine and correspondent objectives. Netherlands armed forces acknowledge that digital technology is the foundation stone for performing tasks effectively and efficiently. Weapon systems, command and control, logistics support depend on digital systems on a large scale. Military branches tasked for positioning and situational awareness also rely on digital assets. Information systems and computer networks have become the information backbone of the armed forces. On the other hand, digital technology opens new kinds of vulnerability. Armed forces for assuring their missions must safeguard reliability of information systems and networks and have assets and knowledge for self-protection against cyber attacks. Also, the digital age demands constant updates of emerging cyber threats. Armed forces recognized objectives in cyberspace:

- Comprehensive approach
- Develop of defense element
- Develop of offensive element to conduct cyber operations
- Develop intelligence element in cyberspace the intelligence position in cyberspace
- Gain knowledge and innovation
- Promote national and international cooperation in cyber (NDL Cyber Strategy, 2012).

German armed forces created a new organization unit with holistic responsibility for dimension cyber and information space as a new domain. Unit is constituted by three divisions: 1) Communication and Information System Command with a task for operating and protecting IT Systems, 2) Strategic Reconnaissance Command with a task for reconnaissance and Effects and 3) Geoinformation Command with a task of keeping an Eye on Earth (DE_CIDS, 2023).

Approach To Cyber Security In The Republic Of Croatia

Croatian National Cyber Strategy (HR_NCSS, 2015) was presented in 2015 with objectives:

- Common approach in applying and updating of national legislative
- Conducting measures that raise security, resilience, and availability of cyberspace.
- Establish efficient methodology for data exchange.
- Raising cyber awareness
- Interconnected education
- Give secure government e-services
- Research and Development
- International cooperation

National Cyber Defense Strategy defines Areas of Cyber Security which are: a) CIS infrastructure, b) Electronic Government, c) Digital financial Services, d) CIS critical infrastructure and cyber incident governance, e) Cyber Crime. Action plan of execution of Strategy details strategic goals, action for realization of the strategic goals, stakeholders, and time limits. Based on the Action plan, stakeholders can control Strategy execution and guide further measures.

Croatian government constituted National Cyber Council for purpose of constant forward looking and updating of Strategy and Strategy execution action plan and tasked it:

- Coordination, discussion, and surveillance of Strategy execution
- Strategy updating and maintaining
- Execute Cyber exercises
- Give recommendations and make reports of Strategy execution.

With reference to EU directive 2016/1148 (EU_DIR, 2016), concerning measures for a high common level of security of network and information systems across the Union and national cyber strategy State declared The Office of the National Security Council (UVNS) as Singled point of contact (SPOC), The Information Systems Security Bureau (ZSIS) as Computer Security Incident Response Team (CSIRT) responsible for cyber incidents occurring in information systems of government and states agencies, Croatian Academic and Research Network (CARNET) as National Computer Emergency Response Team (CERT) for public information services and Ministry of Defense CERT as part of cyber defense strategy. Cyber defense strategy is part of National Cyber Strategy, and it is the responsibility of the Ministry of Defense of the Republic of Croatia. It is a separate part of the national Cyber Strategy, and it will be discussed, formulated, and stated independently with reference to national strategy (UVNS, 2023). Croatian armed forces recognized the new cyber domain and gave cyber defense objectives to Joint Staff, J-6 department, and Cyber Command unit. Beside cyber defense, Cyber Command is declared as a cyber knowledge center (OSRH, 2023).

EXPECTED FUTURE DEVELOPMENTS AND CONCLUSIONS

Comprehensive digitization accompanied by IoT, Big Data and AI make cyber an unavoidable topic in security matters. Evidence confirms that the number of cyber incidents is increasing, and their complexity is growing. All this leads to the conclusion that it is necessary to raise awareness of this problem and develop comprehensive measures to counter cyber threats at all levels.

An important aspect of this is the development of national authorities responsible for countering cyber threats. Our overview of national strategies and military doctrines of partner countries and comparison with those existing in Croatia indicates that the framework is well set, but also that there is space for improvement. We have detected that national cyber strategies of partner countries go through regular updates. This is necessary due to the great pace of changes in technology and strategies. On the other hand, Croatian National Cyber Strategy was published in 2015 and has not been revised since then.

Organizations need individuals who can recognize the speed and scale at which adversaries are accumulating and refining their cyber capabilities. All system users should be aware of security risks. This is also necessary due to compliance in the field of maritime affairs, as Croatia is a signatory to the SOLAS convention. The defense sector needs to continuously develop these capabilities, maintaining concepts not only of defense, but also of the ability to carry out cyberattacks as an integral part of operations in the event of war. Cyber should supplement and enhance kinetic means of executing military operations, which is why it was declared the fifth dimension of warfare.

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Optimization of the Application of Autonomous Underwater Vehicles in Underwater Protection

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The underwater environment is an under-researched area, and in recent years there has been a great interest in its research. Robotization, or the use of underwater vehicles, achieves significant effects related to the research of the underwater environment, which avoids exposing people to risk, for example, for mine countermeasures. The correct choice of technological solutions is of crucial importance for future efficient and economically justified application. One of the basic problems related to the protection of the undersea is the lack of interest in society for a more serious consideration of what and how to do with the undersea. Maritime countries must have control over the processes that take place under their seas.

KEY WORDS

Underwater Vehicle, Undersea Protection, Crisis, Military, Threat

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INTRODUCTION

With today's technology, a big step forward is achieved in scientific research and search of the sea and undersea. Autonomous underwater vehicles (AUV) are used most often in three areas: scientific (oceanographic) area, economic (commercial) area and for military activities (Radionov Radenković and Mandžuka, 2007).

In relation to military activities, the most common application is autonomous underwater vehicles for mine countermeasures. In short, the task of the anti-mine diver is to search the given area, examine suspicious objects in more detail and place an explosive charge next to those that turn out to be mines, which will neutralize them when the anti-mine diver moves away. Another important military application of AUV is military reconnaissance and espionage (Radionov Radenković and Mandžuka, 2007).

As mentioned, AUVs are becoming increasingly important in various applications. Many physical situations are beyond human reach so an AUV must be able to operate without direct intervention. This requires the ability to plan and adapt to unexpected situations. This paper gives the division and mode of operation of underwater divers, which is determined by the expected type of mission, and shows the importance of underwater vehicle mission planning, which contributes to increase the security of mission success.

UNDERWATER VEHICLES

People in search of solutions have developed several different types of divers - those that are controlled directly by people, remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs) and bulky special systems.

Remotely operated vehicles

The difference between remotely operated vehicles (ROVs) and autonomous divers (AUVs) is primarily in the thrust composition and active movement through the water medium. Remotely operated divers are characterized by a connecting cable that connects the ROV and the mother platform, usually the mother ship, from where the operators control it. Through the cable, the ROV communicates with the mother platform and is supplied with electricity from it. Despite its clumsiness, cable is inevitable for remote-controlled divers because there is no method of wireless underwater communication with an information flow density high enough for classic remote control. From the equipment, the ROV can be equipped with a variety of sensors, among them mandatory television cameras that provide an image for the operator, reflectors connected to them, and it is often equipped with manipulators (robotic arms). Manipulators have great maneuverability and achieve high guidance precision, but their movement speed is relatively low. As such, ROVs can perform a very wide range of tasks, and the tasks on which they have already proven themselves include more complex measurements, surveys, inspections and monitoring of water areas, and manipulative operations (Matika and Liović, 2014; Mišković, 2007). The Remotely Operated Vehicle is shown in Figure 1.

Figure 1. Mission Specialist Pro 5 (Source: https://videoray.com/products/mission-specialist-pro-5/)

Autonomous underwater vehicle

Autonomous underwater vehicle, on the other hand, do not have a connecting cable, so they cannot be functionally tightly connected to the mother platform even by remote control. They must have their own energy source and a certain amount of artificial intelligence. Thanks to the absence of a physical connection with the surface, they achieve higher movement speeds and faster and more dexterous maneuvering. Although operators can give them high-level commands via wireless acoustic communication links and at least somewhat monitor the progress of the diver, due to the low bandwidth of such communication, classical remote control is not possible. Instead, autonomous divers operate according to a pre-programmed (pre-set) mission, using artificial intelligence to monitor the progress of the mission, make management decisions and properly react to unplanned events. The possibilities of using artificial intelligence are still limited because it cannot satisfactorily solve more complex tasks with a lot of unpredictability. Further limitations occur because of the own energy source, which is why the duration of the mission is limited, and the use of energy-expensive devices (maneuvering thrusters, video cameras with reflectors, manipulators) is limited. Nevertheless, autonomous divers are a technology in full swing of development, so that each new generation strongly expands the limits of their capabilities. Tasks on which they have already proven themselves include measurement, survey, search and inspection over a wide water area, sampling, and other similar operations (Matika and Liović, 2014; Mišković, 2007). The Autonomous Underwater Vehicle is shown in Figure 2.

Figure 2. Underwater vehicle Remus 100 (Source: Croatian soldier, number: 524,)

APPLICATION OF AUTONOMOUS UNDERWATER VEHICLES IN UNDERWATER PROTECTION

According to the construction and maneuverability requirements, which are determined by the expected type of missions, autonomous underwater vehicles are divided into cruising and hovering vehicles, universal and specialized vehicles, deep (oceanographic) AUV and AUV for shall waters. The role of anti-mine divers in protecting the underwater world is also highlighted.

Cruising and hovering AUV

Cruising vehicles do not stop or maneuver during normal operation, but they move forward at a constant speed. Because of this, their control system can be simpler and, in addition to the main drive propulsor, it uses control wings for maneuvering, rather than maneuvering auxiliary propulsors. The hull of such vehicles is usually designed in the hydrodynamic form of a torpedo, and they can be required to cover long distances autonomously. Their tasks include monotonous measurements and searches over large water areas, rough inspections of large underwater structures (especially submarine cables and pipelines), transfer and release of objects that do not need to be precisely positioned (Mandžuka, 2009). In contrast to cruising divers, hovering divers are intended for exhaustive inspections and underwater work, for which they must have the ability to dynamically maintain position (stand still) and maneuver in all directions, often anchoring or attaching to an underwater structure at the place of the task. The distance that such a diver must travel independently is usually not large. A hovering autonomous diver has powerful maneuvering propulsors that will use more energy, can carry a variety of tools and instruments, and perform much more complex missions than a cruiser vehicle. There is also a transitional class between cruising and hovering vehicles. Such divers are intended for independent travel to a distant goal or a goal whose exact position is unknown, and then performing some simpler tasks there. Their typical application is finding, examining, and destroying sea mines, but similar requirements will be set for some other tasks, for example serving underwater stationary autonomous devices or oceanographic reconnaissance of points of interest on the ground. An AUV from the transitional class has a hydrodynamic body shape, and for maneuvering it uses control wings while traveling towards the target and maneuvering thrusters in the vicinity of the target. The most important are the vertical, usually tunnel, propulsors that enable the diver to float in place. However, its maneuverability is significantly reduced compared to real hovering vehicles (Mandžuka, 2009).

Universal and specialized AUV

Autonomous divers can be divided into universal and specialized ones. Universal divers are of modular construction and can be easily adapted for different types of missions by installing instruments and other necessary equipment. If the future tasks of the AUV during design are not completely known, then it is necessary to resort to universal versions, which is why, among other things, most experimental AUVs and technological demonstrations belong to the universal class. The most common missions of autonomous divers today fall on relatively simple measurements, searches, and inspections, and since there are many tasks with very similar requirements (only the instruments used different), it is worthwhile to design universal divers for such missions. Universal divers are more common than specialized divers. Specialized divers are adapted for only one type of mission, which is why they can be purpose-built and more efficient in performing their task. Of course, before starting the construction of a specialized divers, its type of mission must be clearly defined, and its future use on such missions must be certain. Specialized divers are almost always built to the order of a well-known user. For the construction of a specialized diver to be justified, its task must be sufficiently different from most others, or the specialized diver must be used frequently to perform tasks. Due to the clear goal and requirements, a specialized diver can be simpler and cheaper than a universal one. Accordingly, to this, there is an opinion that future divers on commercial and other tasks will have to be specialized (Griffiths, 2002; Radinov Radenković and Mandžuka, 2007). Some of the universal divers in operational use perform only one narrowly specialized type of mission. The border between specialized and universal divers is not firm, there are transitional solutions, and it can be noted that many specialized divers can be modified if necessary for missions different from the one for which they were designed (Vukić et al., 2002).

Deep (oceanographic) AUV and AUV for shall waters

An important property that significantly determines the appearance and construction of the AUV is the depth at which the diver will work. Deep-sea, mainly oceanographic, autonomous divers are designed to withstand the high pressures that prevail there. While divers for shallow water cannot dive to a depth greater than about ten meters and mostly work close to the surface. Regarding surface divers, we encounter problems of difficult navigation due to the action of surface waves. Because of the above, most AUVs are designed between these two extremes, i.e., for depths of up to several hundred meters.

Anti-mine diver in underwater protection

Hybrids between remotely controlled and autonomous divers are primarily mine countermeasures divers in military applications. In military doctrines, the sea mine has always been a weapon of the weaker side, which thus prevents the use of the sea by the stronger side. Sea mines can be used for defense against invasion and attack from the sea, for cutting off the enemy's supply and trade sea routes, as well as for diversionary raids inserted deep into the water area. Modern sea mines are stationary and placed under the surface of the water. The NATO alliance considers them weapons against which there is no satisfactory defense, so large financial resources are allocated for research and development of new mine countermeasures (Mandžuka, 2009; Radinov Radenković and Mandžuka, 2007).

The task of the anti-mine diver is to search the given area, closely examine suspicious objects, and next to those that turn out to be mines, place explosive charges that will neutralize them when the diver moves away. There is also important use of small disposable divers that will blow themselves up with explosives near the mine and thus destroy it, as well as survey class divers whose task is only to establish the position of the mine and thereby find a safe passage through the minefield or facilitate its clearing later. In a similar way can be searched for and neutralized unexploded bombs and missiles that have fallen into the sea. Current anti-mine divers are most often remotely controlled devices, equipped with their own energy source. They must stay close to the surface and be within range of radio waves or be connected to the mothership or submarine from which they were launched by a thin connecting cable. Because of that the human crew must be in the relative vicinity of the dangerous area. Robotization can be used very successfully, so the combination of an autonomous diver and a sea mine is not inconceivable. In this combination, it would be possible for the mine to reach the area that needs to be prevented by itself, or even actively seek and hunt its prey. Another potentially important, though not so devastating, application of autonomous divers is for reconnaissance and espionage. The importance of secrecy when talking about espionage is known, because of this wireless communication with the central would be prohibited and the collected data would be available only after the return of the diver. In peacetime, the use of underwater divers will be of great importance during rescue operations and the search for contraband in bunkers on the underside of the vessel or deposited on the bottom, if there is a need to find and rescue sunken cargo, including bodies of victims, containers with toxic chemicals, black boxes after aircraft crash and others (Mandžuka, 2009; Marani et al., 2009.; Radinov Radenković and Mandžuka, 2007; Vukić et al., 2002).

Another purely military application being developed is the detection and tracking of enemy vessels using high-speed autonomous divers. In the future, it is expected that underwater vehicles will be used for combat operations, as intelligent torpedoes, or mobile sea mines, or even for attacking targets outside the water, because the overall development of military technology is clearly moving in that direction. Here, the great powers would prefer to choose remotely controlled weapons that never independently decide on an attack (Vukić et al., 2002).

The AUV characteristics described in Chapter 3 are shown in Table 1.

TYPE OF THE AUTONOMUS UNDERWATER VEHICLE	CHARACTERISTICS OF THE AUTONOMUS UNDERWATER VEHICLE
CRUISING VEHICLES	- they move along the course without changing direction and speed - a simpler control system (in addition to the main drive propulsor for maneuvering, it uses control wings, not maneuvering auxiliary propulsors) - the hull has the shape of a hydrodynamic torpedo - task: monotonous measurements, rough inspections of large underwater structures, transfer and release of objects that do not need to be positioned precisely
HOVERING VEHICLES	- ability to hold position dynamically and maneuver in all directions, ability to anchor (powerful maneuvering propulsors) - task: thorough inspections and underwater work, performing more complex tasks compared to cruising vehicles
A TRANSITIONAL CLASS BETWEEN CRUISING AND HOVERING VEHICLES	- the hydrodynamic form - uses both control wings and maneuvering thrusters (lower maneuverability compared to hovering vehicles) - task: performing a simpler task, e.g., operating stationary autonomous underwater devices, oceanographic reconnaissance
UNIVERSAL AUV	- modular construction and can be very easily adapted to different types of operations by installing the necessary equipment - they are used when the future tasks of the AUV are not fully known in the planning phase - they are more common than specialized AUVs
SPECIALIZED AUV	- suitable only for one kind of mission - purpose designed and suitable for accomplishing the mission (before constructing specialized AUV, its type of mission should be clearly defined and its future use ensured)
DEEP (OCEANOGRAPHIC) AUV	- work at great depths - designed to withstand great pressures
AUV FOR SHALL WATERS	- work at a depth of up to ten meters, close to the water surface - the problem of difficult navigation due to the action of surface waves
A TRANSITIONAL CLASS BETWEEN DEEP AND SHALL WATER VEHICLES	- suitable for depths up to several hundred meters - mostly designed in conjunction with deep and shallow AUVs

HYBRIDS (VEHICLES BETWEEN REMOTELY AND AUTONOMOUS UNDERWATER VEHICLES)	- military application (anti-mine divers) - task: underwater research, mapping of underwater topography; inspection of pipelines, cables and underwater structures

Table 1. Important characteristics of the autonomous underwater vehicle (Source: author)

Table 2 shows the SWOT analysis of AUV for use in the Adriatic Sea.

STRENGTHS	WEAKNESSES
- Capacity to reach areas inaccessible to humans **- Capacity to support high risk activities** **- Capacity to monitor and repair pipelines and cables** **- Capacity to explore unexplored marine habitats**	- Requirements for highly qualified personnel - Lack of management and operational skills - Lack of law regulations - Underwater wireless communication should be improved
OPPORTUNITES	**THREATS**
- Increasing safety at sea and in general **- Approaching areas of high risk to humans** **- Approaching corners of the seabed that were previously inaccessible** **- Gathering more information about the underwater world**	- Loss of human control - Over-reliance on technology - Lack of cost-benefit analysis - Errors in the systems

Table 2. SWOT analysis of AUV for use in the Adriatic Sea (Source: author)

PLANNING THE MISSION OF AN AUTONOMOUS UNDERWATER VEHICLE

During the development of technologies for the detection of explosive devices, engineers encountered numerous problems. How to build a system that distinguishes explosive devices from the environment? How much will the composition of the environment affect the positive identification of explosive devices? If the system were to identify every rock, waste, every edge of the seabed as explosive devices, then they would spend a large amount of time examining non-existent hazards. Otherwise, if the system were to ignore a potentially exposed agent, an error could occur with dangerous consequences. The goal is to find an optimal strategy that would increase the certainty of mission success and optimize the test time, therefore trajectory planning for an autonomous underwater vehicle is challenging (Figure 3).

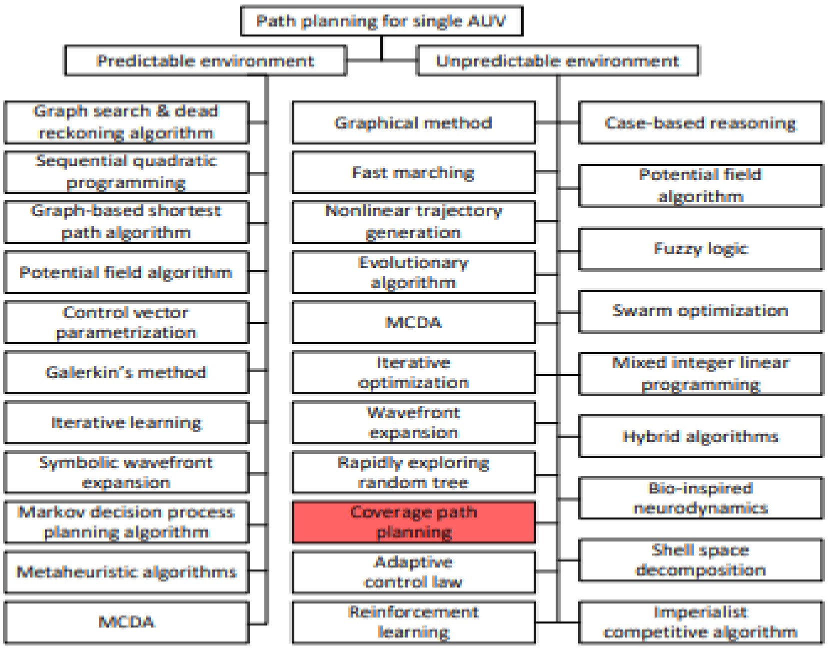

Figure 3. Summary path planning control of single AUV (Source: Wawrzynski et al., 2022)

AUV mission planning is usually carried out with dedicated software (e.g., Hugin OS, Gavia Control Center, etc.). The mission plan should consist of three basic phases:

- launching and immersion of the AUV vehicle,
- data collection process,
- ascent and recovery.

The first planning phase is the phase in which it is possible to achieve the force necessary to sink the vehicle. In the second planning phase, the route points of the AUV vehicle are added or already dedicated patterns are used (Figure 4). For the implementation of the mission aimed at researching port facilities and port surveillance, it is recommended to use the lawnmower model due to the highest search efficiency within the given time frames (Wawrzynski et al., 2022).

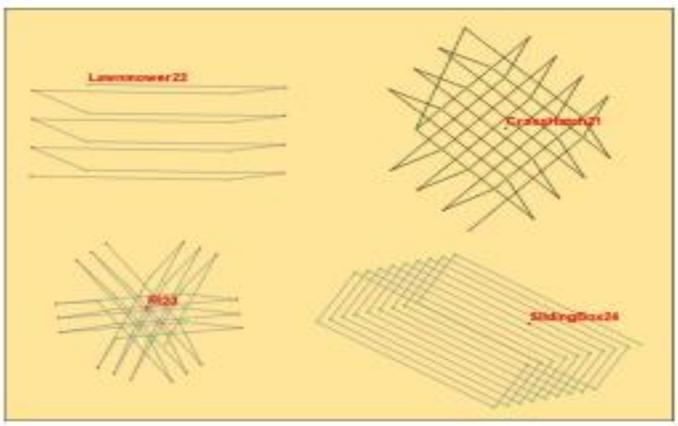

Figure 4. Exemplary trajectory patterns available in Gavia Control Center software (Source: Wawrzynski et al., 2022)

The AUV mission planning process requires the setting of operating parameters of individual subsystems: parameters related to the area of operation, parameters related to the position of the AUV, and parameters related to the AUV sensors (Hegrenaes et al, 2009; Jalving et al., 2003) (Figure 5).

AUV Mission planning parameters

No.	Parameters related to the area of operation	Parameters related to the vehicle position	Parameters related to the auv sensors
1.	operation area limited by geographical coordinates $(\lambda_1, \Omega_1, \ldots, \lambda_n, \Omega_n)$	vehicle altitude measured from the sea bottom	sonar (frequency, ping distance/overlap, near and far ranges, etc.)
2.	depths in area	vehicle positioning accuracy (SDNE – standard deviation of navigational error)	cameras (binning, exposure level, frame rate, light beam, aperture, etc.)
3.	seawater currents	vehicle depth measured from the sea surface	echo sounders (frequency, internal or external trigger, etc.)
4.	water salinity	mission plan waypoints described by latitude and longitude coordinates	
5.	water temperature	vehicle speed described by rpm (revolutions per minute) or speed (m/s)	
6.	speed of sound in water	mission time	
7.	sea state, etc.	vehicle course	
8.		vehicle manoeuvring characteristics (turn radius, acceleration, etc.)	

Figure 5. AUV mission planning parameters (Source: Wawrzynski et al., 2022)

Due to the number of input parameters and the need to take into account external factors that affect the behavior of the vehicle, the mission planning phase is the most important and demanding part of the operation. AUV operations aimed at maritime security surveillance require data collection and display with 100% area coverage. Area coverage is key during mine countermeasure's missions. Based on the knowledge of the area of operation and the technical capabilities of the autonomous system, the operator must choose the optimal settings and create a mission plan that will enable the completion of the tasks within the given time frame (Abreu and Matos, 2014).

The algorithm for generating the vehicle route is designed to shorten the time necessary to prepare the mission plan, consider the characteristics of the environment and the specifics of the AUV vehicle, and avoid errors generated by inexperienced operators (Wawrzynski et al., 2022). (Figure 6).

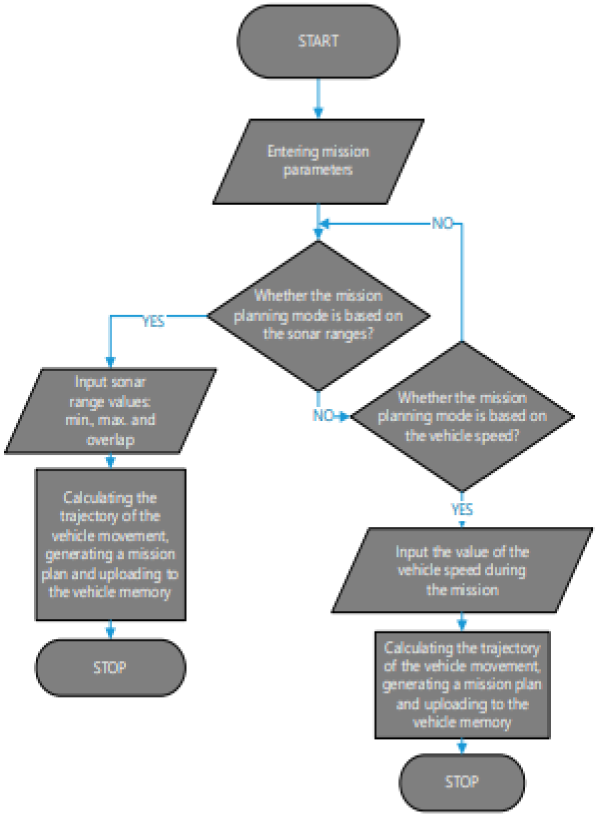

Figure 6. The algorithm for generating the optimal mission plan of the AUV Hugin System (Source: Wawrzynski et al., 2022)

The optimal distribution of the search pattern and the optimal trajectory of the AUV should provide full area coverage, taking into account external factors influencing the movement of the autonomous vehicle and the characteristics of the sensors used in data collection process.

For systems equipped with side sonars, the previously mentioned lawnmower pattern provides the ability to cover the lowest distance below the sonar probe. The distance between the mission plan line is determined by the sonar detection ranges, i.e., the maximum (Rmax) and minimum (Rmin) range (Sanchez et al., 2020; Wiig et al., 2017).

The optimal trajectory of the AUV can be determined in the following ways (Abreu and Matos, 2014; Wawrzynski et al., 2022):

- By entering or loading from a map based on the WGS84 (The World Geodetic System 1984) projection the geographic coordinates describing the area of operation in the format φ = 000°00.000´N, λ = 000°00.000´ E
- Conversion of geographic coordinates into positional points expressed in meters (x, y, z)
- Rotation of the area around the z-axis by the angle value determined in the mission plan by the operator, equal to the general course of movement of the vehicle during the mission.
- Designation of the vertex with the maximum value of y (max) as a reference point from which parallel lines are determined.
- Determining, as a result of successive repetitions that form parallel lines as the basis for generating the vehicle path.
- Re-rotation of the area and designated mission points around the z-axis.

To play such an important role in quickly and safely demining the area, the AUV needs to move properly through the area. Therefore, it is necessary to plan the route carefully to sample the entire area. There is an abundance of path planning algorithms in the literature and for this specific application a small subset known as coverage path planning (CPP) algorithms is usually used (Abreu and Matos, 2014). Then it is understandable why the mission planning phase of traditional mine countermeasures (MCM) operations is so important and often takes as much time as the research: it is necessary to find a path that increases the probability of detecting mines (hence reduces the risk) and minimizes the operational expenditure of time and energy.

CONCLUSION

Today, in a world with the daily development of threats to national security and as well communication technology, the state's investment in the additional development of crisis management systems and the use of artificial intelligence to identify and neutralize threats is essential. One way is the application of autonomous underwater vehicles in the protection of the sea. Thanks to robotization, the possibilities of protecting national interests for exploration and exploitation of the undersea are opening, and many hitherto completely unrealistic plans are thus becoming closer to reality. In general, robotics and autonomous vehicles are recognized as a strategically key area of military systems development in the near future. Although the navies for a long time ignored all the successes that autonomous aerial vehicles achieved in the use of air and ground forces, the time has finally come for the principle of autonomous vehicles to be applied at sea as well. So far, the emphasis is on mine countermeasures and surveillance, even though the possibilities of technology are much greater. Although the goal of roboticists is as much autonomy as possible, it should be noted that at this moment a completely independent robotic vehicle has not been made, but we have a device that will perform its tasks relatively intelligently and reliably with the help and in close cooperation with human operators, as well as other robotic vehicles.

In future works, it is planned to investigate in detail the application of AUV in relation to the safety of the Adriatic Sea.

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Combat System on the Croatian Navy Fast Attack Craft “Kralj Petar Krešimir IV”

Darija Jurko[1], Luka Mihanović, Milan Blažević[2], Dario Javorčić[3]

The European security and defense policy enables the use of EU members’ military and civilian assets for various operational tasks in accordance with the international law. Depending on the nature, scale and the overall impact of a crisis, some situations may require the use of military force. Unlike merchant ships, naval warships have weapons and associated combat systems in order to carry our various combat tasks. Combat systems are the foundation of naval warships and determine their combat power. Combat systems can vary in elements and the level of integration, depending on combat tasks. Numerous global defense industry companies have been developing their combat systems in accordance with new technologies, warfare doctrine and different types of threats. One of the world’s leading companies in the defense industry is the Swedish SAAB, which has been developing the 9LV combat system, integrated on different warships around the world. The system provides complete Command, Control, Communications, Computers and Intelligence (C4I) support for all types of naval warships (from patrol ships, frigates and even larger ships and/or submarines), enabling the commanding staff with exceptional operational capabilities. The 9LV fire control system is integrated on several fast attack crafts of the Croatian Navy, and the first Croatian Navy fast attack craft with this type of fire control system is the RTOP-11 “Kralj Petar Krešimir IV”.

KEY WORDS

Security, Defense, Warships, Combat system, 9LV fire control system.

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INTRODUCTION

Even though the primary purpose of military assets is the combat power projection in a war, the EU members' military and civilian assets are used for various operational tasks in peace-keeping operations, conflict prevention, as well as strengthening the international security, in accordance with the international law. Some of those situations may require the use of military force, depending on the nature, scale and the overall impact of a crisis. Military naval forces (Navies) have been used to keep the *Sea Lines of Communications* (SLOC) secured; whether they would keep them open during peacetime, or closed during wartime. Today, the importance of the SLOC is unquestionable, economically as well as geopolitically, and their security is jeopardized by various asymmetric threats.

Unlike merchant ships, naval warships have weapons and associated combat systems in order to carry out various combat operations. Combat systems are integrated on warships with the purpose of monitoring the adversary's combat actions at sea, and to control possible combat response. They are the foundation of naval warships and determine their combat power, and thus their ability to perform certain combat operations. A warship is one of the most complex combat assets today. In a relatively small space, different systems are combined in order to perform anti-air, anti-surface and anti-submarine warfare, as well as electronic and cyber warfare. The increase in the number of systems and the amount of information that needs to be processed in the extremely dynamic combat environment at sea has resulted in development of advanced weapons *Firing Control Systems* (FCS). The FCS has become a system for managing the entire spectrum of combat capabilities - *Combat Management System* (CMS). The CMS is highly automated, with full sensor fusion; it is capable of processing huge amount of information, can track thousands of targets, analyzes and prioritizes threats and links weapons with sensors. Another important task is the integration with other "friendly" systems and information exchange in real time.

The development of new types of weapons has resulted in new forms of threats, which should be considered during the warship design. A modular approach is being applied more and more, where the system on board can be reconfigured depending on the type of task and possible threats. A flexible "Open Architecture" CMS design allows substitution of individual weapons systems or sensor systems, while maintaining the same level of system functionality. (Janer and Proum, 2014) Numerous global defense industry companies are developing their combat management systems in accordance with new technologies, warfare doctrine and types of threats. The world's most advanced naval combat system today is the Aegis Combat System, produced by the American company Lockheed Martin. This system can simultaneously coordinate attacks on land targets and targets at sea, and at the same time protect its own forces from various threats. Other companies that dominate the market of global naval combat systems are ("Top 5 Vendors in the Global Naval Combat Systems Market from 2017 to 2021: Technavio" 2017) : BAE Systems, Raytheon, Thales and Swedish company SAAB. SAAB[1] has been developing its 9LV[2] combat system since 1970s. The system can be used in all areas of naval warfare, in littoral as well as open sea combat operations and supports all three dimensions of naval warfare – air, surface and sub-surface. The system provides complete C4I support for all types of naval ships, enabling the commanding staff with exceptional operational capabilities. It is well adapted system for a range of mission types at all levels of conflict, such as: *Anti-Access/Area Denial* (AA/AD) operations, protection and escort, maritime patrol and response, border control and interdiction, *Peace Support Operation* (PSO), anti-piracy, *Search and Rescue* (SAR), environmental control, etc.(*9LV CMS | Saab*, 2023) The 9LV combat system with different options[3] is currently used by 20 navies worldwide, such as Royal Swedish Navy, Canadian Navy, Australian Navy and some smaller navies such as Croatian Navy where it is integrated on several Croatian Navy missile attack ships. In addition to 9LV combat system, Croatian Navy also uses systems Deimos (weapons firing system) and Fobos (missile weapons system), designed by the Croatian company Marine Electronic Center [4]- Split. Deimos and Fobos system are integrated on the fast attacks crafts RTOP-21 "Šibenik" and RTOP-12 "Kralj Dmitar Zvonimir", while 9LV system is integrated on RTOP-11 „Kralj Petar Krešimir IV" (Figure 1), RTOP-41 "Vukovar" and RTOP-42 "Dubrovnik". The 9LV system presented in this article is a 2nd generation configuration (Mk2 and Mk2,5) that was started to be developed in 1980s, and was integrated on the fast attack ship RTOP-11 "Kralj Petar Krešimir IV" at the beginning of 1990s. In that configuration analog systems have dominated and simple system changes and reconfigurations were not possible. A step forward was made during the construction of RTOP-12 "Dmitar Zvonimir" where digitalization enabled configurations of the systems with multifunctional consoles and the connection of all systems via a central optical cable. Due to the classification restrictions, certain information is not presented and all tactical and technical information given here are taken from open sources.

Figure 1. Croatian Navy fast attack craft RTOP-11 „Kralj Petar Krešimir IV" (Source: Flickr, https://www.flickr.com)

COMBAT SYSTEMS

Brief history of Combat Systems

At the beginnings of the development of combat operations, simple optical devices (rangefinders) were used to provide information on the range and bearing of the target, but their use was limited at night and in bad weather conditions. At the end of 19th century warships started to use rangefinders to determine target coordinates, and begun to organize special spaces onboard dedicated exclusively as gunnery-calculation centers. Today, such a space onboard warship is called *Combat Information Center* (CIC). In 1920s electronic connection enabled development of devices for central targeting and electronic firing of naval guns. After the First World War, first range clocks[5] were developed for controlling naval guns. Between two World Wars firing systems were significantly automated, electromechanical elements and electrical connections were improved, as well at the operation accuracy. At the beginning of the Second World War the first radar was independent from weather conditions and time of day, very accurate in determination of target coordinates, and had possibility of automatic tracking of selected targets. ('Radar', 2023) During the Second World War the use of radar was intensive, which resulted in further improvements in target detection, range determination, and surveillance in low visibility. Parallel to the development of radar systems, the means and devices for jamming them were also developed, which resulted in uncertain and unsecure use of radars. An automatic radar targeting was used at the very end of the war when targeting radar would automatically get the information on the course and speed of the ship, wind direction and speed, digital clock, which represents the beginning of integrated information combat systems. A Doppler Effect[6] technique enabled more accurate and faster determination of the range, bearing and speed of a moving target is achieved, while the sensitivity to electronic jamming and bad weather was reduced. New measuring devices and methods were used for determining distance (range) such as infrared (IR) and television (TV) targeting devices. The development of missile firing systems starts at in the 1960s, dividing firing control systems into gun firing system and missile firing systems. By the end of the last century, integrated combat systems were developed for operation in all areas of naval warfare[7].

This century has brought extreme advances in the combat systems networking, used by different combat systems platforms. All available information resources are inducted into combat systems. *Command, Control, Communications and Intelligence*[8] (C3I) is a command and control system as a subsystem of the entire combat organization. It enables processing of data and information onboard, as well as connection with the command on land, transmission of data, information and orders. Such systems must work together with warship's combat system, which provides support for decision-making process in situations when weapons are to be used. The implementation of C3I and similar systems significantly increases the possibility of making optimal decisions during the combat tasks. They exist at all command levels, from tactical to strategic, and have different degrees of integration.(Perić, 2002)

Combat Systems in General

Today, companies engaged in the defense industry offer modular types of combat systems that meet C4I requirements and offer exceptional operational capabilities that enable different platforms with weapons to respond to all types of combat operations in a variable environment. New solutions support a large number of weapon systems and meet the requirements of combat resilience. Medium-sized configurations are often based on one type of mission and larger configurations enable a wide range of capabilities and usually contain multiple links for the exchange of tactical data and a highly automated system of tactical responses to a wide range of simultaneous threats, above and below the sea surface.(*9LV CMS | Saab*, 2023) Figure 2 represents an example SAAB's CMS integrated in the CIC onboard HMAS "Perth".

Figure 2. SAAB Saab's combat management system aboard HMAS Perth (Source: UPI Defense News, https://www.upi.com/Defense-News/2017/)

The world's strongest navies develop all areas of naval warfare while small navies, such as the Croatian Navy, develop capabilities for certain areas of warfare and are therefore limited to certain tasks and missions. Tasks of the ship's combat system are derived from tactical requirements for conducting combat operations at sea and must ensure readiness for combat operations- for offensive and defensive operations, in conditions of intensive enemy electronic operations.(Kulić, 2002).

Combat operations require a high degree of integration and automation of all components of the combat system (sensors, computers, weapons), but also good communication with friendly forces at sea, on land and in the air. Warships are equipped with various types of weapons that are used for different targets. Figure 3 shows launching of the anti-ship missile RB-15B from the Croatian Navy fast attack craft RTOP-42 "Dubrovnik" during "Velebit 18" exercise in 2018. Warships therefore use different calibers of naval guns that can use various bullet grains; they also use anti-ship and anti-aircraft missiles as well as mines and torpedoes.

The combat system must also integrate electronic warfare equipment that could anticipate the enemy's intentions, detect possible threat, and accordingly defend own ship with "soft kill"[9] and "hard kill"[10] equipment and weapons.(Rubić, 2010) Every combat system must have effective sensors. Sensors monitor the environment and through the acquisition phase, detect and identify the enemy target, determining its coordinates, platform and affiliation. The target is then tracked and the target data is forwarded to the *Tactical Computer* (TC) which will calculate elements for combat reaction. *Artificial Intelligence* (AI) has been used a lot recently to speed up data processing and calculation of necessary elements for launching various missiles which will significantly increase the effectiveness of target destruction. Also, each warship can exchange data combat situations with other combat platform that have interoperable communication equipment, standardized message formats, standardized operational procedures and standardized communication links.

Figure 3. Launching of RB-15B from RTOP-42 „Dubrovnik“ (Source: MORH, https://www.morh.hr)

THE 9LV COMBAT SYSTEMS DATA FLOW AND ELEMENTS

Every combat system integrates and controls resources and devices to engage targets at the sea, under the sea, on land and in the air, with appropriate weapons (e.g., missiles, naval guns and torpedoes). A combat system must enable sensor management, integration of sensor data, threat assessment, weapons assignment and firing control. The integrated combat information system onboard warships is used for surveillance the sea surface and airspace around the ship, control gun firing and missile launch, as well as defend against enemy's incoming missiles. The 9LV system onboard RTOP-11 can be used in all weather conditions and during intense electronic jamming. It provides tactical presentation of the situation, air targets tracking, surface targets tracking, monitoring of hits, distribution of targets by elements of the combat system, and firing at land targets.(Kulić, 2002)

Elements integrated into a single combat system differ from ship to ship, depending on requirements and missions of certain warship. The 9LV combat system onboard the RTOP-11 can be divided into four subsystems: the sensor subsystem, the data processing subsystem, the command and control subsystem, and the executive system.(Kulić, 2002) All of those systems have specific tasks and elements. Targets are basically data that the combat system processes, and that data should be as accurate as possible. Data needs to pass through all subsystems of the integrated combat system (Figure 4).

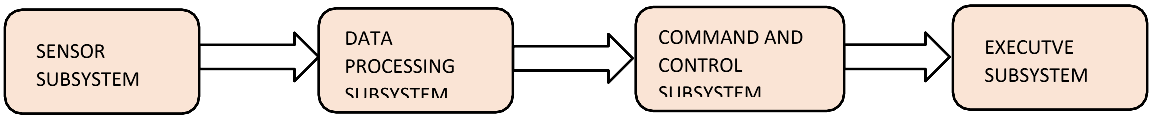

Figure 4. Subsystems of combat systems (Source: Author)

The sensor subsystem contains sensors for collecting data and that collected data is processed in the data processing subsystem, which process, adjust and distribute data to the next subsystems. The next subsystem that processes information about the target is the command and control subsystem, which is intended for command, processing, selection and control of the weapon systems on board. Information is then sent to the executive subsystem, which represents the type, and quantity of weapons that ship has.

The 9LV combat subsystems and elements are show in Figure 5.

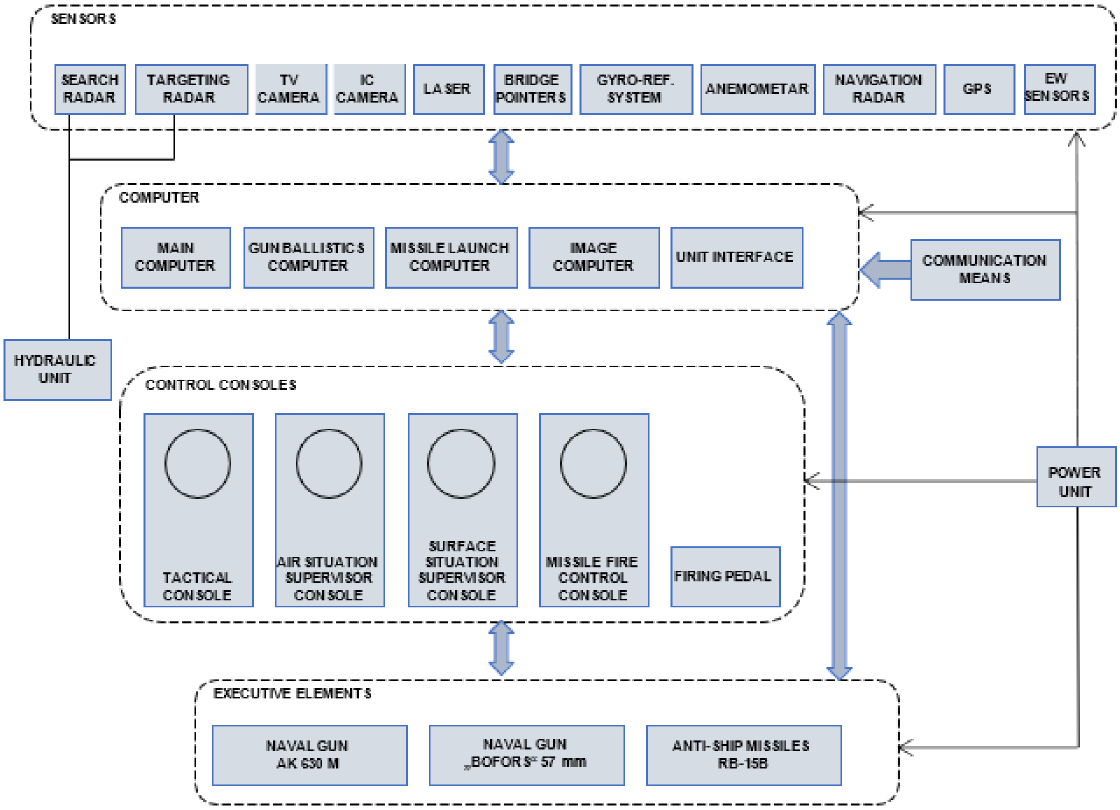

Figure 5. Integrated combat system onboard RTOP-11 (Source: Author)

Every subsystem is consisted of number of elements. Their number and technical requirements vary, depending on the size of the system and combat tasks. Many times, the role of elements can overlap which contributes to the overall resilience of the system, which is important ability in combat environment.

The sensor subsystem collects data necessary for processing and control of weapons firing. It contains sensors for collecting data on targets, data on own position and movement, as well as data on the state of environmental conditions, and auxiliary or additional sensors. The main task of sensors is to monitor targets in available scope, have a high reliability rate of detecting targets, to classify them and determine their position as accurately as possible.

Figure 6. shows some of the sensors onboard RTOP-11. Most of the sensors on any warship are positioned on ship's superstructure.

Figure 6. Sensors position on RTOP-11 superstructure (Source: Paluba, https://www.paluba.info)

Sensors for collecting target data are ('Technical instructions SUV 9LV 209', 1990):

- **Search radar**, also known as surveillance radar is used to scan the air and surface situation around the ship, to detect target and provide sufficiently accurate data for target acquisition and tracking. By choosing different modes, it can distinguish between moving and stationary targets. The range of the search radar depends on the radar design and its transmitter, but the most common ranges are from 50 km to 150 km with the possibility of tracking up to 100 different targets. Modern and larger ships have radars with a range up to 400 km and the ability to track 1,000 different targets.
- **Targeting radar**, also known as Fire Control Radar (FCR) is used for scanning and tracking aerial and surface targets, target acquisition after indication, and simultaneous scanning and marking the bullet grain path during firing. Targeting radar is placed on the same stand as the TV camera, IR camera and laser, and together they form a system that we call the director (Figure 7).
- **TV camera** is used for monitoring and tracking air and surface targets and to observe the fall of bullet grains when firing at surface targets. It is possible to switch to TV tracking in case of difficulties in radar tracking.
- **IR camera** is used for monitoring and tracking targets at night using the source of thermal infrared radiation. An IR camera can also be used together with a laser to determine the exact range to the target; and together with a TV camera to observe the path and fall of bullet grains during gunnery fire.
- **Laser** is used as a rangefinder and serves to measure the range to the target when the targeting radar is jammed. In integrated combat systems, the laser has a range from 300 m up to 20 km.
- **Bridge pointers** are used to mark targets i.e. to indicate the bearing to the target to the operators on consoles as well as to initialize tracking. Target marking is used in conditions of limited radar visibility, by pointing the bridge pointer in the direction of the target and pressing the marking button.

Figure 7. The director - a targeting radar, a TV camera, an IR camera, a laser (On Target Alignment, https://www.ontargetalignment.com)

Sensors for own ship's data are ('Technical instructions SUV 9LV 209', 1990):

- **Gyro-reference system** is intended for determining the course and position of own ship. It provides data on the ship's roll, pitch and course; distributes this data to the 9LV system, the navigation radar and the missile weapons system. The obtained data are used for the stabilization and orientation of radar antennas, for the calculation of the gun's relative angles, as well as the calculation of the exact position of the ship.
- **Anemometer** measures the speed and relative wind direction in relation to the ship. After data processing, the true wind direction and speed are obtained, which are used in further ballistic calculation.
- Additional sensors are:
- **Navigation radar's** basic purpose is to support navigation and ship handling. A navigation radar can also provide data to in conditions of radar silence (surveillance and targeting radar) with the aim of reducing the possibility of detection by the enemy.(Kulić, 2002)
- **Global Positioning System (GPS)** is used for accurate determination of own ship's position, i.e. aligning the position on the Plan Position Indicator (PPI[11]) by latitude and longitude. This way, the combat system is used more effectively during indirect targeting or data exchange with friendly units.
- **Electronic Warfare (EW)** sensors are used to detect any signal from enemy's laser or radar which can anticipate enemy's intentions. Data acquired is used during ship's defense with "soft" and "hard" electronic measures.

The sensor system is show in Figure 8.

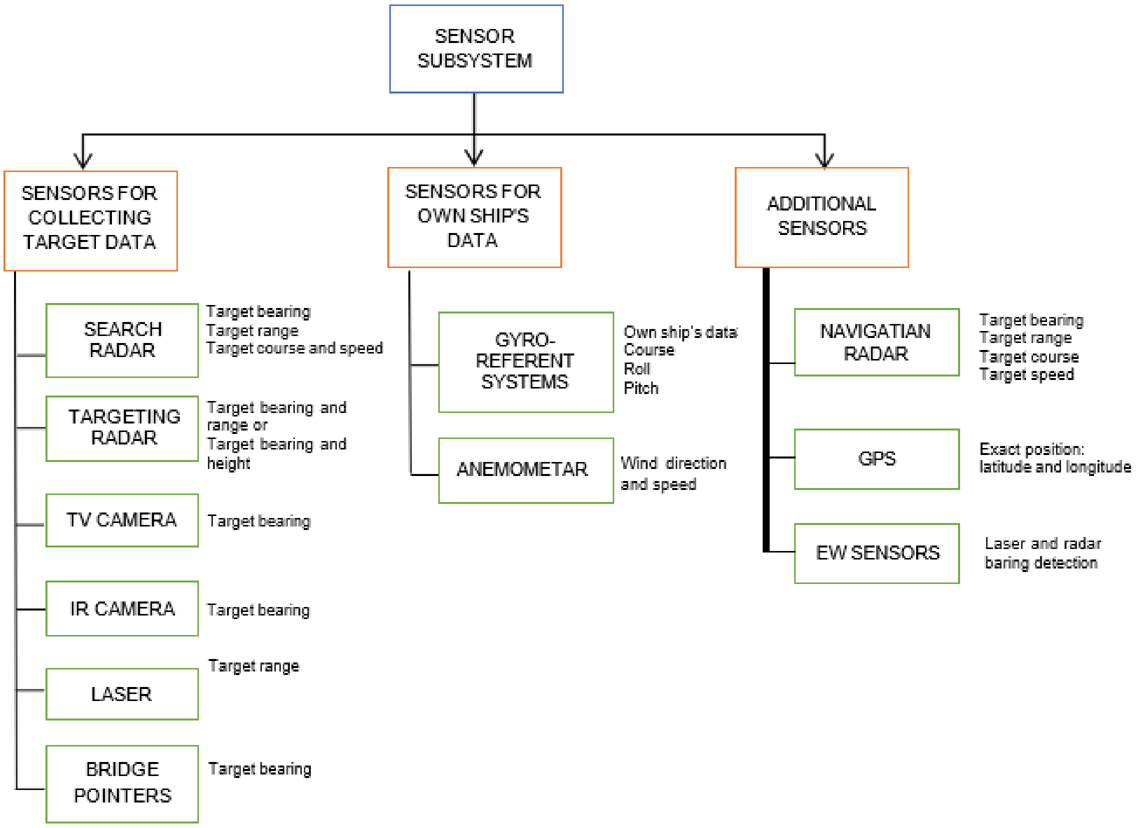

Figure 8. Sensors subsystem onboard RTOP-11 and data sent to data processing subsystem (Source: Author)

<u>The data processing subsystem</u> is intended for the processing, adjusting and distribution of collected data. It is the central part of control system and consists of main computer, gun ballistics computer, missile firing computer, image computer and unit interface (Kulić, 2002):

- **Main computer** is used to boot the system as well as for target tracking, ballistic calculation and calculation of relative gun angles, director and surveillance radar control, recalculation of coordinates due to ship's roll and pitch, data transfer control, the alphanumeric control, communication and representation on control consoles, calculating necessary data for the presentation of symbols on PPIs, and for verifying the correct system operation.
- **Gun ballistics computer** provides output data for gun firing, based on target data, wind data, own ship's data, and the data on the type of naval gun ammunition, and gun limitations.
- **Missile launch computer** perform calculation and conversions to get necessary data for the missile launch and missile flight path. It controls the operation of the entire missile weapons system and communication between the system and the missiles on board.
- **Image computer** serves for the radar image presentation depending on the movement of the time base and the radar pulses frequency repetition, as well as the antenna angle rotation. It also generates all the symbols used on PPIs.
- **Unit interface** contains devices for adjusting the signal format into the appropriate forms that computer can use.

The command and control subsystem is intended for monitoring, processing, selection, management and control of all collected data on targets and for managing weapons systems on board. This subsystem is used by operators on following consoles: tactical console, surface situation supervisor console, air situation supervisor console and missile fire control console. ('Technical instructions SUV 9LV 209', 1990) All consoles are modular designed which enabled simple construction and arrangements of serial link, that connects all modules to the computer.

- **Tactical console** provides the Commanding Officer (CO) with the tactical situation control, indication of targets, exchange of tactical situation with other friendly ships, input data for radio communication, review of automatic target tracking, radar selection (targeting, surveillance or navigation), and adjustment of receiver and PPI for an optimal picture. Using information from the tactical console, the CO evaluates, commands, and controls the combat situation and can make decisions and give out orders.
- **Air situation supervisor console** is used to monitor the airspace around the ship and defend against air attacks, but can be also used for combat operations against surface and land targets.
- **Surface situation supervisor console** is used for monitoring the surface targets and controls the gun firing at surface targets. The PPI gives the same picture to both consoles. Operators on both supervisor consoles can execute remote gun firing from the ship's CIC.
- **Missile fire control console** is used to control the missile weapons system and to launch missiles. It can work in simulation, test and combat mode. Preparation of the missile before launch is carried out via the *Missile Fire Control Unit* (MFCU), which is the link between the integrated combat system and the missile itself. The MFCU constantly calculates the launch conditions and controls launch sequence.(Kulić, 2002)

The executive subsystem represents the type and number of weapons that ship has at a disposal, which are most often anti-ship and anti-aircraft guns and missiles, as well as torpedoes. Specifically, onboard RTOP-11 those are: the "Bofors" 57mm D70 naval gun, the AK-630M naval gun, and "SAAB" RB-15B anti-ship missiles.

The success of combat action depends on the reliability and availability of all subsystems of the combat system as well as on the level of training of the crew that operates the integrated combat system, electronic defense, guns and missiles limitation, and the maintenance of the system. Based on collected, processed and displayed data, the ship's CO makes a decision on which weapon to use on which target and at what time.

Figure 9. shows the data flow in the combat system from the sensors to the output through the implementation units (missiles and guns).

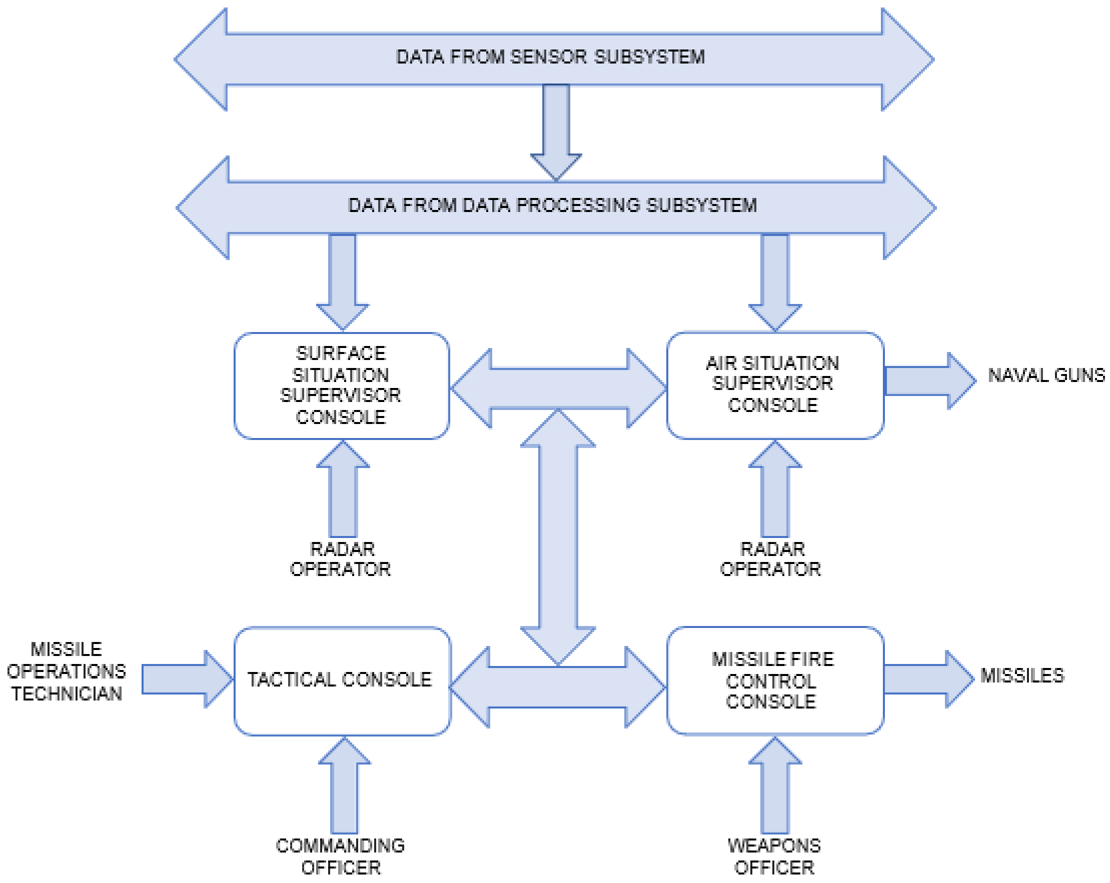

Figure 9. The 9LV combat system data flow diagram (Source: Author)

SUMMARY

The modern combat integrated information system 9LV is a complex information system consisting of subsystems equipped with information resources that provide support in the execution of combat operations. The use of advanced combat systems in combat operations at sea enables operation execution in a timely and correct manner by providing reliable and accurate data and information.

The application of combat information systems enables commanding officers to have a layered, more detailed presentation and understanding of the tactical combat situation at sea. With the aim of increasing support for command and decision-making process throughout the entire life cycle of an individual warship, command and information systems are inducted and used at all command levels.

This article presents the combat system 9LV integrated on Croatian Navy fast attack craft RTOP-11 “Kralj Petar Krešimir IV”. Although this system belongs to the 2nd generation of combat systems, it still meets the requirements set for this warship when carrying out specific combat operations.

The 9LV combat system, as one of the most famous combat systems in the world, is capable of long-term use, which shows the exceptional quality of the system's performance and construction. Due to the "Open Architecture" approach for new systems, it can be upgraded with new and more advanced hardware and software modules in order to increase reliability and availability in the use of various combat operations.

ACKNOWLEDGEMENT

All technical data and photographs in this article are unclassified.

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Adjustment of Records: A Global Crosssectional Survey on the Implementation of Work and Rest Regulations at Sea

Bikram Singh Bhatia, Maria Carrera, Raphael Baumler

Introduction: Fatigue among seafarers has received adequate research attention over several decades, yet it remains under-addressed, making it a growing concern. Currently, the work-rest regulations of the IMO/ILO are the sole indicators of fatigue in this population. However, recent research has raised concerns regarding the implementation of these regulations, including reporting and compliance.

Method: The study utilized quantitative research to survey seafarers worldwide. An online cross-sectional survey captured seafarers' experiences with the implementation of work-rest regulations. In particular, the survey inquired about their recording practices, compliance with work-rest regulations, and actions in response to non-compliance.

Results: Out of the 4287 seafarers' responses, most (77.2%) used computers to complete their records. Eighty-six percent (85.9%) of seafarers reported exceeding work-rest regulatory limits at least once a month, with an average of 7.0 non-compliance per month. Despite this, a significant proportion (49.9%) chose not to report these incidents to their company. Forty-six percent (46.4%) reported that their companies did not respond to their concerns, while 67.1% reported that senior onboard officers were questioned about their work-rest hours management by the company. Only 31.5% admitted to accurately reflecting the record. The primary reasons for adjusting the records were to avoid findings during inspections (80.3%) and problems with the company (75.1%). Sixty percent (60.1%) of the seafarers stated that their company expected them to adjust their records, with 48.9% reported making adjustments on the company's instructions. Only 21.8% reported that their ships were provided with additional workforce.

Conclusion: A large-scale survey showed that seafarers and shipping companies prioritized following record-keeping procedures over addressing work-rest compliance challenges. The adjustment of records hinders accurate reporting, leading to a false sense of compliance with the regulatory framework applied by seafarers to manage their fatigue.

KEY WORDS

Seafarer, Fatigue, Working time, Work-rest records, Falsification of records, Adjustment of records

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INTRODUCTION

The crucial role of the shipping industry in supporting the global economy by enabling the movement of goods and services cannot be overstated (UNCTAD, 2021). Seafarers are the backbone of this vital industry and ensure the delivery of essential goods such as food, fuel, and medicine to communities worldwide. Despite their critical importance, seafarers often face challenging working conditions, including a range of detrimental occupational and environmental factors, such as long and irregular working hours, which result in high levels of fatigue (Project MARTHA, 2017; Andrei *et al.*, 2020).

Seafarer fatigue has become a pressing problem, and its impact has been well documented in the scientific literature. The negative effects include decreased performance (Project HORIZON Consortium, 2012), increased risk of accidents (Marcus and Rosekind, 2017; Parenteau *et al.*, 2022), and adverse health effects (Wadsworth *et al.*, 2008) has been widely recognized. While the literature on seafarer fatigue has grown and expanded in its length and breadth over the years (Gander, 2005; Allen, Wadsworth, and Smith, 2008; Jepsen, Zhao, and van Leeuwen, 2015; Dohrmann and Leppin, 2017; Kerkamm *et al.*, 2022), it provides conclusive evidence that the problem is increasing, not diminishing, and largely remains under-addressed.

Regulating seafarers' fatigue via work-rest hours falls under the International Maritime Organization (IMO) and the International Labour Organization (ILO). The IMO[1] adopted provisions on rest hours for watchkeepers seafarers under the Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), 1978, as amended, in 1995. The ILO[2] adopted the Convention on Seafarers' Hours of Work and Manning of Ships, No. 180 (C180), in 1996, limiting seafarers' work-rest hours. The ILO later adopted the Maritime Labour Convention 2006 (MLC, 2006), integrating provisions from the C180 into regulation 2.3. Further, the IMO's STCW 1978, as amended, and the ILO's MLC, 2006, required seafarers to maintain records of their work-rest hours for monitoring and verification purposes, which became mandatory in 2002 (Baumler, 2020). Although these regulations are assumed to effectively manage seafarers' fatigue, their implementation has been questioned.

Research has revealed the widespread adjustment of seafarers' work-rest records, raising serious doubts about implementing these regulations (WMU, 2020). Such malpractices have been documented since the earliest stages of mandatory record-keeping in 2002. For instance, Bloor *et al.* (2004) found early evidence of seafarers' 'routine falsification[3]' of work-rest records. The Cardiff research group survey by Allen, Wadsworth and Smith (2006) revealed that only 37.3% of participants did not 'under-report'[4] their working hours. Furthermore, Simkuva *et al.*'s (2016) survey found that 52% of seafarers 'distorted' their work-rest records. Recent research (WMU, 2020; Baumler, Bhatia and Kitada, 2021) reinforced previous findings and reported that all seafarers interviewed had witnessed or participated in adjusting work-rest records. The study further suggests the existence of a 'culture of adjustment' that indicates a growing systemic acceptance towards such malpractice and failure by the maritime industry to address the issue effectively.

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[1] Following high-profile accidents such as capsizing of Herald of Free Enterprises and grounding of Exxon Valdez, IMO developed and adopted a number of instruments on seafarers' fatigue to improve safety, In that respect, regulating seafarers work and rest hours was an important development (Baumler, 2020).

[2] ILO adopted C180 after recognizing its failure to regulate work hours since 1919.

[3] Literature has utilized different phrases like falsification, under-reporting, distortion, etc., to portray the deliberate act of hiding non-compliance to work and rest regulations. Nonetheless, for consistency, the paper has opted for a soft term "adjustment" to depict the intentional act of concealing non-compliance with work and rest hours regulations.

[4] Further, respondents who did not under-report were in better health and experienced less fatigue compared to those who under-reported.

Given the concerns surrounding the adjustment of work-rest records, it is essential to assess the prevalence of this culture in the global seafaring workforce. A cross-sectional survey was identified as the most appropriate research method to accomplish this objective. This survey method is advantageous because it enables the investigation of both the extent of adjustment of records and the collection of valuable insights from a representative sample regarding their experiences with recording and reporting work-rest (De Vaus, 2013). Ultimately, the survey results will not only shed light on the extent of the problem within the industry, but also inform efforts to enhance regulations on seafarers' work-rest.

METHODS AND MATERIALS

A global cross-sectional survey was conducted to capture seafarers' experiences related to recording, reporting, and compliance with work-rest hour regulations. The survey was adapted from previous qualitative studies focused on the subject (WMU, 2020; Baumler, Bhatia and Kitada, 2021). It consists of 77 questions organized into 12 sections. The response order was randomized to eliminate bias, and the two questions were reverse coded to increase validity. Both qualitative[5] and quantitative data were collected through a combination of open and closed-ended questions. The survey was made accessible in six languages: Chinese, English, Indonesian, Russian, Tagalog (Philippines), and Ukrainian. It underwent rigorous review and pilot testing by industry, language and technical (software)[6] experts to ensure content validity.

The study population included seafarers who worked on commercial ships on or after February 1, 1997[7]. The survey was open to participation for six months, from June 29, 2022, to December 31, 2022. It was widely promoted through various maritime industry organizations and associations, and online maritime news (on social and print media) to reach a representative sample of the seafaring population.

The study was approved by the WMU Research Ethics Committee (REC), ensuring participant anonymity and confidentiality. The study was developed under the guidelines of CHERRIES (Eysenbach, 2004), CROSS (Sharma *et al.*, 2021), and the Survey Checklist Manifesto (Gehlbach and Artino, 2018) to guarantee the validity and reliability of the results.

RESULTS

The survey collected data from seafarers across the globe regarding their recent (current or last ship)[8] experience with work-rest hours. A total of 9213 surveys were initiated, with 4350 completed, yielding a response rate of 47.2%. On average, the participants took 17 minutes to complete. SPSS was used for the data analysis. Prior to the analyses, the data were cleaned by removing outliers (i.e., inconsistent, or unusual responses). Finally, 4287 responses were included in the study.

The subsequent sections present descriptive data on sample characteristics, the recording system, instances of non-compliance, the extent of adjustment, its justification, and actions taken in response to non-compliance.

[5] These data are not presented in this paper.
[6] Question Pro web-based survey software was used for this study.
[7] The 'fitness for duty' regulation of the IMO STCW, 1978, as amended, came into effect on 1st February 1997, which sets limits on rest hours for watchkeeping seafarers.
[8] Current ship for respondents who were on board the ship at the time of responding the survey, while last ship for those who were not board, including those who have signed off, or are unemployed, or are working ashore.

Sample socio-demographic and work-related characteristics

As outlined in Table 1, the average age of the participants was 37.7 years, ranging from 18 to 78 years. The sample comprised of 95.4% male and 4.1% female participants. Most of the participants were from India (29%), Philippines (10.1%), China (9.2%), Ukraine (7.1%), and Indonesia (4.4%).

Socio-demographic & work-related characteristics	Number of respondents (n=4287)	Percentage (%) 100%	Socio-demographic & work-related characteristics	Number of respondents (n=4287)	Percentage (%) 100%
Age group (years)			**Working status**		
<19	4	0.1%	**Currently on board**	**1815**	**42.3%**
20-29	957	22.3%	**Not on board (last sign off)**	**2472**	**57.6%**
30-39	1803	42.1%	After Aug 2013	2319	54.1%
40-49	937	21.9%	Between Aug 2013 - Aug 2002	72	1.7%
50-59	401	9.4%	Before Aug 2002	31	0.7%
60-69	166	3.9%	**Type of ship (Top 12)**		
>70	19	0.4%	Container ship	895	20.9%
Gender			Bulk carrier	761	17.7%
Male	4088	95.4%	Crude oil tanker	474	11.1%
Female	177	4.1%	Chemical tanker	387	9.0%
Prefer not to say	21	0.5%	Product tanker	296	6.9%
Others	**1**	**0.0%**	Cruise ship	267	6.2%
Nationality (Top 12)			LPG tanker	170	4.0%
India	1243	29.0%	LNG tanker	129	3.0%
Philippines	432	10.1%	Offshore support vessel (OSV)	124	2.9%
China	395	9.2%	General cargo ship	120	2.8%
Ukraine	306	7.1%	Tug	112	2.6%
Indonesia	189	4.4%	Pure car carrier (PCC)	68	1.6%
Germany	149	3.5%	**Others**	**484**	**11.3%**
Croatia	141	3.3%	**Flag State (Top 15)**		
United Kingdom	131	3.1%	Singapore	559	13.0%
Sri Lanka	103	2.4%	Marshall Islands	489	11.4%
United States of America	99	2.3%	Panama	456	10.6%
Russia	77	1.8%	Liberia	369	8.6%
Nigeria	57	1.3%	Bahamas	290	6.8%
Others	**964**	**22.5%**	Hong Kong (China)	213	5.0%
Seafaring experience (years)			Malta	137	3.2%
0-5	666	15.5%	China	135	3.1%
5-10	923	21.5%	Indonesia	131	3.1%
10-15	993	23.2%	Norway	113	2.6%
15-20	616	14.4%	Cyprus	100	2.3%
20-25	446	10.4%	Germany	93	2.2%
25-30	330	7.7%	United States of America	91	2.1%
>30	313	7.3%	United Kingdom	82	1.9%
Rank (Top 12)			Italy	80	1.9%
Captain	849	19.8%	**Others**	**949**	**20.1%**
Chief officer	645	15.0%	**Type of company**		
Second officer	520	12.1%	Ship management	1693	39.5%
Third officer	320	7.5%	Crewing agency	1334	31.1%
Chief engineer	297	6.9%	Ship owners	1171	27.3%
Second engineer	240	5.6%	**Others**	**89**	**2.1%**
Able seafarer	240	5.6%			
Third engineer	180	4.2%			
Deck cadet	155	3.6%			
Electro technical officer	121	2.8%			
Fourth engineer	95	2.2%			
Ordinary seafarer	88	2.1%			
Others	**537**	**12.5%**			

Table 1. Sample socio-demographic and work-related characteristics (Source: Survey data).

On average, the participants had 14.1 years of seafaring experience, with a maximum of 52 years of experience. They represented various ranks on board, including Captain (19.8%), Chief Officer (15.0%), Second Officer (12.1%), Third Officer (7.5%), Chief Engineer (6.9%), and Second Engineer (5.6%).

Of the survey respondents, 42.4% were currently working onboard and 55.8% of the remaining participants sailed after record-keeping became mandatory. Almost all (98.2%) respondents had sailed after record-keeping became mandatory, i.e., after August 2002.

Respondents had experience working on different types of ships, mainly container ships (20.9%), bulk carriers (17.7%), crude oil tankers (11.1%), chemical tankers (9.0%), and product tankers (6.9%). The ships were registered with a mix of flag States, mainly Singapore (13.0%), Marshall Islands (11.4%), Panama (10.6%), Liberia (8.6%), and the Bahamas (6.8%). Respondents were employed by ship management companies (39.5%), crewing agencies (31.1%), and ship owners (27.3%).

Recording system for work-rest

As shown in Figure 1, seventy-seven percent (77.2%) reported using dedicated software to record their work-rest hours, while 25.8% used paper.

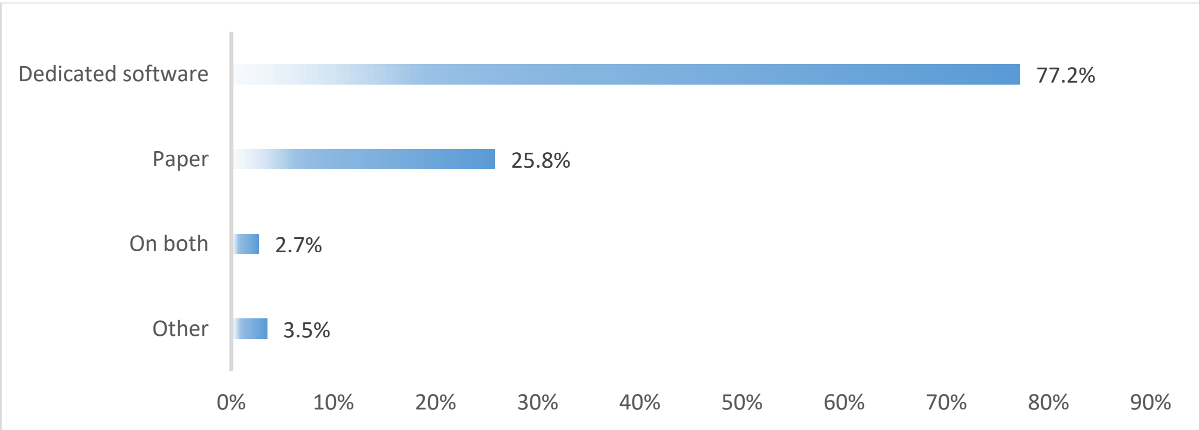

Figure 1. Work-rest hours recording system in use (Source: Survey data).

Among the 77.2% (i.e., 3,309 respondents) who used software, ninety-four percent (93.9%) reported that the software indicated non-compliance, as depicted in Figure 2.

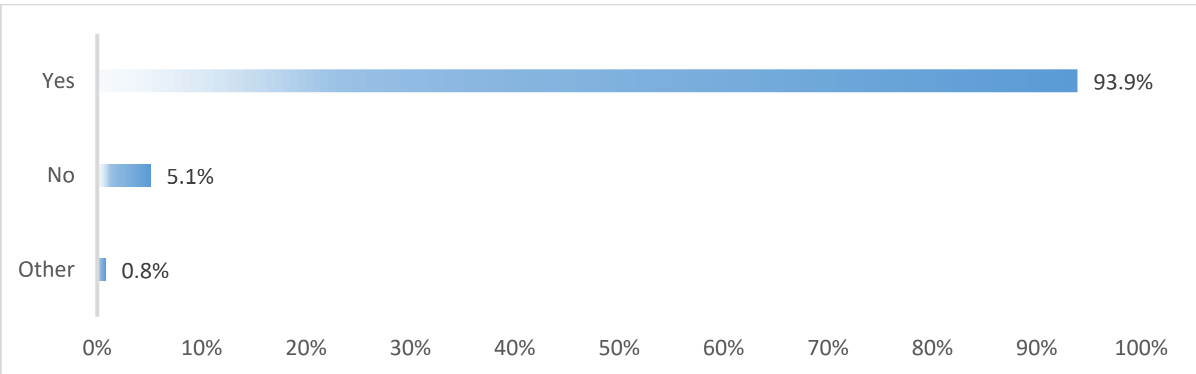

Figure 2. Software recording system highlight non-compliance (Source: Survey data).

Number of non-compliances to work-rest limits

On average, seafarers reported exceeding their work-rest regulatory limits 7.03 times per month. Eighty-six percent (85.9%) of respondents reported exceeding the regulatory limit at least once a month, with 30% exceeding the limit three to five times per month and 16% exceeding the limit more than ten times per month, as shown in Figure 3.

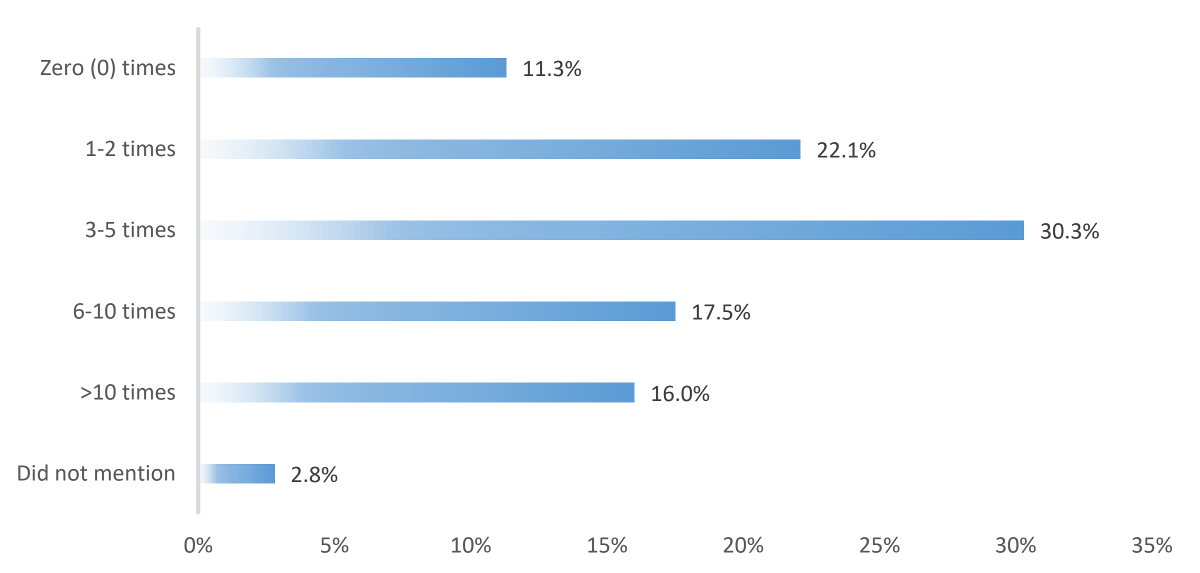

Figure 3. Number of non-compliance per month (Source: Survey data).

The extent of adjustment of work-rest records

The survey asked respondents if they adjusted their work-rest records when they exceeded this limit.

Thirty-one percent (31.5%) of respondents reported that they did not adjust their work-rest records, as shown in Figure 4.

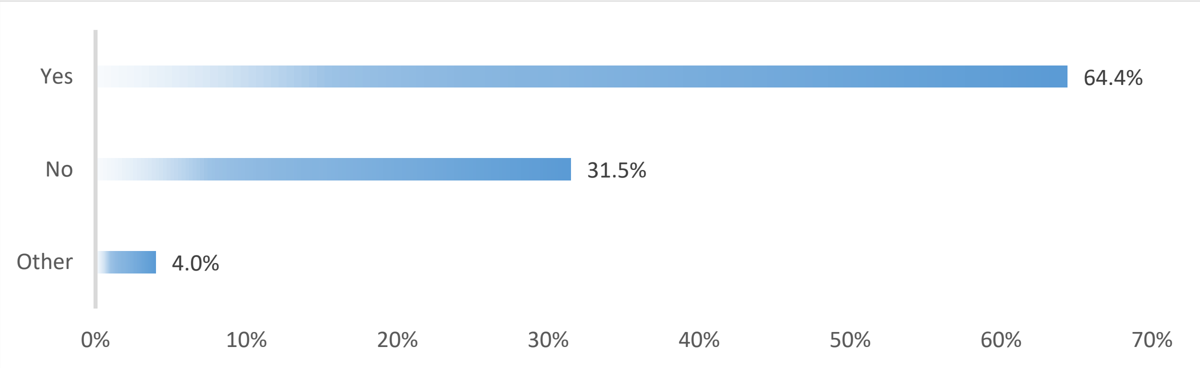

Figure 4. Adjustment of work-rest records (Source: Survey data).

Seafarers’ justification for adjustment of work-rest records

Sixty-four percent (64.4%) of the respondents disagreed that work-rest hour records were adjusted for financial benefits, i.e., bonuses and overtime. Additionally, seventy-five percent (75.1%) agreed that records were adjusted to avoid problems with the company, and 80.3% agreed that adjustments were made to avoid findings or non-conformities during inspections, as depicted in Figure 5.

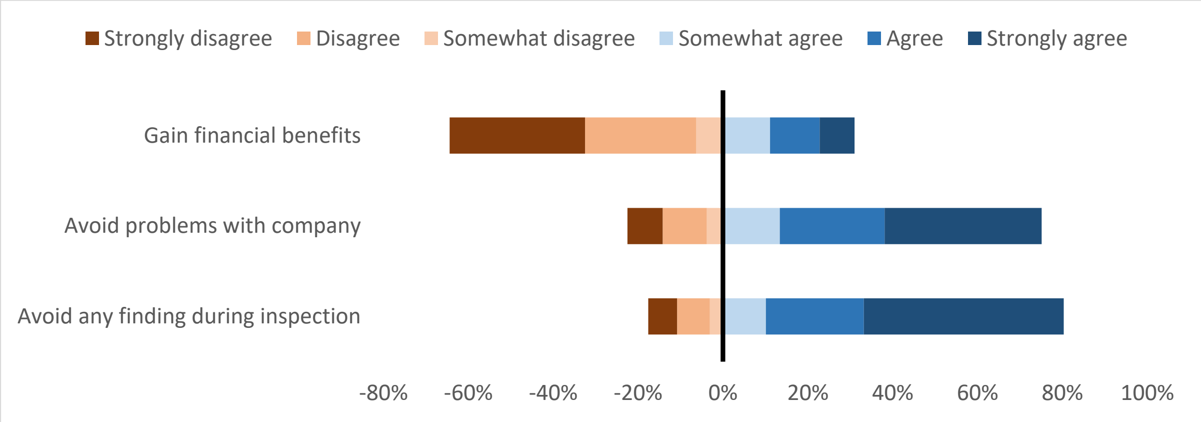

Figure 5. Seafarers' justification for adjusting work-rest hours (Source: Survey data).

Seafarer and company response to work-rest non-compliance

As shown in Figure 6, half of the respondents agreed that they reported non-compliant hours to the company. When non-compliance was reported, twenty-two percent (21.8%) agreed that the company provided additional crew members, whereas 46.4% agreed that the company did not respond. Furthermore, sixty-seven percent (67.1%) agreed that the company questioned the ship's management when non-compliance was reported.

Sixty percent (60.1%) agreed that the company expected the ship to adjust the record, and 48.9% agreed that the company instructed the ship to adjust the record.

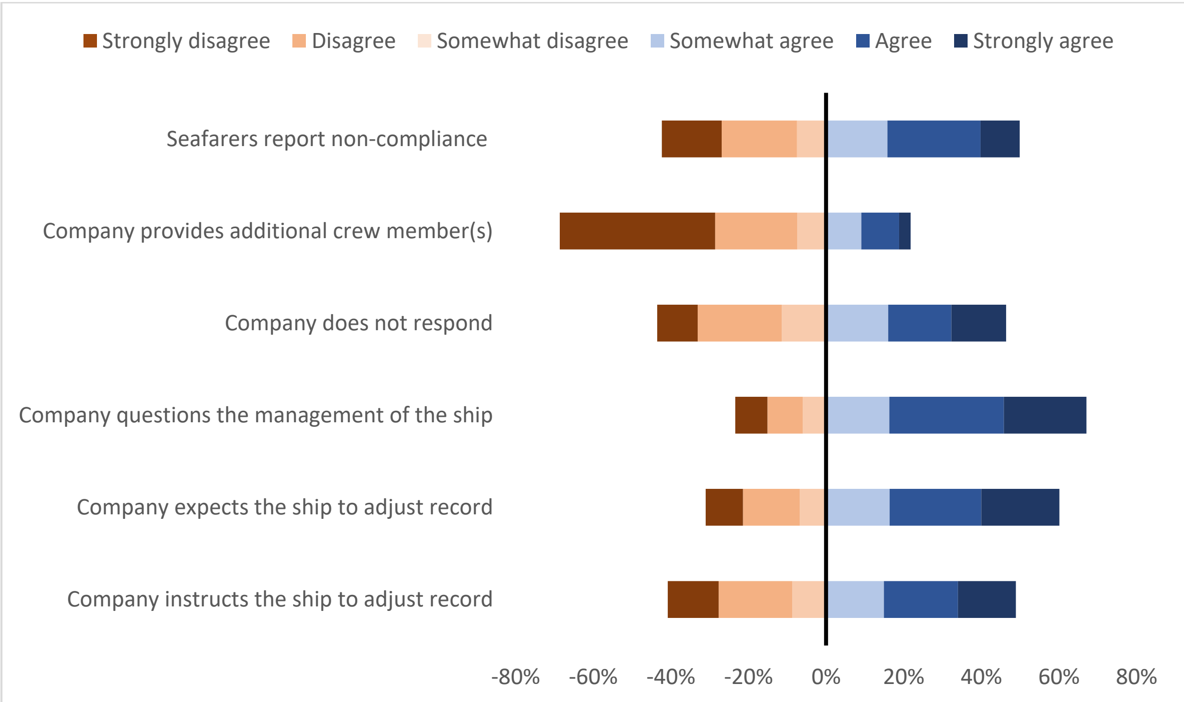

Figure 6. Seafarer and company response to non-compliance (Source: Survey data).

DISCUSSION

A large-scale cross-sectional survey was conducted globally to gather seafarers' experiences with the implementation of work-rest regulations, specifically focusing on recording practices, action to non-compliance, and the extent of adjustment. The study comprised 4287 seafarers' responses, mainly representing major seafaring States, as outlined by (BIMCO and ICS, 2021; Drewry, 2022). The respondents characterized a wide-ranging gender, seafaring experience, rank, ship type, registered flag State, and company type. Nearly all respondents sailed after record-keeping became mandatory in 2002, with 42% responding to the survey while they were on board.

The study found extensive (77%) use of dedicated software to manage and record seafarers' work-rest, which corroborates with Baumler, Bhatia and Kitada (2021), who found that 85% of seafarers relied on software for this purpose. The use of software highlights the importance of modern technology for the better planning, control, and monitoring of seafarers' work-rest. Despite the large-scale use of software, most seafarers (89%) exceeded the regulatory limits, with the study reporting an average of seven instances of non-compliance per month. Furthermore, 16% of respondents were found to exceed regulatory limits more than ten times per month, which was consistent with Simkuva *et al.'s* (2016) survey findings that non-compliance is 'regular and systematic[9]'. High workload and operational demands, such as during multiple port calls and inspections, have been reported elsewhere to be the common cause of non-compliance with seafarers' work-rest (Hjorth, 2008; Tang and Bhattacharya, 2018; Rajapakse *et al.*, 2019). While a significant number of non-compliance remains widespread, this study demonstrates that the current regulatory standards on seafarers' work-rest have limited control over seafarers' actual working and resting hours. It further suggests that the ability of recording software to improve compliance with work-rest regulations is limited (Allen, Wadsworth and Smith, 2006).

The ineffectiveness of the recording system is further exemplified by its inability to record accurately. This is confirmed by this study, where only 31.5% of seafarers were admitted to accurately record their work-rest non-compliance. This finding is consistent with the survey by Allen, Wadsworth and Smith (2006), who found that only 37.3% of British seafarers on British registered ships were not under-recorded. The survey by Simkuva *et al.* (2016) also found that only 31% of Latvian Bridge Officers reported overtime on record. This widespread practice of adjusting records, facilitated by software, is concerning as it undermines the accuracy of the records and the ability to improve compliance with work-rest regulations. While the study demonstrates endemic adjustment of records, it substantiates that this persistent issue has remained under-addressed for almost two decades, ever since it was first reported by Bloor *et al.* in 2004.

Furthermore, the results indicate that the primary motivation for adjusting records is to avoid findings during inspections and problems with the company, rather than financial benefits. Similar findings were reported by Tang and Bhattacharya (2018) that seafarers freely updated the records the way they were meant to be presented to the inspector, while Devereux, Wadsworth, and Bhattacharya (2020) reported that records were fabricated to ensure that inspectors overlooked non-compliance. On the other hand, Allen, Wadsworth and Smith (2006) pointed out that seafarers are often caught in a difficult situation due to the unspoken threat of adverse effects on their employment prospects, which implicitly forces them to under-report their work-rest hours.

[9] The research reported 44% of the respondents had non-compliances occurring between 6-12 times per month.

Moreover, the study found that most seafarers agreed that the company does not respond to non-compliance reports and questions ship on work-rest management. This lack of response from the company, despite non-compliance being reported, was consistent with the findings of Zhang *et al.* (2020) field study, while Colliander, G., & Olsson (2021) interviews reported that the company questioned seafarers' capability to manage work-rest.

Most concerning was the finding that 60% of seafarers perceived that the company expected the ship to adjust the record when non-compliance was reported, and half agreed that the company instructed the ship to do so. Zhang *et al.* (2020) reported similar findings that some shipping companies explicitly asked seafarers to falsify records, while Tang and Bhattacharya (2018) stated that companies (managers) indulge and support such adjustments. Such blatant malpractices demonstrate a perpetuated culture of adjustment (WMU, 2020), which undermines the validity of the work-rest hours records and the ability of the company to implement regulations. These further questions the effectiveness of the ISM code, a regulatory framework that seeks greater oversight and accountability from companies to ensure that the regulations are being observed, and that the records accurately reflect seafarers' work-rest hours.

CONCLUSION

The results of the cross-sectional survey presented in this study remain valid across seafarers' gender, ranks, ship types, registered ship flag States, and company types. It is concerning that a significant number of seafarers continue to exceed regulatory limits and that these non-compliances are concealed through adjusted records. Such widespread malpractices demonstrate a permeated ‘culture of adjustment’ within global maritime community.

Although recording software is designed to identify non-compliance and is employed for multiple purposes, its ability to improve compliance and accurately record is limited. Therefore, the current recording system for work-rest hours is ineffective and cannot be enforced. This study emphasizes the need for a robust recording system to ensure accurate recording. While the implementation of such a system may not necessarily enhance seafarers' work-rest hours compliance, it will provide an accurate picture and substantiate the pervasiveness of excessive working hours among seafarers. In this regard, it is necessary to evaluate the current regulatory frameworks that oversee ship manning (crewing) to ensure that seafarers’ working-resting hour limits are respected.

Additionally, the extent of adjustments perpetuated by companies’ ‘oblivious behavior’ when reported non-compliance suggests a cultural disregard for these regulations, placing the goal of addressing fatigue at risk. The prevalence of such practices not only points to a failure in implementing work-rest regulations, but also reveals a more profound cultural issue within maritime where the notion of a ‘ship first’ takes precedence over seafarers’ health, individual and business ethics, and morality.

The widespread malpractices and cultural neglect of the work-rest records highlighted in this study should prompt policymakers and the broader maritime industry to consider industry-wide implications. Adjusting records distorts the accurate depiction of seafarers' working hours, leading to longer working hours, which inculcate fatigue and negatively affect seafarers' health. Moreover, record adjustment impedes compliance monitoring by enforcement agencies, creating a false impression of compliance and making policy interventions challenging. These implications can have long-term impacts on safety and regulatory compliance in the maritime industry, making it more challenging for stakeholders to identify issues and make the necessary changes.

ACKNOWLEDGEMENTS

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Maritime Accident, Incident Analysis Methods: A Systematic Literature Review

Sunil Kumar Panda[1], Sanjeet Kanungo[2]

Incidents and accidents in the maritime sector always cause the unavailability of entities and services and significantly impact the performance, finance, usability, and ambience of the service. Hence the formulation of accident analysis methods and models is gaining importance. It is required to get an overview of all existing analysis methods and models to find any overarching methods and commonalities between models. Accident analysis methods have greater application in many industries and many methods are applied to the maritime industry cases. Furthermore, it is required to find out any methods that had been applied to maritime incidents. In this article, a systematic literature review of incident and accident analysis methods tried to establish across domains. As several accidents happen irrespective of all kinds of obligations to regulatory statutes, it has been found that accident analysis methods have elevated gaining attention over the last 20 years, resulting in a surfeit of methods and models. There are three classes often found in existing literature, they are the sequential method, epidemiological method, and systemic method. Each class has its features, advantages and disadvantages. The sequential method may be easier to understand and communicate, can be executed in less time, but may miss vital underlying causes. The epidemiological method is time-consuming but can identify and resolute the underlying cause which may prevent future mishaps. A systemic method is rightly used for complex situations but needs a lot of time and resources, rendering this an expensive method. Finally, for maritime incident or accident analysis, any structured methods and models are not defined; also, any specific method does not apply to the whole maritime sector.

KEY WORDS

Maritime, Accidents, Incidents, Literature, Methods

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INTRODUCTION

The advent of the ISM code increased the importance and awareness towards safety. Very often accident analysis provides new insight into system errors and the impact of these errors on the safety culture. Varieties of methods used, although different, still make the comparison of different accidents and incidents easier. The definition of 'marine incident' in various literature (Doytchev and Szwillus, 2009) conclude that incidents are actions that do no harm or only minimum harm but have a higher potential in a different environment whereas the definition of 'accident' in these works of literature, specifies accident as an unwelcome transfer of energy (US DoE, 2000) and it is also an incident that occurs with damage (Doytchev and Szwillus, 2009).

These cause the unavailability of entities and services and stress the performance, finance, usability, and ambience of the service. Hence the formulation of accident analysis methods and models is gaining importance. Knowing all existing analysis methods and models to find any predominant methods and harmonies between models gains priority. So in this document, it is tried to find the state of the art in incident and accident analysis methods, which raised the following questions.

- Find the incident, and accident analysis methods that exist in today's maritime context.
- Identify the domain-specific popular incident methods.
- Find the important methods that are in use.

METHODS

The procedure used by the first author during this research is depicted in Fig. 1.

Firstly, a systematic approach is applied to gather and filter the data sample. Subsequently, bibliometrics. Finally, the literature review is conducted.

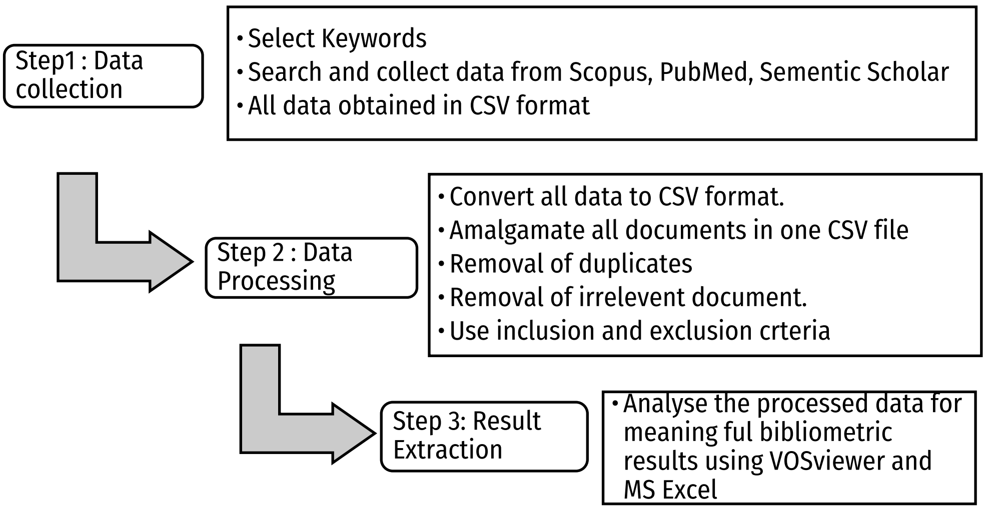

Fig. 1 Flowchart of bibliometric analysis methodology.

Overview of the process

Bibliometrics is applied to investigate the collected data sample and is analysed quantitatively and scientifically through the representation of bibliometric parameters (Skelt, 2002).

Selection of data

Three databases (Scopus, Google-Scholar, Semantic-Scholar) were searched by the first author for published journal articles for the interval 01 January 1990 to 31 December 2021, inclusive. The keywords used for search criteria are:

Title: Accident/incident/event; or Analysis/model/method/tree; or Maritime/marine/ship/vessel

Information was obtained in CSV(comma-separated value) format, and many citations were obtained in RIS (Research Information Systems) format. Mendeley software is used for citation management applications. Later all data was collected in CSV format, and all CSV files were amalgamated into one file. After the removal of duplicates and using some inclusion and exclusion criteria, 7980 documents were finalized.

Eligibility criteria

Inclusion criteria involved the near-miss, accident and incident cases that use some particular method as mentioned in table 01. The documents must be in English and sourced from a peer-reviewed journal.

Exclusion criteria retailed the traditional analysis-dependent tools like fault tree-inspired theory, performance assessment methods, and languages other than English excluded.

After applying inclusion and exclusion criteria, 1455 documents were shortlisted that have relevance to the research data and analysis methods.

Analysis method

These documents are subjected to text mining, using VOSviewer software for its advantages of being user-friendly, freely available, and with special features such as network mapping and normalisation (Van and Waltman, 2017). This resulted in relevant 1124 documents, that are using these 41 methods. The other documents discuss the methods or accidents but are unrelated to any analysis.

These 1124 documents were subjected to document-term analysis by VOSviewer software, resulting in a Data matrix for these 42 variables or terms from 1124 literature. 42 variable contains 41 methods and another term ‘accident’, is considered as the dependent variable in statistical analysis. The data matrix obtained was subjected to statistical analysis by IBM SPSS 20. Each method is one variable and is dichotomous by nature.

If a term or method is used in the literature, then its Lebel is 1, if not used indicates Lebel 0.

All documents (n = 1124) were classified based on publication type (i.e. journal article (JA n = 829), conference paper (CP, n= 255), review (REV, n=8), book (B, n=16), and Thesis reviews(TR, n=16).

ANALYSIS RESULTS

Analysis methods

Fig 2 obtained from VOSviewer as per the occurrence and relevance of the terms, depicts the key methods of accident analysis with a bibliographic coupling. It consists of all 42 terms used by different documents and the bibliographic link with each other.

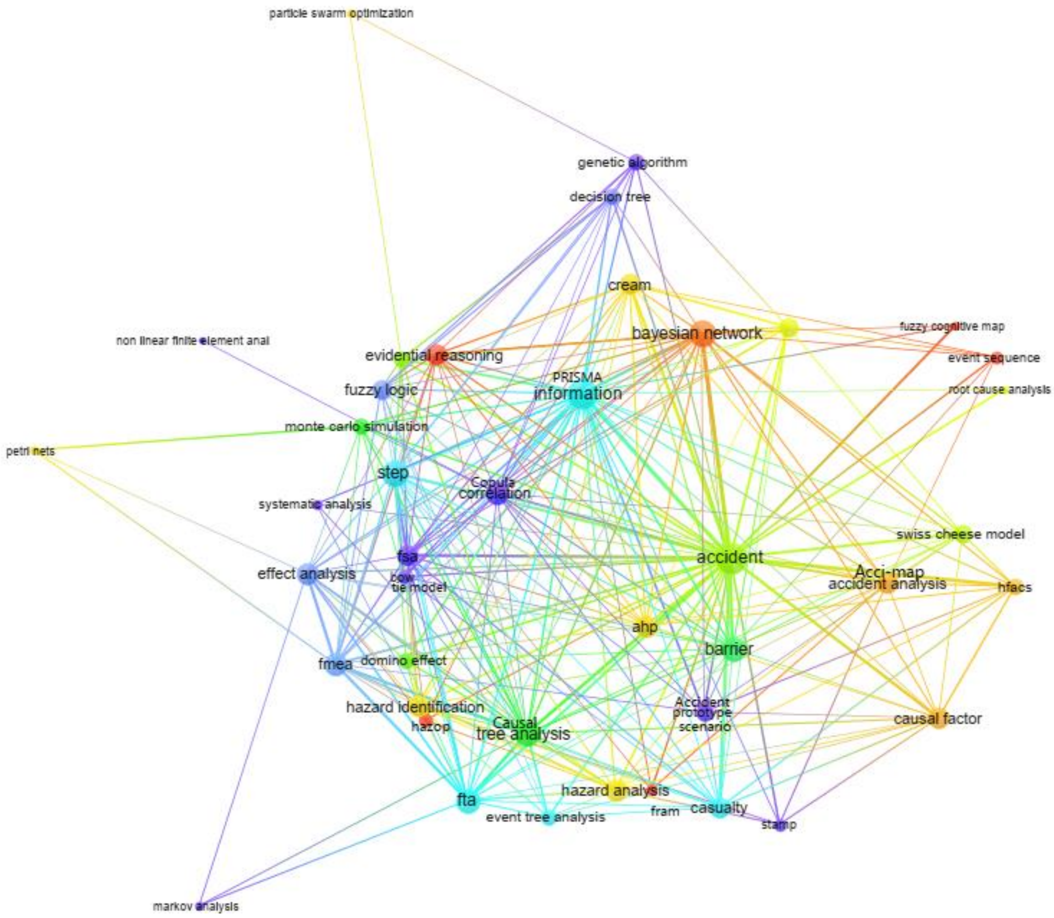

Fig. 2 Key research methods and models applied for accident investigation by using VOSviewer.

Literature trend

Fig 3 depicts the number of documents published in the last 20 years on maritime accident and incident analysis that used these specified 41 methods.

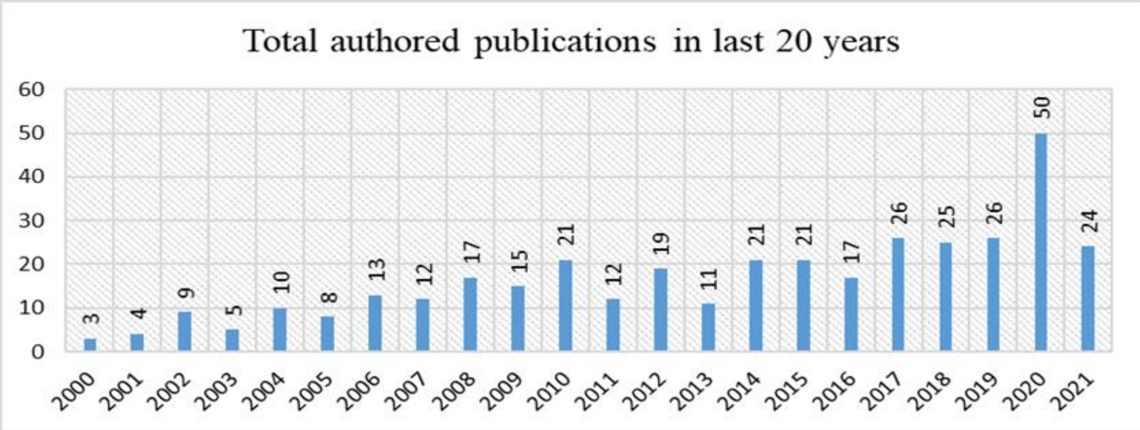

Fig 3 Documents published in last 20 years

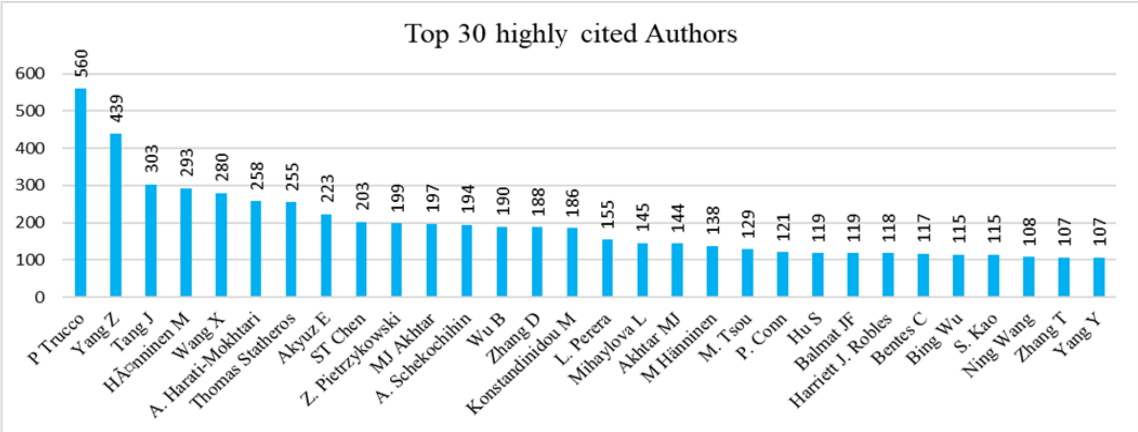

Fig 4 Author name of top 30 highly cited documents

Fig 4 depicts the author name of the top 30 highly cited documents. The highest cited document found is by Author P. Trucco, who discusses Bayesian Belief Network (BBN) (Trucco et. al. 2007) is used to deduce the mutual influence among the ship-owner, shipyard, port, and regulator. The five documents authored by second author Yang Z, discuss the Fuzzy rule, BBN, FMEA, evidential reasoning, human reliability analysis, and CREAM. Fig 5 depicts the list of authors with-highest citations.

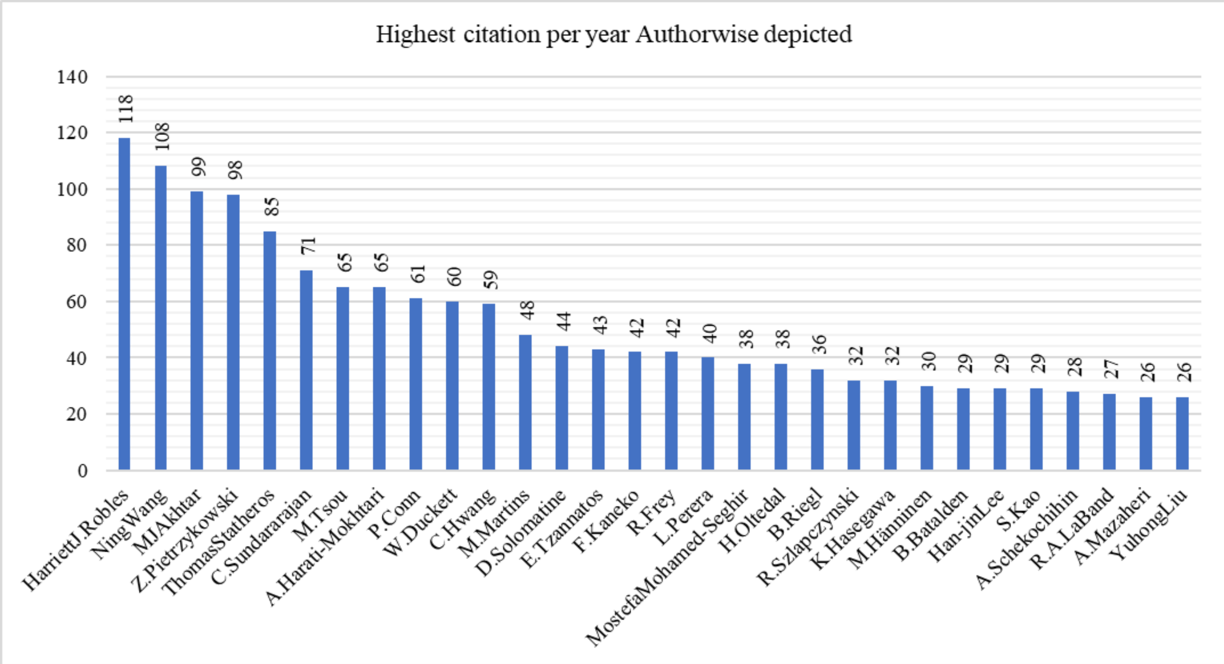

Fig. 5 Top 30 authors with a high rate of citations per year.

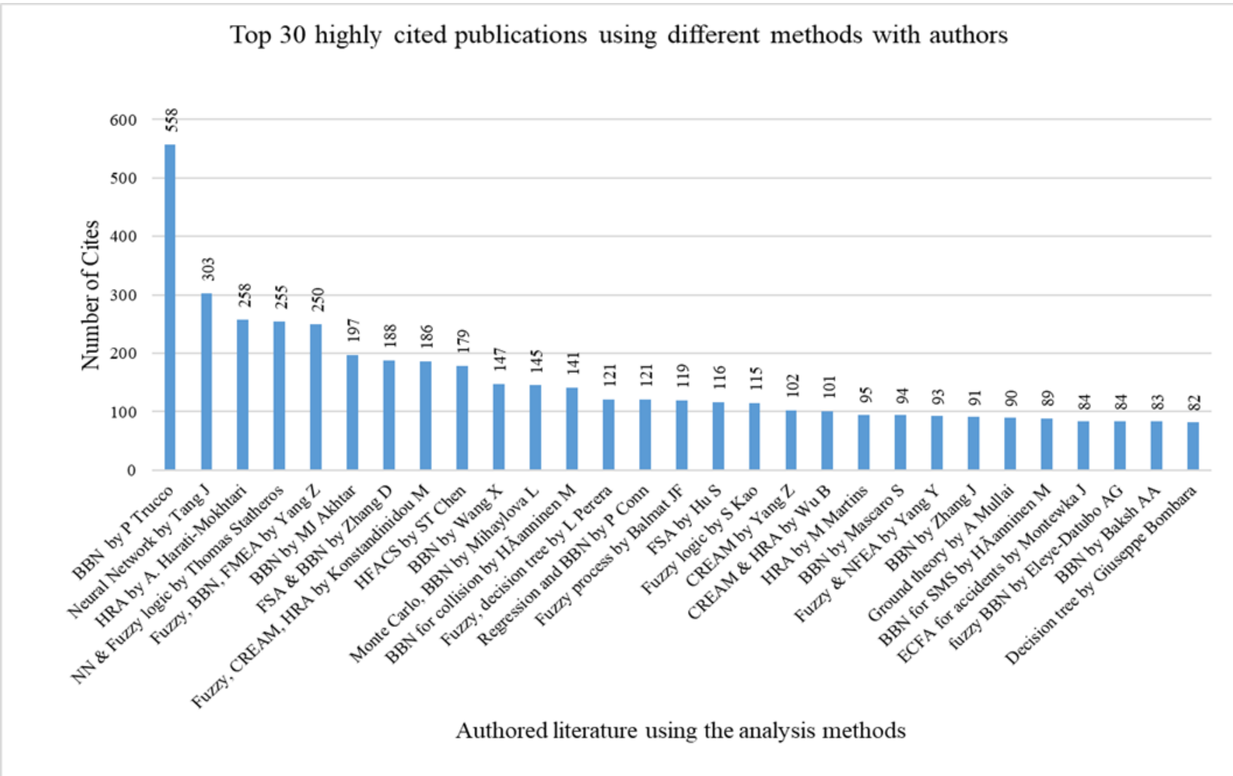

Fig. 6 Analysis methods used by the top 30 highly cited documents

Fig 6 depicts the top 30 highly cited documents that use one or more methods for carrying out accident or incident analysis in the maritime domain. The majority of documents are found using the BBN model. Some documents were found using more than one method. A calculation is made to enumerate how many documents a particular method is used. To do this, the document-term relationship obtained by the VOSviewer software became useful. The Matrix data of the document and term relationship was useful.

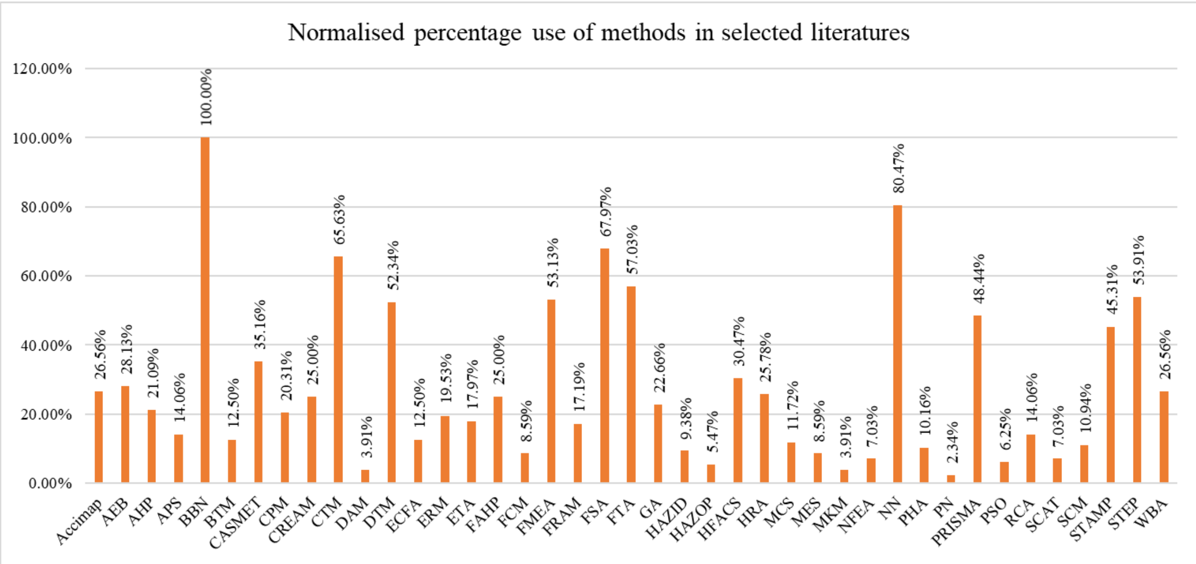

Fig. 7 Percentage occurrence of various methods in the selected documents.

Three types of literature models

Three types of models are found in the literature (Hollnagel, 2004), they are Sequential accident models, Epidemiological models, and Systemic accident models.

DISCUSSIONS

Themes

The theme involves many entities and defines an interrelationship. The abbreviations used are Epi: Epidemiological; Sys: Systemic; Seq: Sequential;

Modeling Methods	Type	Model theme	Number of referred documents	Reference
AHP-Analytic-hierarchy-process	Epi	In AHP, complex, unstructured events are broken down into components, then arranged hierarchically, analysed for highest-priority component and should be acted upon to influence the result.	27	(Saaty, 2000)
AcciMap	Sys	Plans for achieving goals by different levels of functions in an organization lead to decision-making considering preconditions. Decisions lead to frame orders to perform a task that defines the actions. Direct and indirect consequences related to the action are the events. Accidents are the critical direct consequence of an event.	34	(Sanders, 2013; Strömgren et al., 2013; Underwood and Waterson, 2013.)
AEB-Accident-Evolution-	Epi	Error events result from actions or previous error events. If these error events are not	36	(Hollnagel et al., 2008)

and-Barrier-Function		blocked by barriers (physical barriers and management barriers), then it may lead to an accident. This model provides the evolution of events or actions of an incident.		
APS-Accident-Prototypical-Scenario	Seq	A sequence of situations, distributed in phases leads to the accident. Each phase has situations that lead to an event or may create another new situation.	18	(Yang, 2014; BSI, 2016)
BBN-Bayesian-Belief-Network	Seq	Uses a set of nodes or variables with their needs (correlated nodes) to represent interconnected functions. Conditional probability tables (CPTs) represent the relationship between the dependencies.	128	(Ben-Gal et al., 2007)
BTM-Bow-Tie-Model	Seq	It starts with the identification of potential reasons that could cause an event. Reasons and consequences are consequently analysed to assess the overall occurrence of the event. Also, it lets analyse the potential barriers during entry and execution.	16	(Papas, 2014)
CASMET-Casualty-Analysis-Methodology-for-Maritime-Operations	Epi	Day-to-day operations governed by management and available resources. Inadequacy of these leads to accidents including causalities.	45	(Caridis, 1999)
CTM-Causal-Tree-Method	Seq	An accident can be regarded as a result of a chain of events. Factors of incidence lead to an event. These factors either in combined form or branch form influence the event chain.	32	(Jacques, 1978)
CREAM-Cognitive-Reliability-and-Error-analysis-Method	Epi	The probable cause(s) of an analysed Event are Consequent-Antecedent Links that trigger Error Modes in the Task.	84	(Hollnagel and Josephine, 2008; Strömgren et al., 2013)
CPM-Copula-method	Seq	Copulas describe the dependence (inter-correlation) between random variables.	6	(Jonathan et al., 2010)
DAM-Domino-Accident-Model	Seq	In the social environment, a person makes an error, which results from an unsafe act, and which can lead to an accident.	5	(Anthony, 2010)
DTM-Decision-Tree-model	Seq	Decision Trees use attributes of variables for classification and making decisions for a decision-making process.	67	(Smith, 2002)
ECFA-Events-and-causal-factors-analysis	Seq	Incidents happen as an event in the prevailing environment and cause other events. The events and causal factors are charted in a sequence of primary and secondary events with influencing conditions.	16	(Hollnagel and Josephine, 2008)

ETA-Event-tree-Analysis	Seq	The sequence of events and actions that may lead to an incident is plotted sequentially till the leaf reached bifurcating branches by either success or failure, where each branch specifies a possible outcome of that previous event or action.	25	(Mokhtari et. al., 2012)
ERM-Evidential-reasoning	Seq	It is to associate evidences obtained from two or more sources. Like fuzzy logic method, ER can handle the uncertainty by using belief structures to describe an assessment as spread over reasons instead of a single numerical score.	23	(Mokhtari et al., 2012)
FMEA-Failure-mode-effect-analysis	Seq	Used for hazard identification and risk analysis for incidents. Traditionally, three attributes are used: probability of occurrence (O), severity of consequences (S), and probability of failures being undetected (D). The risk priority numbers (RPNs) are calculated by multiplying the aforementioned three attributes.	32	(Alyami et al., 2016)
FRAM-Functional-Resonance-Analysis-Method	Sys	Organization and systems consist of interactive functions with six characteristics: input, output, precondition, resources, control, and time. These affect the execution of the respective function and may or may not lead to an incident or accident.	11	(Hollnagel and Josephine, 2008)
FTA-Fault-Tree-Analysis	Seq	FTA describes a tree of events following one another in a time series. Events may branch to inhibit some event or may combine to give rise to a new event. Here in these documents, FTA recognizes five types of events.	68	(Smith, 2002)
FSA-Formal-safety-assessment	Seq	It has five steps: Hazard Identification, Risk Analysis, Risk Control Options, Cost-Benefit Analysis of these options, and finally decision-making recommendations.	22	(Njumo, 2021)
FCM-Fuzzy-Cognitive-mapping	Sys	Represented either graphically showing interconnection between aspects or as an adjacent matrix have entries quote the weighted interconnection between the aspects.	87	(Lazzerini and Mkrtchyan, 2011)
FAHP-Fuzzy-Analytical-Hierarchy-Process	Seq	The FAHP method is popular for determining the weightage of the evaluation criteria among decision-makers.	73	(Smith, 2002)
GA-Genetic-Algorithm	Sys	The number of variables from the database is reduced to certain sets of constructs. They are clustered and the relationship among the variables within the construct is determined. Later both non-inferential and	29	(Kuhlemann and Tierney, 2020.)

		inferential statistics are applicable to the data.		
HAZOP-Hazard-and-Operability-studies	Seq	It is to systematically search for deviation from normal defined operations that may lead to a hazardous situation. Hence it is necessary to identify the purpose of each part of the system.	12	(Primatech, 2018)
HAZID-Hazard-Identification	Seq	Hazard identification is a primary step to finding the risks involved primarily during the design stage, so used in strategic planning. Any deviation or non-coverage gains a potential towards the accident occurrence.	7	(Primatech, 2018)
HFACS-Human-Factors-Analysis-and-Classification-System	Sys	HFACS investigates active failures and latent conditions at four levels. They are unsafe acts, pre-conditions, unsafe supervision and organization influences.	39	(Andreas, 2009)
HRA-Human-Reliability-Analysis	sys	As per this model, an accident or incident begins with behavioral variability, which is always present in a socio-technical system.	33	(Zhang, 2011)
MCS - Monte-Carlo-Simulation	Seq	Mathematical technique to find the risk and make the decision.	15	(Cunningham et. al., 2010)
MES-Multilinear-Events-Sequencing	Seq	During task execution, actions in multiple directions as desired. They propel a stable situation into an accident.	11	(Sanders, 2013)
PN-Petri-Net	Seq	A Petri net or place/transition (PT) net is a bipartite graph of two elements, places, and transitions. These are sequenced as white circles and rectangles respectively.	5	(Bošnjak et al., 2020)
MKM-Markov-model	Sys	The ship safety modeling takes (ship, human, environment) boundaries to define the scope of the analysis. The factors associated with ship (failure, design defect), human (human error, workload, operation), environment (emission, place, time), safety (related to a system's design, accident rates, and risk).	9	(Smolarek, 2009)
NFEA-Nonlinear-FEA	Seq	Accident sequences have three phases, they are initial, conclusion, and injury phase. Each phase is designated with many determining factors. Deviations of these factors will lead to an accident.	103	(Strömgren et al., 2013)
PRISMA-Prevention-and-Recovery-Information-System-for-	Seq	It is a combination of various methods, classifications and actions. It has 3 aspects: incident description, root cause classification, and the translation to structural measures.	13	(VanderSchaaf, 1996)

Monitoring-and-Analysis				
PHA-Preliminary-Hazard-Analysis	Seq	This identifies possible hazards that may result in any severity. This is known as proactive risk management.	3	(BSI, 2016)
RCA-Root-Cause-Analysis	Seq	Has 4 steps. It identifies the entities that, if corrected, would prevent the occurrence of incidents. Causal factors are required.	62	(Hollnagel and Josephine, 2008)
SCAT-Systemic-Cause-Analysis-Technique	Epi	A hazardous situation contains immediate or underlying causes. This situation leads to accidents if not addressed.	8	(Strömgren et al., 2013)
SCM-Swiss-Cheese-Model	Epi	The accident is an outcome of deficiencies or missed out areas which are represented as holes in the slice of cheese. Inappropriate decisions, incompetent action, unmet pre-requisites, unsafe execution, and inadequate defense mechanism when falling in line will lead to an accident.	18	(Underwood and Waterson, 2013)
NN-Neural-Network	Sys	It is a series of algorithms and-contains layers of interconnected nodes where each node is a perceptron and is comparable to multiple linear regression.	9	(Yang, 2014)
PSO-Particle-swarm-optimisation	Epi	It is a type of population-based optimization algorithm and used to adjust the connection weights with the center and width of the radial basis function.	14	(Yang, 2014)
STAMP-System-Theoretical-Accident-Model-and-Processes	Sys	The basic concept is the constraint and considers accidents result not from component failures, but from inadequate control of safety-related restrictions during design and operation. It is made from three basic concepts: constraints, hierarchical levels of control, and processes.	58	(Sanders, 2013; Strömgren et al., 2013)
STEP-Sequentially-Timed-Events-Plotting	Seq	It contains event-building blocks linking one action to one actor. It is based on a multilinear sequence of events and processes.	69	(Strömgren et al., 2013)
WBA-Why-Because-Analysis	Seq	Events, non-events, situations, processes, factors cause incidents and accidents. These have their reasons to occur.	34	(Sanders, 2013)

Table 1. Modelling Methods Found in Documents Including Themes

Fundamental method or supportive method

Fundamental methods are stand-alone techniques, whereas supportive methods are to provide input to the other methods. ECFA, STEP, and AcciMap are fundamental methods, FTA, and ETA may be both fundamental and supportive. Others may be regarded as supportive methods.

Identifying the safety barriers, and factor potential use methods such as AcciMap, APS, CREAM, CPM, DAM, ECFA, ETA, FRAM, HAZID, HFACS, MES, PHA, SCM, WBA. The other methods like AEB, AHP, CASMET, FMEA, HRA, MKM, and STAMP facilitate providing weightage to the factors, and their results may be included in secondary methods.

Influence among each other

Methods like BBN, Copula method, ECFA, ETA, FRAM, FAHP, HAZOP, SCAT, PSO, and UGF, find the relationship among the barriers, factors, causes, and reasons. Methods like BTM, FRAM, FSA, GA, and PRISMA helps in grouping (factors, barriers).

The analysis methods are influenced by different accident models. RCA, APS, AEB, BTM, CREAM, and ECFA are based on causal-sequence models. STEP, CTM, CASMET, and AEB methods are all based on process models. AHP, FTA, ETA, MORT, and DTM are based on logical tree models. Acci-map, FSA, and FRAM are based on a combination of the process model and logical tree models.

Statistical analysis to find the importance of methods

The importance dictates the relative influence of the method that is processed in the network.

In the literature, if a method is used then designated as 1 otherwise 0, made all variables dichotomous. Thus a matrix is obtained containing all the respondent cases whether it is involving a particular method or not. The matrix is put to binary logistic regression of statistical analysis by SPSS 20.

In the 'case processing summary', there are 1124 respondents or documents that were obtained after exclusion processes. Goodness-of-fit statistics help to determine whether the model adequately describes the data at hand. The Omnibus tests of the model coefficient are showing the level of significance Priori-values as 0.000, this indicates the fitness of the model.-

In model summary, the Nagelkerke R square is obtained at 0.655 means a 65.5% change in the criterion variables can be accounted for by the predictor variables in the model. This means 65.5% of the variance in the outcomes, whether the documents discuss accidents or not, can be explained by the predictors.

In the classification table, the model percentage accuracy in classification (PAC) is 95.4%, which can be regarded as the rate of correct prediction. The specificity (true-negative-rate) is 79.3% means the model predicted 79.3% of cases or 165 documents predicted correctly that do not involve accidents but failed in 43 cases. Similarly, sensitivity (true-positive-test) is 99.0% means the model can predict 99.0% of cases correctly for the documents that involve accidents, that is 907 documents correctly predicted for documents discussing accidents and failed for 9 cases. Overall PAC is 95.4%. The model exhibits good specificity and high sensitivity.

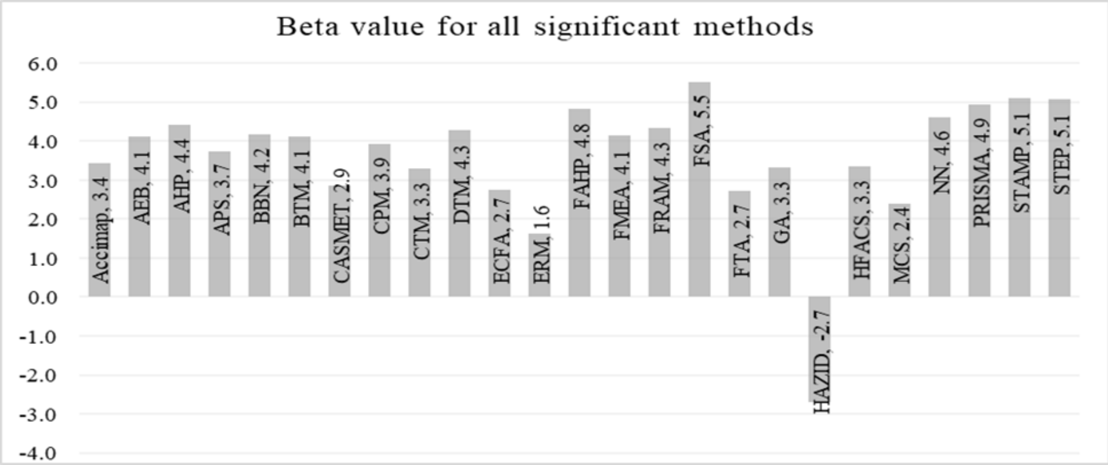

Fig. 8 Beta value for all statistically significant methods that have a p-value less than 0.05

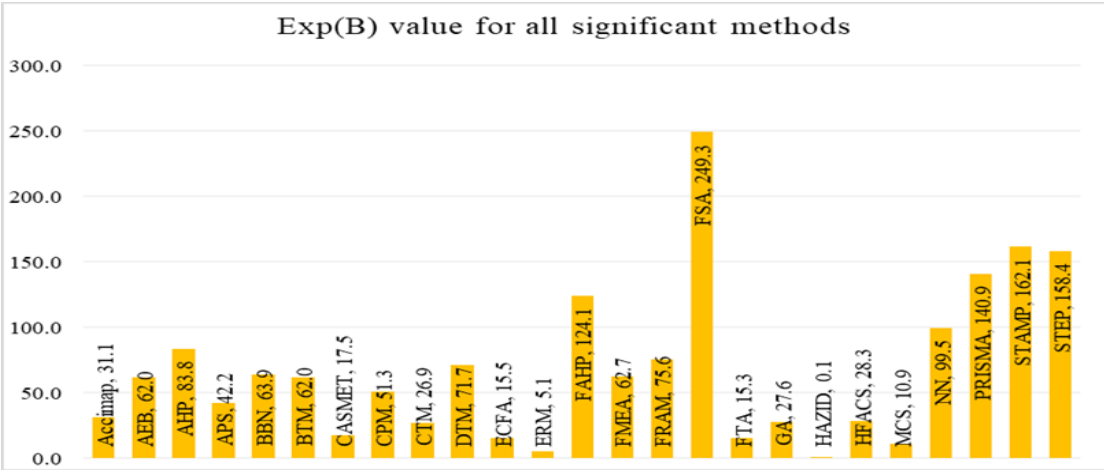

Fig. 9 Odds ratio, the Exp(B)

'Variables in the equation' is specifying the importance or impact of independent variables in accident documents. Out of 41 variables, 24 number variables are significant with a level of significance p-value less than 0.05, which indicates their significant role in the model. The methods are AEB, AcciMap, AHP, APS, BBN, BTM, CASMET, CTM, CPM, DTM, ECFA, FAHP, FMEA, FRAM, FSA, FTA, GA, HAZID, HFACS, MCS, NN, PRISMA, STAMP and STEP. Beta coefficient and Exp(B) shown in the figure are such that for 1 unit change in the predictor, there is an amount equal to Exp(B) value, change in the probability of an outcome, and these values are substantially high as shown in fig-8. So, it infers that the documents where any of the methods are involved are definitely discussing the accidents and incident cases. The remaining methods show a significance p-value greater than 0.05 and an Exp(B) value of less than 1, which means the documents involving these other methods have a lesser probability of discussing accidents, which means they may be used for other discussions.

The Exp(B) is the odds ratio, which is the ratio of the probability of success to the probability of failure. This infers that if literature contains the method say Acci-map, then it is 31 times more likely to be discussing accident cases. Exp(B) value 1 means it has a 50% probability of each involving or not involving the accident discussions. When the value is less than 1 as for HAZID, it infers that the documents that use this method find the factors that may lead to an accident, but may not factors that caused the accident.

		95% C.I.for EXP(B)		
Method	Exp(B)	Lower	Upper	
AEB	61.968	13.435	285.826	a
Accimap	31.094	6.348	152.315	a
AHP	83.772	10.444	671.966	a
APS	42.183	4.910	362.427	a
BBN	63.897	28.237	144.591	a
BTM	61.986	7.519	510.980	a
CASMET	17.541	6.242	49.291	a
CTM	26.854	7.154	100.805	a
CPM	51.267	6.155	427.042	a
DTM	71.652	23.455	218.887	a
ECFA	15.549	1.494	161.847	a
ERM	5.052	.892	28.613	b
FAHP	124.110	15.825	973.364	a
FMEA	62.664	19.096	205.635	a
FRAM	75.563	9.209	619.989	a
FSA	249.268	50.053	1241.373	a
FTA	15.346	3.816	61.710	a
GA	27.644	8.519	89.707	a
HAZID	.067	.009	.516	c
HFACS	28.299	7.506	106.699	a
MCS	10.882	1.805	65.615	a
NN	99.479	36.281	272.759	a
PRISMA	140.908	18.126	1095.374	a
STAMP	162.121	34.239	767.636	a
STEP	158.429	16.245	1545.088	a

Table 2. ODDS RATIO and CONFIDENCE INTERVAL for Exp(B)

CONCLUSION

In this paper, a bibliometric analysis-based review of documents on maritime accidents and incidents is displayed using the information available in various databases. Maritime accident and incident review is a popular area of research in the maritime domain and found out with an increase in the number of publications from 1990 onwards.

In summary, no single model has the capability of serving all incidents, accidents, systems, subjects, issues, and requirements in the maritime industry at all times – “one size does not fit all”.

After specifying the basic characteristics of the methods, the importance of the methods was found by using statistical methods. This indicates that whenever literature deals with factor finding or cause finding of a maritime accident, there is a high probability that it is using any method out of these twenty-four methods. Hence it can be asserted that accident analysis has frequent use of these methods. This is the inference concluded from this bibliometric analysis.

FSA was found to be a more influential method in these documents, followed by STAMP and STEP. The popular method in the documents is the BBN followed by Neural-Network and later FSA.

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Safety Learning Culture in Shipping Takes Two: Data Quality and Trust

Raphael Baumler, María Carrera

Background: Learning culture requires the capacity to assess safety situations, draw accurate conclusions and willingness to implement recommendations. Such a culture necessitates effective feedback and feedforward mechanisms between reporters, managers and authorities on safety-related data.

Objectives: Assessing the current status of safety culture and learning culture in shipping and identifying needs to enhance safety learning culture.

Methods: The EU-funded project SAFEMODE has conducted a qualitative study based on in-depth interviews with seafarers and casualty investigators as well as focus groups with regulatory bodies, safety agencies, shipping companies and maritime education and training institutions.

Results: The study: 1) identifies the main barriers to overcome to facilitate reporting and enhance learning in daily operations, 2) reviews the critical ingredients of a safety learning culture for shipping, and 3) proposes recommendations for the industry to move from a reactive to a proactive safety culture.

Conclusion: Data quality and trust are conditions for an effective reporting system and the establishment of a strong learning culture for the shipping industry. Low-quality data affects feedback/feedforward accuracy and models to learn from. The study suggests strengthening reporting mechanisms by establishing trustful relationships between front-line operators, shore-based management and authorities.

KEY WORDS

Human Factors; Safety Learning Culture; Learning Culture, Data Quality, Trust, Casualties

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INTRODUCTION

According to the International Maritime Organization (IMO, 2008b) "An organization with a 'safety culture' is one that gives appropriate priority to safety and realizes that safety has to be managed like other areas of the business". Safety culture in shipping (as in any other safety-critical industry) is not a "dichotomic" attribute that organizations either have or do not have. On the contrary, some kind of safety culture is always present in organizations. It is the integration of safety as part of the work and the focus on learning that distinguishes the maturity level of the safety culture in organizations, progressing from a poor (reactive) to a high (proactive) culture. Indeed, in organizations with a proactive and integrated level of maturity of safety culture, the safety systems are designed to support staff, not the other way around, and the focus is on reliability, learning and doing work well (Lloyd, 2021).

Giving priority to safety and integrating safety in the daily work done are characteristic of organizations whose safety culture's level of maturity is high, this is proactive and generative/integrated cultures (Hudson, 2001). Giving priority to safety does not mean claiming it or developing inapplicable safety management systems (SMS) (Bhattacharya, 2012); but integrate systematically frontline operators' experience into safety.

A safety learning culture demands the willingness and competencies to draw the right conclusions from its safety information systems, implement recommendations and make necessary changes (Reason, 1997). To learn from data flows emanating from reporting systems and implement necessary changes affecting the whole system, data (in quantity and quality) need to freely flow within the organization, particularly from front-line operators who 'inform' the organizations about the realities of operations. Only by cultivating trust and motivation safety-critical industries can move in the direction of achieving learning and seeking continuous improvement that defines more mature cultures (i.e., proactive, integrated). Safety derives from cooperation and integration of all systems components, from human factors to technology and management (Leveson, 2011).

In summary, without accurate data or with poor quality data, the information flow that is necessary to maintain any system cohesion fails. Consequently, the operational picture of the system becomes inaccurate; preventing from drawing relevant conclusions and recommendations. Therefore, the system cannot evolve if learning processes are uncertain and information is missing (Meadows, 2008).

Feedback and feedforward mechanisms for safety learning culture

A learning culture relies on reporting mechanisms allowing information flow between companies and employees (Lloyd, 2021). More generally, the integrity of any system depends on the physical and informational connectivity binding its elements (Meadows, 2008).

The modes of exchanging safety-related data are either feedback or feedforward-oriented (Leveson, 2011). Both types are necessary for learning purposes and complement each other, but while the first focuses on past events the second intends to anticipate foreseeable events in an uncertain environment or when feedback's delay is unacceptable (Hollnagel and Woods, 2005; Leveson, 2011; Wang and Chen, 2014; Ahmed, 2016).

On one hand, in safety, feedback mechanisms collect visible and, often, pre-selected datasets (e.g., contributory factors to an accident) and/or quest for low-intensity signals informing about safety status (e.g., erratic functioning of an engine onboard). Such feedback mechanisms provide relevant information about past safety events (e.g., accidents or wrong functioning of machinery) and are learning tools for similar events. Using these feedback mechanisms brings benefits both by triggering actions/corrections post-events whenever possible or by facilitating continuous and long-term improvements if followed by adequate reforms.

On the other hand, feedforward mechanisms intend to monitor the system's environment to anticipate difficulties (e.g., weather monitoring to modify the ship's routing and prepare for heavy weather). When focused on wider analysis (including ship design or crew composition), it allows cooperation between operators and decision-makers to enhance system reliability by identifying weaknesses. Thus, feedforward mechanisms can identify enhanced conditions of operations preventing possible disturbance (e.g., quantity and quality of crew). The benefits of feedforward rely on its capacity to anticipate safety issues and offer proactive responses while acknowledging the complexity of sociotechnical systems (STS)[10] in operation.

In the shipping industry, the feedback loops between crews, companies and authorities are mainly dependent on data derived from near-misses, checklists, accident investigations or wrong functioning of any element of the systems on board vessels. This kind of data leads, eventually, to *post-event adjustments*. For enhanced safety, these feedback loops need to be complemented with feedforward loops. Feedforward requires direct contact and trustful relationships with those in operations who can openly share their views about safety improvement, pitfalls to avoid, and difficulties to overcome. The purpose of such an unconstructed analysis of the work situation is to anticipate future safety-related events by learning from the environment and actions that either avoid accidents or contribute to successful operations.

Table 1 shows the main characteristics of feedback and feedforward reporting mechanisms, including their safety-related aim, purpose, type of data needed, strengths, limitations and use in shipping.

	Feedback	**Feedforward**
Safety-related aim	Post-adjustment (reactive) Trigger actions or corrections post-events	Anticipation (proactive) Prepare to operate in an uncertain environment
Purpose in safety	Gather data from past safety events Estimate safety status Learn from past events	Ascertain the condition of good operations Identify disturbances inside and outside STS which may impact the safe operation Continuous dialogue between parts of the system (e.g., seafarers, managers, regulators) On-going learning and adaptation
Data needed	Pre-selected datasets (e.g., lost time accident) Low-intensity signals informing about the safety status (e.g., near-misses)	Unlimited dialogue between STS's parts as well as between STS and its environment Capacity to understand uncertainties and complexity Establish cooperation between STS operators and decision-makers for high-reliability data
Strengths	Well-known practice Easy to implement, through data management processes	Pre-event risk analysis Beyond risk assessment because include permanent dialogue Preparation for uncertain worlds

[10] The term sociotechnical system (or its acronym STS) refers, in this article, to the ship meaning the location of transport production. This distinguishes it from the system itself which includes STS and its shore relationships (shipping company and any other linkage such as flag or ports).

	Limited resources are taken in isolation (e.g., onboard and ashore) Possible automation of some key variables A powerful tool to learn from post-events	Extend analysis to the wider environment – a combination of internal and external risk analysis Acknowledge the complexity of sociotechnical system operations Impose trustful relationships and dialogue as well as sharing identical agendas and goals
Main limitations	Reactive response post-event (delay) Dependency on feedback data particularly in terms of quantity and quality The separation between those reporting (seafarers) from those analyzing/responding (companies) Agenda priorities between seafarers and managers may affect analysis and response The level of trust may be affected by the power gap between reporting staff and management Feedback focus on localized issues and often omit impacts of the wider operational context	Require deployment of continuous research and analysis capacities (including social environment monitoring) High dependence on research capacities Variability of data and data sources – difficult to streamline Difficulties to process data and automatize it (except limited decision-support-systems) Inability to overcome subjectivity in an uncertain environment with limited or no data Imperative trust and identical finality between the system's parts (e.g., seafarers and management)
Use in shipping	Despite being widely used in shipping, the data quality is often questionable indicating structural issues (e.g., lack of casualty investigation reported to IMO or issues related to IMDGs in containers) or rampant mistrust (e.g., low-quality of near-misses or adjustment of records)	Feedforward practices require the establishment of trust and research capacities which are usually not available in companies

Table 1. Feedback and feedforward reporting mechanisms (Source: Authors)

Difficulties in collecting and sharing safety-related data in shipping

Several indications suggest that feedback related to safety in shipping remains insufficient:

- Casualty investigations even when mandated by Conventions such as SOLAS 1974 regulation I/21, MARPOL articles 8 and 12, LL 1966/1988 article 23 and the Casualty Investigation Code (IMO, 2008a) are not rigorously managed by some flag States. Essential feedback mechanisms to learn from past events, marine casualty investigations are poorly addressed as suggested in recent maritime intelligence reports spotlight: (1) delays in completing accident investigations (over 2 years in some cases); (2) low rate of reporting serious casualty; (3) and low standards of published investigation[11] (Bakhsh, 2018, 2021; Adamopoulos, 2019; Osler, 2019; Bush, 2021).

Underreporting of marine casualties is not an isolated issue. Information mechanisms are failing. The following represent some symptomatic examples:

- Unreliability of near-miss reporting, rest hours or the International Safety Management (ISM) Code recordings have been reported in research publications (Allen, Wadsworth and Smith,

[11] "Nearly 40% of very serious casualties do not result in a flag state investigation being published, and even when governments do manage to file the mandatory reports, many of them fail to meet the basic standards set out for reporting"(Bakhsh, 2022).

2006; Bhattacharya and Tang, 2013; Simkuva *et al.*, 2016; Størkersen, 2018; Baumler, Bhatia and Kitada, 2021; Xue, Tang and Walters, 2021)[12];

- Forged certification of seafarers (Obando-Rojas *et al.*, 2004; IMO, 2022b) and fraudulent ship registrations (IMO, 2022a; Weise Bockmann, 2022; Raanan, 2023) are regularly disclosed in maritime news, academic publications and at IMO;
- Fraudulent declarations related to container weights and contents[13] have been pointed out as major hazards for containerships and ports (MAIB, 2008; Ellis, 2011; Baumler, 2013; Bakhsh, 2019; Allianz, 2022; Bridget, 2022);
- Frauds on bunker delivery notes lead to non-compliant bunkers[14] (Gardner and Kenney, 2022) or bunkers containing hazardous wastes (Ship & Bunker News Team, 2012) detrimentally affecting ship conduct and health.

Previous examples show structural issues in shipping with consequences on regulators' capacities to analyze shipping functioning and develop/apply appropriate conclusions to enhance safety. This indicates a structural inability or willingness to learn from past events.

On the sociotechnical-ships side, lost trust and associated fears impact, including being blamed, have been reported as contributing factors to under-report safety-related events or violations (Bhattacharya, 2009, 2011, 2012; Oltedal and McArthur, 2011; Sampson, 2017; Sampson *et al.*, 2019; Baumler, Bhatia and Kitada, 2021). Studies also reveal a wide gap between practices and policies resulting from the inefficacy in the ISM Code implementation (Lappalainen *et al.*, 2011; Bhattacharya, 2012; Georgoulis and Nikitakos, 2019; Xue, Tang and Walters, 2021).

The lack of trustful feedback and feedforward jeopardizes the circulation of information between front-line operators and decision-makers. Therefore, models to analyze ship operations may become inaccurate or invalid models generating unsuitable safety measures.

Addressing such failures requires exploring the situation to restore trust within the industry allowing a Safety Leaning Culture. One work package of the EU-funded project SAFEMODE explored, with aviation partners, barriers to adequate reporting.

METHODS

Fully described in the White Paper "Towards a Safety Learning Culture for Shipping" (Kirwan *et al.*, 2022), the methodology was purposedly developed (*SAFEMODE Project*, 2022). It included nineteen in-depth interviews with seafarers and casualty investigators as well as focus groups with regulatory bodies, safety agencies, shipping companies and maritime education and training institutions. To limit bias, aviation partners managed data collection after in-depth discussions with maritime partners. Eight areas were covered: 1) incident and accident investigation, 2) reporting, 3) near-miss reporting, 4) the Human Element, 5) the factors that keep the ship safe, 6) the role of the Safety Management System, 7) Just Culture and 8) Safety Learning.

[12] "For seafarers, the sole objective of recording work/rest hours is to confirm compliance to avoid disruptions to vessel operations and not to confirm actual working time onboard." (Baumler et al., 2020).

[13] "These fires often start in containers and can be the result of mis-/non-declaration of hazardous cargo, such as chemicals and batteries. It is estimated about 5% of containers shipped consist of undeclared dangerous goods."

[14] "[...] in excess of one million metric tons of off-spec or non-compliant fuels are detected each Year [...]"(Gardner and Kenney, 2022).

RESULTS

The current barriers identified in the study concerning safety culture and learning culture in shipping are presented in Table 2:

Areas explored during interviews	Main outcomes identified
Incident and accident investigation	• Conflicting objectives in marine accident investigation (e.g., learning vs. prosecuting) • Lack of trustful relationships hindering free information sharing (e.g., between investigators and seafarers, between seafarers and companies' management) • Tendency to focus on human error more than organizational and structural factors
Reporting	• Reporting is sometimes complicated and its purpose is unclear (e.g., blaming vs. learning) • An unfavourable mindset to reporting (e.g., fear of consequences, use of reporting) • Structural mistrust between shore and ship crew
Near-miss reporting	• Focusing on reporting indicators of satisfaction more than quality • Reporting system itself hinders quantity and quality reporting (e.g., easiness, use of information etc.) • Lack of tools and resources to analyze reporting
Understanding the Human Element	• Insufficient knowledge and attention to Human Factors • Tendency to focus on individual factors but omit system analysis and organizational factors impacting the safe operation • Overemphasis on procedural compliance
Factors that keep ships safe	• Crew professionalism and training of individuals • Resilience and flexibility of seafarers at work • Need for a balance between experience (crew) and procedures (company) • Current procedures do not always take into account operational realities
Role of the Safety Management System (SMS)	• Seen as burdensome • Too generic and does not properly integrate operational demands • A gap between onshore departments (i.e., designers of the SMSs) and ship (i.e., owners of the operational context) • Some companies exhibit learning processes but not a systematic Learning Culture
Understanding of Just Culture	• Frequent blame and punishment hinder reporting • Unstable working conditions make seafarers uneasy to report • Scarce trust and cooperation • Ships not perceived as connected to the shipping system
Understanding of Safety Learning	• Learning is limited to the event and rarely leads to system changes • Recommendations following investigations are not sufficiently applied/implemented • Structural reluctance to consider organizational factors in investigations and reporting

Table 2. Areas related to safety and learning culture in shipping (Source: SAFEMODE project)

The outcome of the research identified practices previously reported. First, superficial investigations do not reveal structural and endurable factors contributing to accidents. Second, reporting and data sharing do not reflect operational realities decoupling safety learning policies and practices. Finally, the lack of trustful relationships between frontline operators, companies and authorities compromises the validity and reliability of safety-related information.

DISCUSSION

Safety learning culture relies on effective reporting systems and practices. The goal of a safety learning culture is to become safer by letting people, organizations and industries learn from past accidents, incidents and near-misses, as well as successes (Kirwan *et al.*, 2022).

Previous research has stressed the low rate of reporting and low quality of reporting standards about accidents and incidents data in shipping. The study reinforces that lack of trust and fear of the consequences impact negatively proper information sharing (Bhattacharya, 2012a, 2012b; Oltedal and McArthur, 2011; Sampson, 2017; Sampson et al., 2019). The study stresses enduring deficiencies, including seafarers' employment characteristics, blame and reticence to explore organizational and upstream factors. These factors impact negatively data sharing and learning (Walters and Bailey, 2013).

In alignment with previous research (Lappalainen et al., 2011; Bhattacharya, 2012b; Georgoulis and Nikitakos, 2019; Xue, Tang and Walters, 2021), SMSs seem unable to connect ship operation to idealized ship operation constructed ashore and imposed via burdensome SMS. Instead of a safety tool, SMSs undermine initial intentions by transforming into a bureaucratic exercise to regulate unbalanced power relationships (Bhattacharya, 2009; Dekker, 2014) Furthermore, the research confirms previous literature related to reporting failures and inefficacy. Low-quality and inaccurate data flourish in shipping hindering feedback/feedforward and affecting any modelling and solution-finding.

The study proposes strengthening data quality and reliability by first establishing trustful relationships between front-line operators, shore-based management and authorities because "Where there is fear you will get bad data" (Lloyd, 2021).

Figure 1 shows a revised version of the trust loop (Lloyd, 2021) with the addition of "data flow and data quality enhancement" in the trust loop.

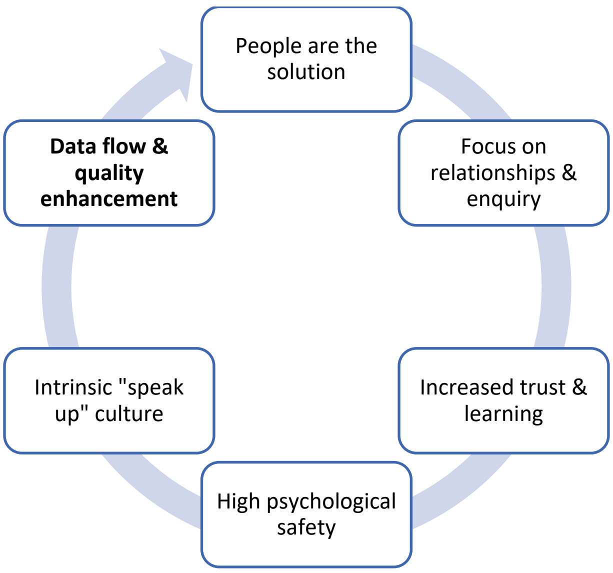

Figure 1. Trust loop. Relationship between trust and data sharing (Modified from Lloyd, 2021)

The loop starts with valuing people, i.e., frontline operators, who experience real operations and can share the most accurate information. Rather than focusing on changing frontline operators' behaviours related to specific safety-related events to meet managers' beliefs, the focus must be on trust enhancement for a common goal of joining ship crew and shore-based staff.

People are not automaton driven by frozen software or procedures. Human intelligence allows adaptation and adjustment in complex, dynamic and uncertain worlds (Reason, 2017). Shipping needs to integrate system thinking in safety development as successfully done in aerospace and aviation (Leveson, 2011).

Shore-based safety managers must acknowledge the multi-dimension of safety and human factors as highlighted by the IMO (IMO, 2004) and recall that ship operations exist within larger systems determining critical elements such as decisions during the design, budget allocation, crew selection, etc.

Thinking in systems will allow companies to refrain from punishing or blaming seafarers when questioning or reporting safety issues (Baumler *et al.*, 2020) and develop effective safety mechanisms. Only motivated and respected staff working in confidence can provide trustful and accurate reporting and allow improvements (Lloyd, 2021). Therefore, the first step towards safety learning culture in the system is trust and respect.

CONCLUSIONS AND RECOMMENDATIONS

First, data quality and accuracy are conditioned by trustful relationships. Elimination of fear and building respect and care for operators are unavoidable prerequisites to feedback/feedforward and safety learning culture. Second, shore-based managers must refrain their habits to control and blaming frontline operators. They must accept that safety requires a systemic understanding and their behaviour/decision pre-determines ship operation setting. Third, willingness to apply system thinking to safety requires demonstrating appreciation for seafarers' lives and well-being.

Adopting a safety learning culture in shipping means a willingness to:

- Choose between blame or learning;
- Build and demonstrate trust to seafarers;
- Focus on and accept workplace realities;
- Obtain an accurate and consistent understanding of critical factors leading to incidents/accidents;
- Include operators in accident analysis and determination of solutions;
- Establish dialogue and cooperation (seafarers/shore-management/authorities) for data quality;
- Think about the ship in its system and the impact of this wider system on its safe operation;
- Research impacts of environment on ship safety (feedforward);
- Ensure a system impact, so learning occurs at all levels, whether on the ship, onshore, across the fleet, across a segment of the industry, or throughout the industry as a whole.

ACKNOWLEDGEMENTS

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Ability of the Coast Guard Respond to Marine Pollution Incidents in the Exclusive Economic Zone due to Increased Maritime Traffic

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Perseverance and existence of the Republic of Croatia is largely determined by its maritime orientation. Apart from natural, historical and cultural importance of the Adriatic Sea, it also has strategic importance since it represents one of the key economic resources.

In the current context of the high uncertainty of energy supply through the existing corridors, it is being foreseen that the countries of the European Union will increase the supply by sea through the Adriatic Sea. The increased maritime traffic also results in a higher probability of maritime incidents.

Croatia, Slovenia and Italy have recognized the degree of potential risk of marine pollution incidents, especially in the area of the Adriatic Sea, and catastrophic consequences thereof. Hence, on the basis of this, in addition to the national systems for accidental marine pollution preparedness and response, they have accessed joint prevention activities at a sub-regional level.

This paper analyses the existing model of the contingency management in the Republic of Croatia, as well as some of deficiencies that reduce the ability to manage interventions in the event of accidental marine pollution, especially in the area of the Exclusive Economic Zone of the Republic of Croatia. Furthermore, it shows the importance and the role of the Coast Guard of the Republic of Croatia as a bearer of maritime safety and an important instrument for the prevention, restriction, preparedness and intervention in case of accidental marine pollution, especially in the area of the Exclusive Economic Zone of the Republic of Croatia, and its current capability to respond to requirements of the marine protection system.

KEY WORDS

Accidental marine pollution, Coast Guard of the Republic of Croatia, Exclusive Economic Zone

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INTRODUCTION

The Mediterranean Sea is an area of the utmost importance for global stability and security, and the processes taking place in this area have a multiple impact on Croatia and the Adriatic area. The geographic position of the Adriatic Sea confers a significant advantage to Croatia over neighbouring countries, especially over those that have no access to the sea. The fact that the Adriatic Sea with its littoral connects Croatia to the Central Europe and the Mediterranean Sea contributes to its essential geostrategic and geopolitical value (Priroda Hrvatske, 2022). The Adriatic Sea provides Croatia with an exceptional position, a huge transit and economic potential and an advantage which is necessary to exploit and eventually capitalize.

The Adriatic Sea is a shallow and semi-enclosed sea representing a great importance to Croatia. A special importance in terms of transport, economy and ecology is given to the area of the Northern Adriatic. The Northern Adriatic represents an essential resource, not only in terms of ecological heritage, characterised by the eco-system, but also as an area of interest for numerous economic activities taking place both on the surface of the sea and in its depths. It is known that the Northern Adriatic is also a cul-de-sac of the Mediterranean Basin with a very slow exchange of waters, and the exchanges take place counter-clockwise from the Strait of Otranto. All this gives specific features to the local eco-system of the Northern Adriatic and eventually makes it extremely sensitive when it comes to the prevention of dangers and overall conservation thereof (Ministry of Defence, 2016).

The figures referring to the population density and concentration of industries and other economic activities, maritime transport, and especially transport of oil tankers are very intensive in the area of the Northern Adriatic and every year these figures have a tendency to grow. For example, in 2017, the number of ships transporting hazardous and noxious substances that berthed in Croatian ports during their international or national navigation amounted to 2078 ships, whereas in 2019, it amounted to 2888 ships (Lušić et al., 2011; State Audit Office, 2021;).The sensitivity of a certain traffic route does not depend exclusively upon the commodities being transported on certain routes, but also upon the standard and performance of the vessels involved, and in particular upon the average age of the fleet, the observance by ships of regulations concerning safety of navigation and protection of the marine environment, the level of training of the crews regarding ship and cargo handling, and finally upon the level of management of ship-generated wastes, which together with other cargo related risk elements determines the level of risk along a certain route (Kardum, 2003).

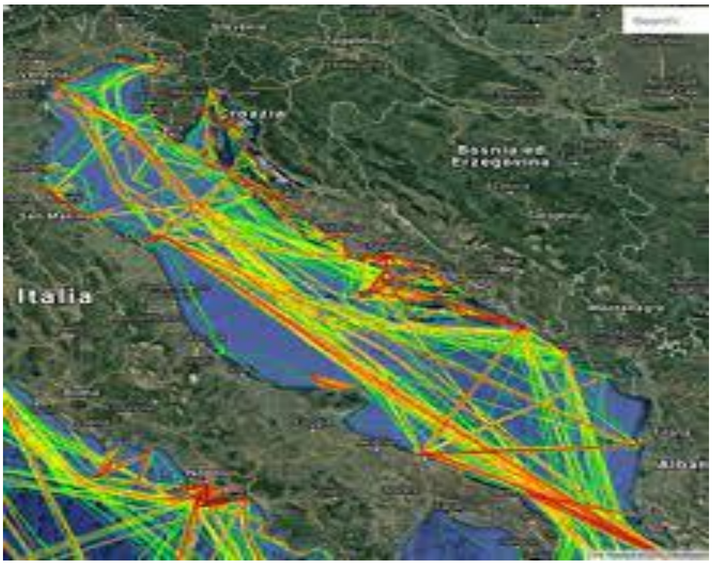

Figure 1: Density and directions of maritime traffic routes in the Adriatic Sea in 2019 (source: http://www.marinetraffic.com)

MECHANISMS PREVENTING POLLUTION IN THE ADRIATIC SEA

Croatia, Italy and Slovenia, the three countries bordering the upper part of the Adriatic Sea, have been Contracting Parties to the Convention for the protection of the Mediterranean Sea against pollution and to the Prevention and Emergency Protocol which is a part of the Barcelona Convention referring to cooperation in preventing pollution from ships and other harmful substances in cases of emergency. (Barcelona convention, 2002; The Croatian Parliament, 2021). Because the countries became aware of the extreme sensitivity of the Adriatic Sea, and especially of the vulnerability of the Northern Adriatic for its geo-strategic importance and because they considered that only coordinated joint preventive actions at the sub-regional level, taken in conformity with the applicable international regulations, can considerably reduce the risk of marine pollution incidents and contribute to the protection of the marine environment, they launched an initiative whose objective was to find the best model for joint actions against possible threats, referring to pollution incidents (The Government of The Republic of Croatia, 2008).

Sub-Regional Contingency Plan

Being aware that a serious marine pollution incident may significantly and almost irrevocably damage on one hand the Adriatic ecosystem and on the other the economic activities in the region, including in particular tourism, fisheries and energy generation, representatives of Croatia, Italy and Slovenia, with the aid of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) drew up the Sub-regional Contingency Plan for the prevention of, preparedness for and response to large-scale marine pollution in the Adriatic (Tadin, 2017). The purpose of the present Sub-regional Contingency Plan is to establish, within the framework of the Prevention and Emergency Protocol, which is a part of the Barcelona Convention, and according to the obligations of the Contracting Parties under this Protocol, a mechanism for mutual assistance, under which the competent national Authorities of Croatia, Italy and Slovenia will co-operate in order to coordinate and integrate their activities related to prevention and response to accidental marine pollution affecting or likely to affect the territorial sea, coasts and related interests of one or more of these countries, or to incidents surpassing the available response capacity of each of these countries alone (The Government of The Republic of Croatia et al., 2008).

The Signatory Countries consider prevention of accidental marine pollution from ships as an integral part of their policy for the protection of the marine environment in the Mediterranean Sea in general, and in the Adriatic Sea in particular. They also agreed to strengthen their efforts in prevention of pollution from ships in the Adriatic Sea primarily through closer cooperation in the implementation of international regulations adopted globally within the framework of the International Maritime Organization, and in the implementation of multilateral agreements adopted by the States bordering the Adriatic Sea. Furthermore, the Parties agreed in particular that all measures for prevention of accidents causing or likely to cause marine pollution in the area covered by the Plan, shall be taken in conformity with the provisions of the United Nations Convention on the Law of the Sea (UNCLOS) (The Government of The Republic of Croatia et al., 2008). The above-mentioned Agreement has not been ratified by the Republic of Italy yet, and because of that the Agreement has not entered into force (State Audit Office, 2021). All three countries have developed their respective national systems for preparedness for and response to accidental marine pollution. Croatia drew up the agreement (hereinafter referred to as the Contingency Plan) (The Government of The Republic of Croatia, 2008). Existing national Contingency Plans are not sufficient to tackle this transboundary threat. Therefore, the countries continue to cooperate through the North Adriatic Maritime Incident Response (NAMIRS). NAMIRS will support better preparedness and a more coordinated response at a transnational level. Strengthen regional cooperation and coordination will be achieved by integration resources, tool and the knowledge available with in the NAMIRS. All this, will provide specific guidelines for the revision and update of the Sub-Regional Contingency Plan.

Contingency Plan For Accidental Marine Pollution

The Contingency Plan establishes the procedures and measures for predicting, preventing, restricting and preparedness for as well as response to accidental marine pollution and unusual natural marine phenomena for the purpose of protecting the marine environment. In addition, the Contingency Plan is implemented in case of accidental marine pollution caused by oil and/or oil mixture if the amount of pollution exceeds 2000 m^3, by hazardous and noxious substances, and in case of unusual natural marine phenomena.

The Contingency Plan shall be implemented in marine areas, on seabed and marine subsoil of the Republic of Croatia which include the maritime domain, internal sea waters, territorial sea and the Exclusive Economic Zone (hereinafter referred to as: EEZ) (UNESCO, 2004). The decision of promulgation of the Exclusive Economic Zone of the Republic of Croatia in the Adriatic Sea placed the established Protected Ecological and Fishery Zone (hereinafter referred to as: ZERP) out of force (OG 10/21) (The Croatian Parliament, 2008). Pursuant to this Decision, in the area of the Adriatic Sea where the Republic of Croatia from 2003 to 2021 through exercised its right through the legal regime of ZERP, in line with UNCLOS, the legal regime of the Exclusive Economic Zone has been established.

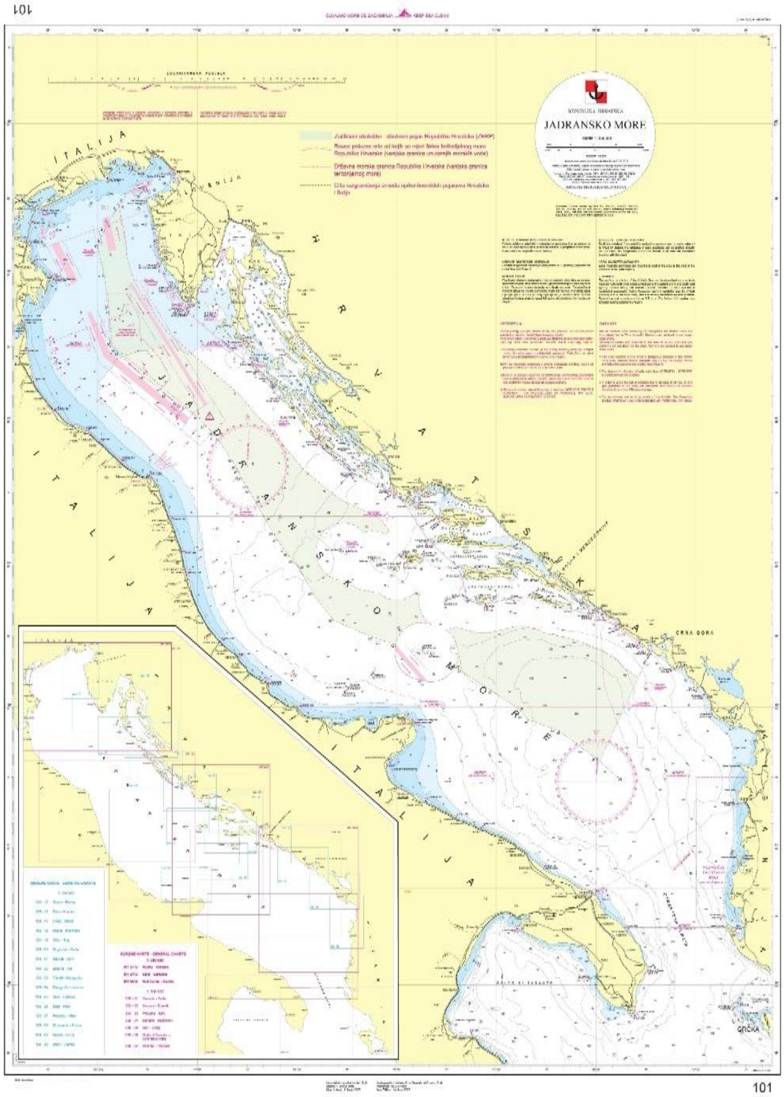

Figure 2 The map of the area covered by the Contingency Plan (Source: https://mmpi.gov.hr)

A county contingency plan, which is adopted by a county representative body, subject to prior approval of the central state administrative body in charge of environmental protection, shall be implemented in case of pollution caused by oil and/or oil mixtures if the amount of pollution does not exceed 2000 m^3 (Istra County, 2009; Lika-Senj County, 2009; Sibenik- Knin County, 2010; Dubrovnik- Neretva County, 2010; Zadar County, 2010; Split- Dalmatia County, 2010). When observing capacities for combatting oil pollution in the Republic of Croatia, it can be concluded that mostly private firms are engaged, in line with the Contingency Plan for Accidental Marine Pollution. These firms are as follows: Cian d.o.o. Split, Ciklon d.o.o. Zadar, Dezinsekcija d.o.o. Rijeka, Jadranski pomorski servis d.d. Rijeka, Ind-Eko d.o.o. Rijeka, DVD Kaštel Gomilica d.o.o., and some other smaller ones. These firms own about 20 smaller craft, about 9,000 m of inflatable oil containment booms that are 0.6 m high, and 1650 m of containment booms for the open sea that are 1.2 m high, out of which 300 m in Split and 1350 in Rijeka. All the devices are deployed along the coast from Rijeka to Dubrovnik (State Audit Office, 2021).

Entities For The Implementation Of The Contingency Plan

Entities which participate in the implementation of the Contingency Plan in case of an accidental marine pollution are the following: - Headquarters, national centre responsible for coordinating maritime search and rescue operations (MRCC) in Rijeka and County Operational Centre (COC). The Headquarters is the body appointed by the Government of the Republic of Croatia from among representatives of central state administrative bodies competent for the sea, environment protection, nature protection, internal and foreign affairs, finances, protection and rescue, defence and representatives of the MRCC. By way of exception, if there is a need for emergency action in case of accidental marine pollution, the decision on activation of the Contingency Plan may be made by the Headquarters Commander without prior approval of the Headquarters. The MRCC in the city of Rijeka is the body in charge of coordinating the Headquarters and COCs in case of accidental marine pollution in the Republic of Croatia (The Government of The Republic of Croatia, 2008). The National Centre also monitors satellite images and checks the presence of fatty substances in water as part of the CleanSeaNet program, which is managed at European level by European Maritime Safety Agency (EMSA). EMSA offers technical expertise and operational assistance for strengthening maritime safety, preparedness for pollution and remediation measures, and maritime protection (EMSA, 2023). In the event of possible pollution, EMSA forwards satellite images to the National Centre, which, in cooperation with the Coast Guard, sub-centres and merchant ships, verifies that the pollution has actually occurred.

For the purpose of providing safe navigation and prevention of pollution from ships within the European Union, EMSA provides the Member States the highest degree of technical and expert assistance so as to support them in the implementation of EU legislation on maritime safety, security, and prevention of and response to pollution by ships; monitoring the implementation thereof and evaluation of efficiency of measures taken. EMSA has established a network of stand-by oil spill response vessels with commercial vessel operators. In the Republic of Croatia, EMSA concluded a contract with a Croatian firm called Dinamarined on services of a stand- vessels for removal of oil spill in the area of the Adriatic Sea until 11 May 2024. Dinamarined, with its vessel KIJAC, has joined the European network of clean-up vessels for the area of the Adriatic Sea, whose modern equipment for combatting pollution was provided by the European Maritime Safety Agency in July 2020. EMSA's contracted vessels have been adapted for oil spill response operations and are on stand-by while carrying out their usual commercial activities. In the event of an oil spill, the selected vessel will cease its normal activities and will be made available to the requesting party fully-equipped for oil spill response services under established terms and conditions and tariffs. Following a request for assistance, the maximum time for the oil spill response vessel to be ready to sail is 24 hours. Regardless of their area of commercial operations, all vessels in the EMSA network can be mobilised to respond to an oil spill anywhere in European waters and shared sea basins. EMSA currently maintains 17 fully equipped stand-by oil spill response vessels around Europe. All vessel arrangements comprise two different containment and mechanical recovery options available for response operations depending on the weather conditions and type of pollutant. Equipment Assistance Service (hereinafter referred to as EAS) consists of stockpiles of stand-alone oil pollution response equipment in the selected areas around Europe. EAS equipment is on stand-by in storage, ready to be mobilised around-the-clock for an oil spill anywhere in European waters and shared sea basins.

EMSA currently maintains four EAS stockpiles:

- Frederikshavn, Denmark (EAS Baltic Sea)

- Rotterdam, Netherlands (EAS North Sea)
- Tolkkinen, Finland (EAS North Baltic Sea)
- Ravenna, Italija (EAS Adriatic Sea)

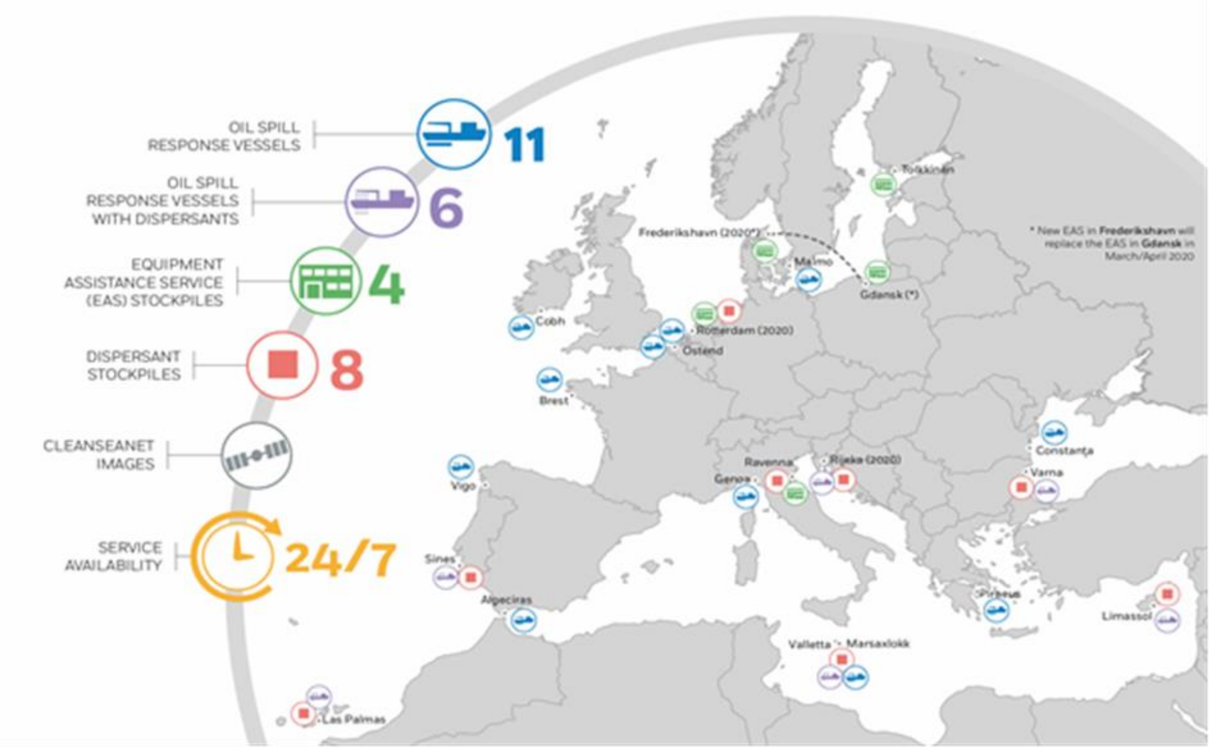

Figure 3 EMSA, Projection of operational services (https://www.emsa.europa.eu/)

COAST GUARD OF THE REPUBLIC OF CROATIA

The Coast Guard is a unit organised within the Croatia Navy (hereinafter referred to as the CN) responsible for implementing surveillance and protection pf rights and interests of the Republic of Croatia and is composed of the Headquarters of the 1st Division (based in Split) and 2nd Division (based in Pula). Currently, it comprises vessels and boats, and for carrying out operational monitoring it also has Croatian Airforce aircraft at disposal as well as systems of unmanned aircraft of the Intelligence Regiment of the General Staff of the Armed Forces of the Republic of Croatia (hereinafter referred to as the General Staff) (Barić -Punda et al., 2017; Urlić, 2009).

Tasks Of The Coast Guard

The Coast Guard, as is required by law, has a task to monitor systematically activities at sea and to control uniformly the overall area under the jurisdiction of the Republic of Croatia. Furthermore, it is an important tool for preventing, restricting and preparing for as well as responding to accidental marine pollution; controlling the implementation of regulations governing marine fishery, combatting and preventing transnational organised crime and proliferation of weapons of mass destruction; combatting piracy and other uses of the sea in non-peaceful ways; controlling the implementation of regulations on established safety zones, apparatus and devices on the sea used for researches and exploitation of the seabed and subsoil in the continental shelf of Croatia; controlling the implementation of regulations on the passage of foreign war ships through the internal waters and territorial sea of the Republic of Croatia; combatting and eliminating safety risks of importance for the national security (Vokić- Žužul, 2003; The Croatian Parliament, 2007; Ministry of Defence, 2009;).

Role Of The Coast Guard In Case Of Marine Pollution

In case of accidental marine pollution, spill of oil, oil mixture, hazardous and noxious substances, and in case of sudden natural catastrophes, the Coast Guard shall act in line with the Contingency Plan for Accidental Marine Pollution in the Republic of Croatia. The Coast Guard may for the purposes of the Contingency Plan hire legal entities specialised in open sea interventions such as towing, firefighting, installing booms and alike, in order to undertake measures for preventing and restricting the spreading of marine pollution, as ordered by the Headquarters' Commander. A member of the Coast Guard shall, as a representative of the Ministry of Defence, be appointed to the Headquarters for the implementation of the Contingency Plan for Accidental Marine Pollution in the Republic of Croatia. Cooperation between the Coast Guard with other competent bodies is prescribed by the Ordinance on Coordination of the Coast Guard with bodies competent for the control of accidental marine pollution (Ministry of Defence, 2016). The Central Coordinating Committee for Surveillance and Protection of the Maritime Rights and Interests of the Republic of Croatia is a body whose members are representatives of ministries competent for defence, sea, internal affairs, fisheries, environment protection, economy, finances and foreign affairs. In addition to the mentioned ministries, the director of the directorate in charge of maritime safety of the ministry competent for the sea, Director of the Customs Directorate, Director of the Civil Protection Directorate, Director General of the Police, Chief of the General Staff of the Croatian Armed Forces, Commander of the Croatian Navy and the Commander of the Coast Guard are also included (Komadina, 2003; Ministry of Defence, 2014; Nimac, 2014; The Croatian Parliament, 2015).

CAPABILITY OF THE COAST GUARD TO RESPOND TO MARINE POLLUTION

Through joint operations with the bodies competent for surveillance and protection of the maritime rights and interests, and by applying the principles of cost-effectiveness and efficiency, and in line with international law and regulations, the Coast Guard has conducted a series of activities within the scope of its work so as to respond successfully to accidental marine pollutions in the internal waters, territorial sea and EEZ. For the purposes of implementation of the Contingency Plan for Accidental Marine Pollution, the Coast Guard has assigned the patrol boat OB SB-73 "Faust Vrančić", which has necessary technical characteristics for combatting marine pollution. The last few years, several reconstructions have been made in order to adapt the boat to carrying out actions laid out in the Contingency Plan. By analysing marine pollution response boats from other coast guards, it has been concluded that it is necessary to equip OB SB-73 "Faust Vrančić" with an IC camera or a special radar for detecting oil spills on the sea surface. This equipment would enable an early detection of oil spills in the whole area of responsibility (detection with a radar or IC camera), accurate and reliable locating of oil spills, identification of ships that caused the pollution, development and providing of evidence about oil pollution (quantity and characteristics for processing the source of pollution).

The Coast Guard may employ its other vessels for the purpose of swift and efficient intervention of securing maritime traffic in the area of an incident.

Awareness of complexity of operations, training and coordination of all the participants in the Contingency Plan when responding to accidental marine pollution, especially when COCs cannot respond to the scope of marine pollution, resulted in the execution of interdepartmental exercises and international workshops where the members of the Coast Guard participated as an equal partner. During the national exercises “ADRIATIC 2017”, “ADRIATIC 2018” and “NAMRIG Pula 2019” the communication system was checked and the exercises of cleaning the polluted sea and coast in case of accidental marine pollution were carried out (The Government of The Republic of Croatia, 2008; Ministry of Defence, 2009).

The Coast Guard participated with OB SB-73 “Faust Vrančić” in the interdepartmental exercise “ADRIATIC 2020”, within which the capability of combatting oil pollution of the sea was demonstrated in the waters of the island of Vis with the EAS (Equipment Assistance Service) equipment of the Danish manufacturer “TRAWEL NET-1599-DESMI”:

The objective of the exercise was to check preparedness for interventions in cases of accidental pollution, and to check the response mechanisms pursuant to the Contingency Plan for Accidental Marine Pollution. The current preparedness and level of skilfulness of the crew when handling the equipment and functionality of material and technical resources were also tested. During the execution of the exercise, the crew demonstrated a high level of skilfulness when handling the installed equipment. The exercise also showed that the OB SB-73 “Faust Vrančić” with her own capacity could store and use the equipment except for storing of collected oily water until the port of discharge. For this it is necessary to install a floating tank or to have a support of another vessel that would sail alongside the OB SB-73 “Faust Vrančić” and to which oily water would be transferred. In addition to the mentioned equipment, the Croatian Navy also used the Norwegian system called Nofi Current Buster 6. The both systems are of a container type and they were -loaded aboard the OB SB-73 “Faust Vrančić” for the purpose pf training of the crew. The equipment used for combatting marine pollution was owned by the EMSA, and in accordance with the Agreement on the temporary transfer of European Maritime Safety Agency's assets to the Republic of Croatia concluded between the EMSA and the Ministry of the Sea, Transport and Infrastructure (hereinafter referred to as MSTI), it was delivered in July to Croatia for the temporary use, and on the basis of the Agreement on the Joint Cooperation between the MSTI and Ministry of Defence this equipment was issued to the Coast Gard until October 2020.

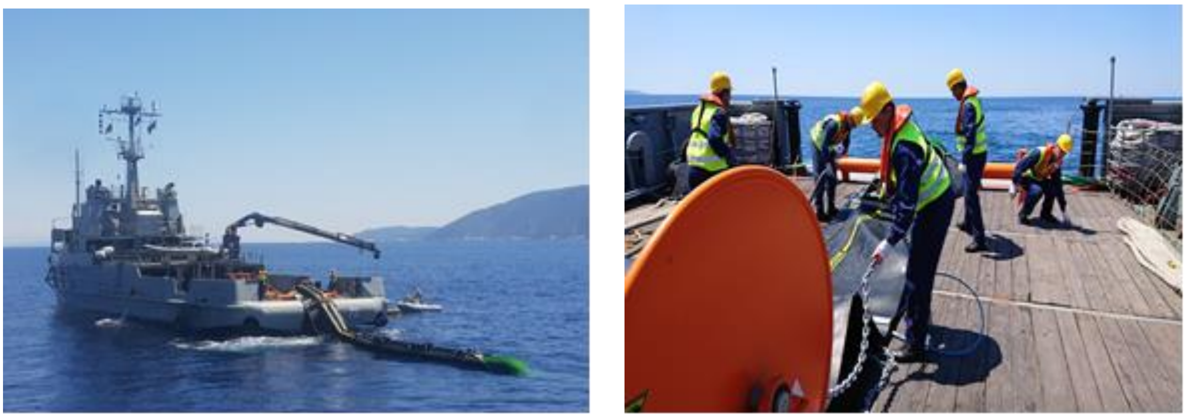

Figure 4. Picture showing the Coast Guard during the execution of the exercise “Adriatic 2020 – Combatting marine oil pollution” (Source: https://www.morh.hr/)

Within the scope of the 13th Plenary Conference of the European Coast Guard Function Forum, which was chaired by the Coast Guard of the Republic of Croatia, in 2022 an interdepartmental exercise “COASTEX 22” was carried out and its objective was to improve interoperability and mutual understanding of EU agencies participating in the comprehensive protection of the sea and its resources. The Deputy Commander of the Coast Guard was a director of the exercise, and it consisted of more scenarios, out of which one was dealing with a collision of two ships, which resulted in marine pollution. During the execution of the exercise, a special attention was paid to the accurate and timely flow of information towards all the bodies and services in accordance with their competences.

During 2022 members of the Coast Guard took part in a regional workshop "Enhancing Oil Spill Preparedness and Response in the Adriatic and Mediterranean Regions" whose objective was to improve regional cooperation, familiarisation with new technologies in the industry and exchange of knowledge and experiences with manufacturers of equipment and members of services in charge of responding to accidental marine pollution. In addition to the above, Coast Guard personnel have been invited to participate in the Adriatic Spill Conference (ADRIASPILLCON) in May 2023. The goals of ADRIASPILLCON are to present the latest developments in the technical, scientific, legal and organizational fields of dealing with accidental marine pollution, and to ensure the platform where international, regional and national institutional, shipping industries, specialized companies, equipment manufactures and individuals experts could share their experienced and knowledge in the field of protection of marine environment. By participating in exercises and workshops, members of the Coast Guard increase their knowledge about trends in the development of capabilities oriented towards the marine pollution prevention, activities in Croatia and in neighbouring countries. Furthermore, these exercises and workshops are contributing to the interdepartmental coordination, by integrating knowledge, tools, means within the complex managing system and responses to marine pollution. They will also improve the cooperation and interoperability that will contribute to the development of the sub-regional operation mechanism for interventions of the Northern Adriatic countries.

Having realised the importance of the Coast Guard and its technical and human resources as well as the importance of the conducted activities, the State Audit Office audited the effectiveness in the period from 2017 to 2019 and found certain deficiencies among which are the following: the range of 2,000m^3 of spilled oil from the Contingency Plan for Accidental Marine Pollution is too big range for activities of the County Operational Centres. The Coast Guard has a ship that is adapted for using and setting containment booms, and ships for surveillance of the sea and adequate storage facilities for equipment disposal and educated people, but do not have the necessary equipment to prevent and restrict marine pollution in the EEZ.

The State Audit office also defines that it is necessary to determine sufficient equipment that would be used by the Coast Guard for rapid interventions in the event of accidental large-scale marine pollution in the open sea (State Audit Office, 2021).

A quick and efficient intervention in the event of a marine pollution incident has to result in a more successful system of protection and conservation of the sea. Therefore, the MSTI has, for the purpose of the Coast Guard's activities, provided for three sets of the equipment that will contribute to responding to accidental large-scale marine pollution in the areas of the EEZ, territorial sea and internal sea waters. The procurement of the equipment should be accomplished within the next three years and the equipment would be deployed to military installations in Pula, Split and the area of the South Adriatic. Such an arrangement of the equipment will enable the Coast Guard to react more rapidly, especially if a ship, at the moment of the incident, marine pollution, while on its regular tasks of the surveillance and protection of maritime rights and interests of the Republic of Croatia, is farther away from its Naval base home port (Split). If the ship is directed towards the closest base with the deployed equipment, it, considering the hotspot, will reduce the precious time for appropriate and timely reaction to the crisis situation, which, eventually, may be of the crucial importance.

CONCLUSION

The Adriatic Sea is of the special importance, not only for the Republic of Croatia but for the whole region, regarding interactions in different uses of the sea such as: transport of goods and passengers, oil and gas, energy and communication, fisheries, coastal and sea tourism, protected areas, cultural heritage. Economic activities in the Adriatic Sea are growing significantly every year, which is leading to an increase of the maritime traffic. A consequence of the increased maritime traffic is the increased risk of marine pollution due to spillage of polluted waters, maritime accident, disposal of industrial waste and other forms of pollution. In this context, accidental marine pollution, and particularly the one caused by an oil spill, represents a great threat with potentially devastating ecological and economic consequences.

Activating the Coast Guard as an important tool of response to accidental large-scale marine pollution in the open sea, territorial sea or internal sea waters will be efficient if the Coast Guard has at its disposal the specialised equipment for combatting large-scale marine pollution, which includes containment booms, skimmers, oil spill detection systems and, if possible, containers for storing collected oily waste. The specialised equipment would enable the Coast Guard to conduct exercises, which would increase the preparedness and skilfulness of the crew and this implies that the existing contingency model for accidental marine pollution in the area of the Exclusive Economic Zone of the Republic of Croatia would be more efficient and could respond to the set requirements.

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Raising the Level of Navigation Safety Using the AIS System

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The marking of waterways and other navigational hazards has a crucial role in maintaining a high level of navigation safety at the sea. The aforementioned use different types of equipment, installed on maritime signaling facilities and based on different technologies, but all of them are not applicable in all conditions and micro-locations. In addition to the classic, i.e., visual ways of marking maritime signaling facilities, in recent times the use of electronic aids to navigation has become increasingly widespread. Among the electronic aids for marking maritime signaling objects, the most prominent application is the AIS (Automatic Identification System) system, which is used, among other things, for navigation, meteorology, data transmission, and many other applications. This work analyzed the functioning of the AIS system and AIS AtoN devices on maritime signaling facilities.

KEY WORDS

Safety of navigation, Automatic Identification System, Navigation, AtoN, Communications

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INTRODUCTION

The Adriatic Sea is a shallow, spacious bay and the most northern part of the Mediterranean Sea (Pravilnik o oznakama i načinu označavanja na plovnim putovima u unutarnjim morskim vodama i teritorijalnom moru Republike Hrvatske, 2007; Pravilnik o sustavu obilježavanja plovnih putova i objektima sigurnosti plovidbe, 2020). The Croatian part of the Adriatic, geographically located to the east, has a more rugged coastline than the part geographically located to the west (Perić, 2016). Confirmation of this is the total length of the Croatian coast of 5.835,3 km and the island coast of 4,058 km (Burn, 1995). The surface, together with the islands, is 138,595 km^2 or 5.5% of the total area of the Mediterranean Sea (Jardas, Pallaoro, Vrgoč, and Jukić-Peladić, 2008). Furthermore, the existence of 1.185 islands, islets, reefs and rocks in the mentioned area represents obstacles in navigation and significantly increases the possibility of accidents and unwanted events at sea (Lušić, and Kos, 2006). Obstacles are assumed to be static and do not change shape (Ari, Aksakalli, Aydogˇdu, and Kum, 2013). The safety of navigation at sea is achieved through the installation and maintenance of maritime signaling facilities, the arrangement and maintenance of waterways and the performance of maritime radio services.

Maritime signaling facilities are installed by the "Rulebook of markings and marking methods on waterways in internal sea waters and the territorial sea of the Republic of Croatia". The rulebook harmonized with the recommendations of the International Association of Maritime Aids to Navigation and Lighthouse Authorities - IALA. The Republic of Croatia is a full-fledged member of IALA. The purpose of building maritime signaling facilities is to maintain the level of navigation safety at the highest level in the territorial sea of the Republic of Croatia.

Maritime signaling facilities are divided into three categories of nautical significance:

- The first category of nautical importance - maritime signaling facilities located in ports open to public traffic, which are of international economic importance for the Republic of Croatia. The availability of maritime signaling facilities of the first category is prescribed to be at least 99.8%. The deadline for reactivating the maritime signaling facility is 24 hours from the moment a malfunction is reported (Pravilnik o sustavu obilježavanja plovnih putova i objektima sigurnosti plovidbe, 2020). The activation of faulty objects depends on the weather conditions at sea (Pomorski zakonik, 2020),
- The second category of nautical importance - maritime signaling facilities located in ports open to public traffic that are of local importance. The availability of the mentioned facilities is prescribed to be at least 99%, and the deadline for activation is 48 hours from the moment a malfunction is reported (Pomorski zakonik, 2020), and
- The third category of nautical importance - maritime signaling facilities that complement the facilities of the first and second categories of nautical importance. The prescribed availability of facilities is at least 97%. The deadline for reactivating the maritime signaling facility is 96 hours from the moment a malfunction is reported (Pomorski zakonik, 2020).

Currently, there are 1.227 maritime signaling facilities in the Croatian part of the Adriatic. The number of facilities is constantly increasing, and less than 10% of them are under remote monitoring (Zec, Jugović, Frančić, and Žgaljić, 2019). Restrictions for the inclusion of additional facilities in the monitoring system are of a technical and economic nature. The technical problem is the transfer of data from all micro-locations maritime signaling facilities. From existing maritime signaling facilities, data transmission is carried out using the GSM (Global System for Mobile Communications) network and data traffic. GSM signal is not available at all maritime signaling facilities (Karin, Vrlić, Belak, and Ružić, 2013).

Regarding the observed problem, the authors of this paper analyzed the equipment on maritime signaling facilities. The advantages of marking objects using AIS AtoN devices, which enable direct monitoring using the AIS system, are also presented. Emphasis is placed on the possibility of using the AIS system for data transmission from maritime signaling facilities located in micro-locations where the GSM signal is unavailable and insufficiently strong. Data transfer is done through the remote monitoring system. A prerequisite for the establishment of a remote monitoring system is electrical equipment, which is installed exclusively on maritime signaling facilities that are equipped with maritime lights. Based on that, the work analyzed only maritime signaling facilities that meet the stated prerequisite. The level of navigation safety at sea is in direct correlation with the number of supervised maritime signaling facilities. It is considered justified that the increase in the number of supervised maritime signaling facilities would contribute to the safety of the crew, passengers, and property at sea.

EQUIPMENT ON THE MARITIME SIGNAL FACILITIES

The quality of work of maritime signaling facilities is measured through their availability. Availability was introduced as an official measure of the effectiveness of maritime signaling facilities. The minimum satisfactory availability is 99.8% of the total working time for objects of the first category of nautical significance (Trainor, 2011).

Availability is represented as the ratio of correct operation time and total operation time, expression (1), (IALA recommendation R0130, 2017.).

$$A = \frac{T_f - T_e}{T_f} \quad \text{..................................} \quad (1)$$

where is *A – availability,* T_f *– total operation time, and* T_e *– time of failure.*

Uptime is defined as the difference between the total uptime and the time the equipment was down. In order for maritime signaling facilities to work correctly and within nautically prescribed characteristics, electronic equipment is installed on them, as shown in Figure 1.

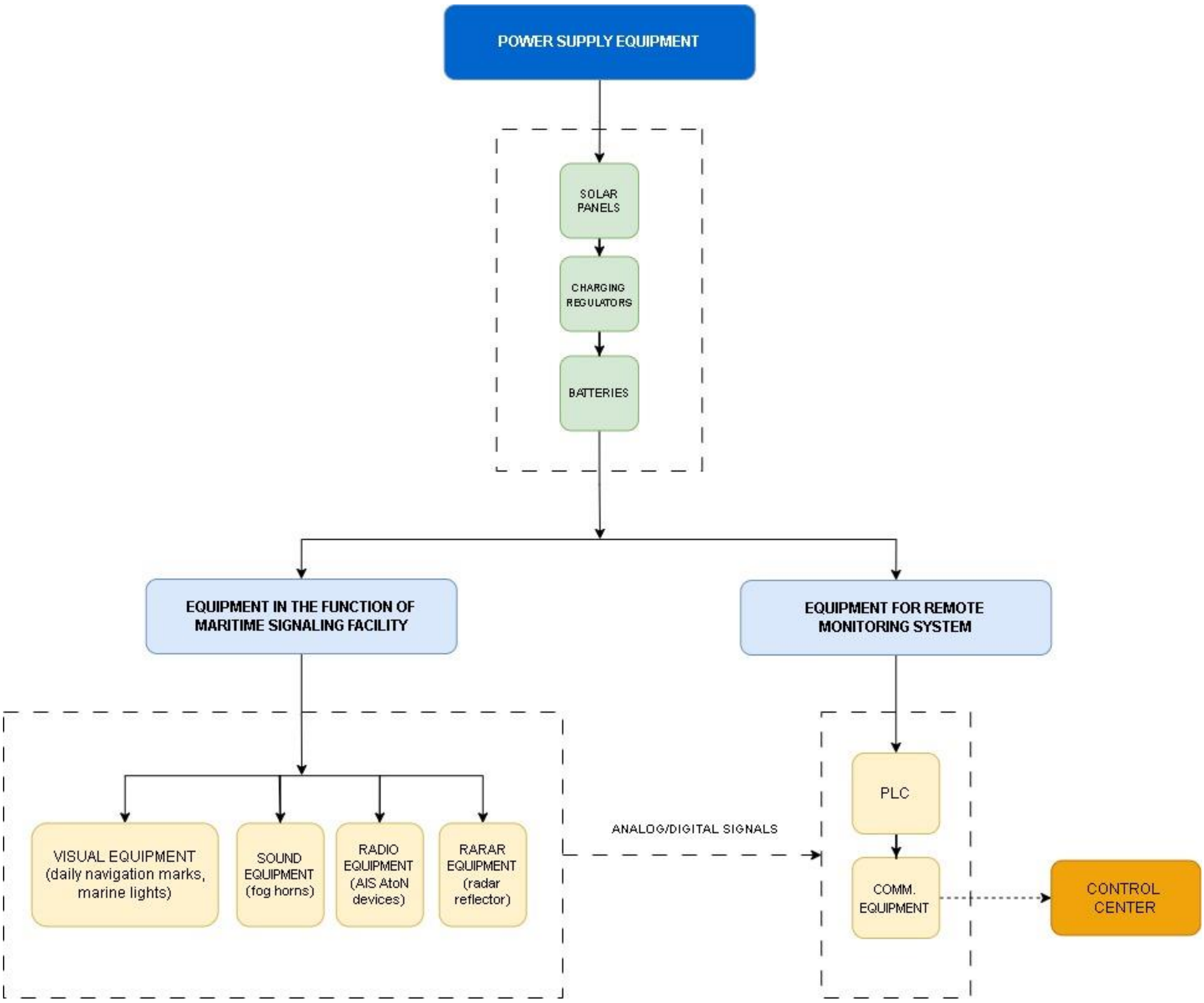

Figure 1. Equipment on maritime signaling facilities (Source: Authors).

According to Figure 1, the equipment on maritime signaling facilities is generally divided into:

- Power supply equipment,
- Equipment in the function of the maritime signaling facility, and
- Equipment for the remote monitoring system.

The power supply equipment includes the equipment installed on the maritime signaling facilities, the purpose of which is to provide the electricity necessary for the operation of all the equipment installed on the maritime signaling facility. The equipment consists of accumulator batteries, which are charged with solar energy. Charging is done using solar panels and electronic components for regulating the strength of the charging current. The equipment in the function of the maritime signaling facility and the equipment for the remote monitoring system is powered by the mentioned equipment. Signals from measurement sensors or equipment are collected using a remote monitoring system. The sampled signals are analog and digital type. The signals are processed in a PLC (Programmable Logic Controller) device, and after that, they are delivered to the monitoring center using communication equipment. The control center is located on the coast, not on the maritime safety facility.

The characteristic of the maritime signaling facility is determined by the color and range of the light, as well as the sequence and duration of the light signals. Classic bulbs with single and double filaments are used as light sources. Classic light bulbs are gradually being replaced by light sources in LED technology.

The functioning of maritime signaling facilities equipped with maritime lights is shown in picture 2.

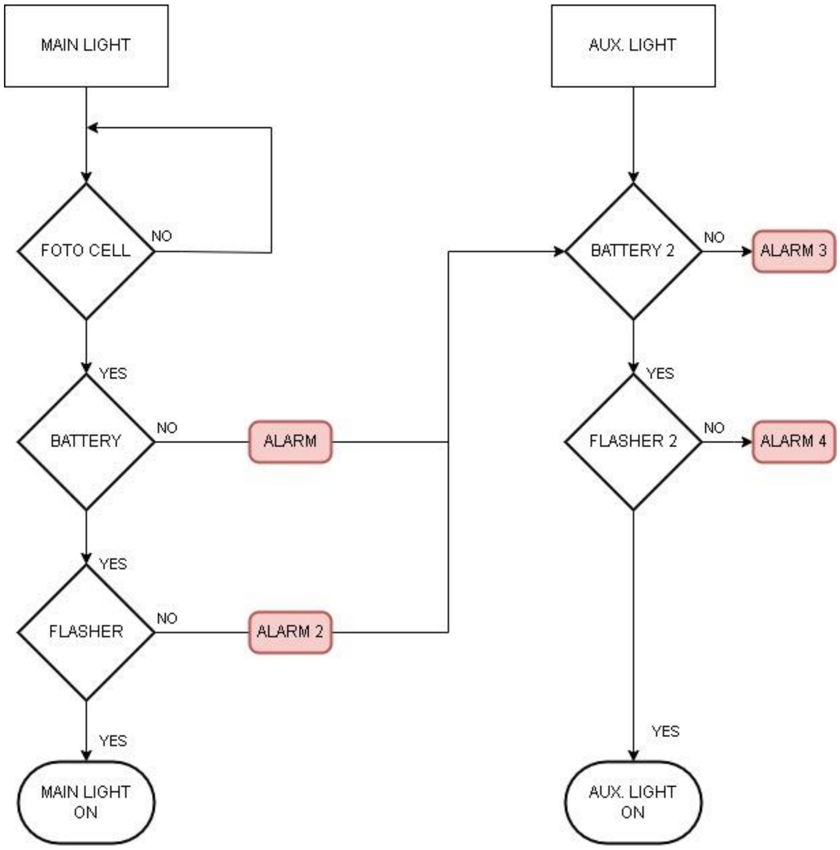

Figure 2. Flowchart of maritime signaling facilities (Source: Authors).

Figure 2 covers the operation of the main and auxiliary light, as well as the conditions under which operation is switched from the main light to the auxiliary light and vice versa. In order for the main light to turn on, several conditions must be met. The first of the conditions is the resistance value of the photocell, which defines the state of day or night. If the state of the photocell is in the value of the resistance that represents the night and if the voltage level of the accumulator battery is optimal, the electronic device, the so-called "flasher" is activated. The mentioned device represents the tact by which the light on the maritime signaling facility is switched on and off. It is defined for each object separately and depends on the nautical requirements at the micro-location of the maritime signaling object (IALA recommendation R0130, 2017). If the tact generated by the flasher is correct, the light is switched on. If the battery voltage is low, an "alarm" condition is generated, which is forwarded to the monitoring center using the remote monitoring system. At the same time, the auxiliary battery is activated locally on the object. Analog to the above, it also applies to flash. If the generated flash is not correct, an alarm condition occurs, which activates the auxiliary battery and the auxiliary flasher. By activating the auxiliary battery and flasher, the auxiliary light turns on. The presented logic is also applicable for the reverse case, switching the work from the auxiliary light to the main light.

The importance of quality of the equipment installed on the facility is crucial for the correct and uninterrupted operation of the maritime signaling facility. In this way, a high percentage of the availability of the maritime signaling facility is achieved, and thus a high level of navigation safety at sea.

AIS SYSTEM AND AIS ATON MARKS IN SAFETY OF NAVIGATION FUNCTION

The equipment installed on the maritime signaling facilities can be monitored remotely. One way of monitoring is by using the already available AIS network. It is justifiably considered that the implementation of the AIS system aims to raise the level of safety of navigation at sea, the protection of human lives, and the protection of the maritime environment. It is stated in accordance with the current general objectives of the International Maritime Organization (Inland ECDIS Expert Group and Vessel Tracking and Tracing Expert Group, 2017).

The modern AIS system in the Republic of Croatia was established in 2022. The main purpose of the AIS system is the monitoring of maritime signaling facilities, using AIS AtoN devices, which are installed on the mentioned maritime signaling facilities. The physical architecture of the existing AIS system used in the Adriatic is shown in Figure 3.

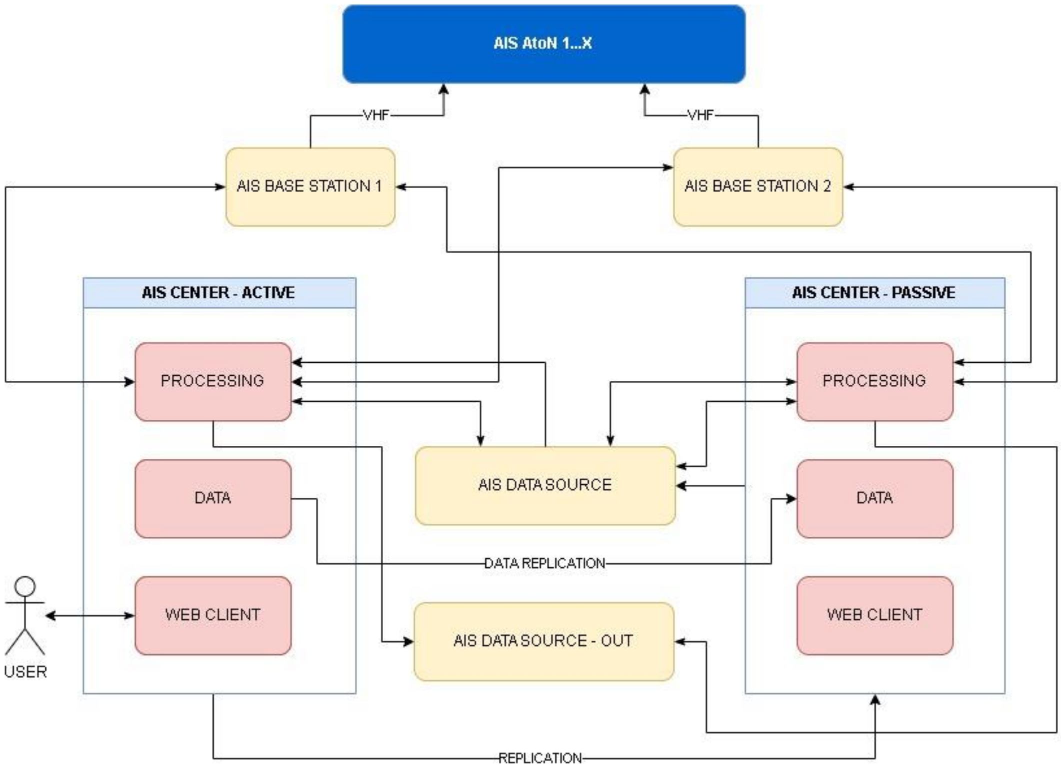

Figure 3. The physical architecture of the AIS system used in the Adriatic (Source: Authors).

The architecture of the AIS system includes:

- Active AIS center,
- Passive AIS center, and
- Base stations.

The AIS system was built through a model of two AIS centers and ten base stations. Base stations are strategically located along the Adriatic coast. This means that the AIS signal coverage is optimal in a geographical sense. AIS centers are located in Split and Rijeka and configured in such a way that the center in Split is active, while the one in Rijeka is passive. The active center performs all communication with base stations, external sources, receivers, and users. The passive center represents the redundancy of the entire system, so all the data of that configuration is replicated between the centers. In addition to communication between two servers and ten base stations of the system, replication between the active and passive servers has also been established. This replication represents system redundancy. In the event of a prolonged system outage, it is necessary to synchronize significantly large amounts of data, which can represent a system deficiency in the context of continuous operation. Also, in this scenario, it is necessary to download a large amount of archive data.

The basic elements of AIS centers include data processing, a repository, and a web application. AIS data processing has the functionality of receiving, filtering, storing, and forwarding the received AIS data. AIS data in practice are AIS messages, which can be received in the system from ships, AIS AtoN, or other AIS transceivers. The data repository has the functionality of keeping AIS data in original and decoded form. AIS data is originally in binary form, while decoding is done depending on the needs of the end users. The web application represents the user interface, which enables end users of the system to access all system functionalities.

The performance of the AIS system used in the Adriatic enables parallel use of the system for a maximum of thirty users, receiving data from at least two external sources of AIS data and sharing data on ten parallel interfaces. The system is configured to be available a minimum of 99.5% of the total time. System availability implies the availability of all system components and all data.

The term AIS AtoN represents the scenario of using an AIS transceiver as a digital marker of a maritime signaling facility. It is possible to globally register the digital markings of the maritime signaling facility through the AIS system. In the Republic of Croatia, a total of 50 maritime signaling facilities are marked with AIS AtoN. The number is continuously increasing. In the current year, it is planned to install five new AIS AtoN devices in the area of Pula, Rijeka, Zadar, and Split (Godišnji plan poslovanja i plan ulaganja u osnovna sredstva za 2023. godinu, Plovput d.o.o.). Figure 4 shows the types of AIS AtoN.

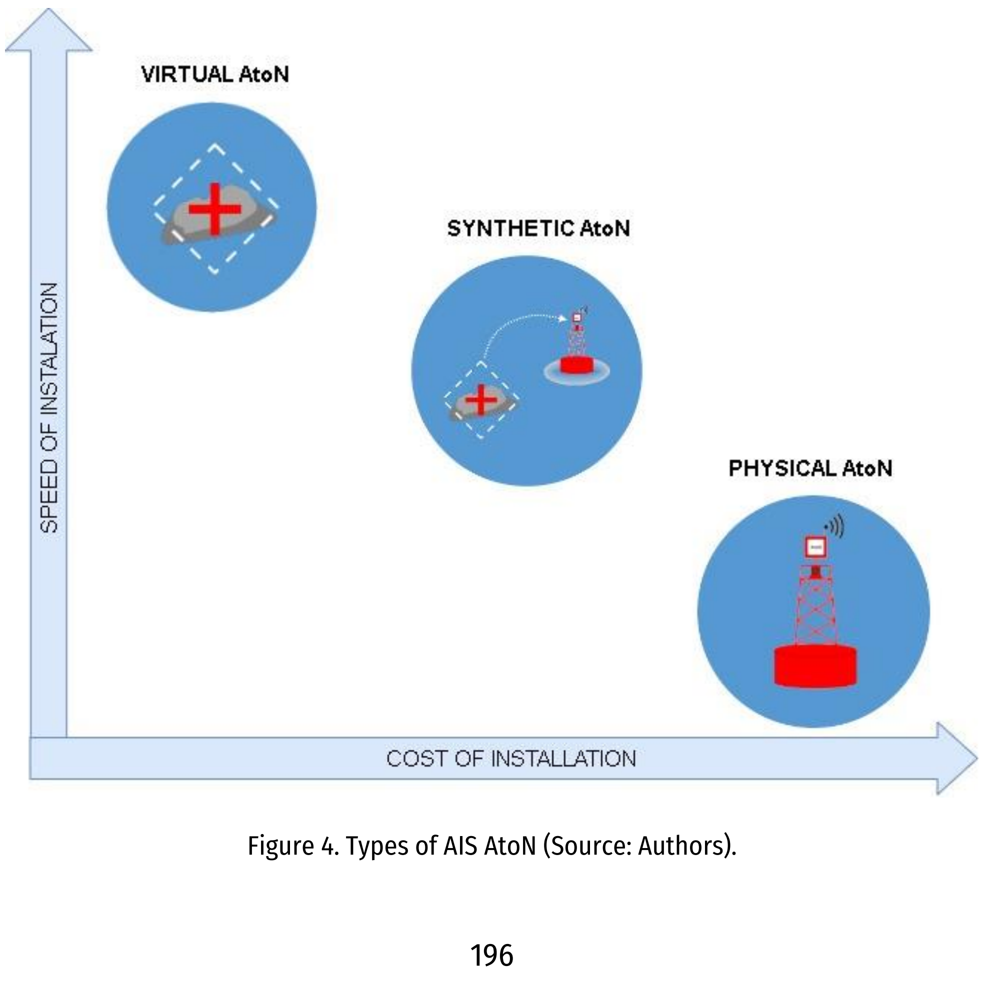

Figure 4. Types of AIS AtoN (Source: Authors).

Marking of maritime signaling facilities is possible using three types of AIS AtoN:

- Physical AtoN,
- Virtual AtoN, and
- Synthetic AtoN.

A physical AIS AtoN is an actual, physical device that is installed on a maritime signaling facility. Various information about the status of the object is transmitted from the specified AIS AtoN using structured AIS messages. AIS messages are structured by type and there is a total of 27 of them. They broadcast information such as light operation status, information about the correctness of light characteristics, the position of maritime signaling objects, maritime light battery voltages, meteorological data, and others as needed. The aforementioned is used for the above-mentioned monitoring of maritime signaling facilities. All messages from the AIS AtoN device are transmitted in binary form. Decoding of messages is performed on the receiving side of the message. In this case, the receiving side is represented by the AIS system or the ship's receiver. Application of physical AIS AtoN is allowed on both fixed and mobile maritime signaling facilities.

Virtual AIS AtoN is a virtual, digital mark. It is used on maritime signaling facilities where a physical AtoN device does not exist. The application of virtual AtoN takes place on fixed maritime signaling facilities. Exceptionally, it is also possible to apply it to mobile maritime signaling facilities that have been installed temporarily, until the installation of the physical AtoN. The application of virtual AtoN allows the availability of safety details of an incident, such as a platform sinking or marking waterways that change frequently (IALA recommendation R0110, 2021.). Details available include updated incident information, exact micro-location, information about the maritime signaling facility that is micro-located, maritime light operational status, AIS AtoN health status, and more. Information is available at ships on ship's ECDIS (Electronic Chart Display and Information System) receivers and is directly related to navigation safety at sea.

Synthetic AIS AtoN is an electronic mark displayed on the ship's integrated graphic electronic system, linked to the actual maritime signaling facility (Pravilnik o sustavu obilježavanja plovnih putova i objektima sigurnosti plovidbe, 2020) Synthetic AIS AtoN can be supervised and unsupervised (Grant, Thompson, and Ward, 2008). The difference between virtual and synthetic AIS AtoN is that when applying synthetic AIS AtoN, there is a physical AIS AtoN nearby, which is used as a reference point for marking, while this is not the case with virtual AIS AtoN.

CONCLUSION

The basic function of maritime signaling facilities is to mark waterways with maritime lights or digital markers. Different types of equipment, installed on maritime signaling facilities, are used for marking, but also based on different technologies, which in certain cases is a problem. It is justifiably considered that the level of navigation safety is directly dependent on maritime signaling facilities. It should also be noted that the generally recognized positive result of using the AIS system in various applications. Although it is most often used to avoid collisions and other unwanted events at sea, this paper emphasizes its usefulness in terms of the establishment of supervision over the operation of maritime signaling facilities. Its usefulness is particularly evident when monitoring maritime signaling facilities located in micro-locations where the GSM signal is insufficiently strong or completely unavailable.

Based on the data and analysis presented in the work, it can be concluded that the application of the AIS system and AIS AtoN is frequent in the so-called digital marking of maritime signaling facilities.

Of course, it is about the use of AIS AtoN, which is installed on maritime signaling facilities by nautical requirements. Taking into account all the possibilities of AIS AtoN, which are included in this paper, it can be concluded that the possibility opens up for the use of AIS AtoN and for the digital marking of objects and data transmission at the same time, to establish remote monitoring of the object of maritime signaling.

Finally, based on the data from the work, the conclusion is that the established AIS system and AIS AtoN devices can provide a network for reliable data transmission from all locations of navigation safety facilities on the Adriatic, and thus raise the level of navigation safety to a higher level.

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Neglection of Sailboat Day Shape – Theory and Practice

Ivan Mišlov, Mate Barić, Vinko Pavić, Luka Grbić

The International Regulations for Preventing Collisions at Sea (COLREGs - Rules) from 1972, in rule 25 paragraph e), state the following: "A vessel proceeding under sail when also being propelled by machinery shall exhibit forward where it can best be seen a conical shape, apex downwards". These Rules are adopted in order to maintain adequate level of safety of navigation at sea and they show that the day shapes required by these Rules are an integral part of sailing rules. However, observing the traffic in Adriatic Sea during summer period when the number of the sailing vessels is at its peak, it can be seen that some of the Rules are not obeyed, mostly regarding the exhibition of day shapes. In accordance with before mentioned observation it can be stated that Rule 25, paragraph e, is usually never being obeyed by sailing boats. Proving that statement was the main goal of this paper. The research was conducted at Zadar County area by visual observation and by distributing questionnaire among seafarers, sailors and skippers. Visual observation results showed that in 3 months period during summer season, in all weather and visibility conditions, conical shape with apex down has never been spotted on a sailing boat. Also, the questionnaire showed that most sailors are not familiar with the meaning of day shape which consists of a conical shape with apex down. These results indicate low level of knowledge of basic COLREGs parts, and it can be concluded that better education should be applied towards sailors, sailboat skippers, seafarers and staff in marinas.

KEY WORDS

COLREGs, Sailing vessels, Day shape, Safety

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INTRODUCTION

In 1972, the IMO organized a conference in London where the Convention on International Rules for Preventing Collisions at Sea (COLREGs - Rules) was adopted. These rules completely replaced the previous Collision Regulation from 1960. The greatest changes related to introducing provisions on traffic separation schemes after the establishment of the first traffic separation scheme in the Strait of Dover in 1967. COLREGs Convention entered into force in 1977 after the required number of member states ratified it. The rules have been regularly amended and updated over the years, and the current version from 2013 came into force in 2016.

By publishing the international rules for preventing collisions at sea, the IMO prescribed a set of legal provisions which arrange the conduct of maritime navigation. In its currently in force version, COLREGs comprises of 41 rules divided into 6 parts. Often, seafarers, especially recreational sailors, have the wrong idea about COLREGs. It is dangerous if the prevailing thought is that these are only guidelines for navigators on how to conduct while sailing. Navigators must be aware that these are the rules enforced by law, which they must follow exactly as specified.

Violation of obligations and duties specified by COLREGs results in misdemeanor liability for participants in maritime traffic. However, if a participant in maritime traffic, by violating regulations on traffic safety, endangers traffic in such a way as to cause a danger to human life or property on a large scale, including when he commits the crime out of negligence, he will be penalized with imprisonment (Criminal Code of the Republic of Croatia, 2011). Such consequences can most often arise due to a collision of a vessels, but reasons for collision of a vessels can be various. Reasons can, among other things, be found in the violation of rules that specify the exhibition of appropriate shapes or lights, or failure to follow a certain direction of navigation in traffic separation schemes, etc. Depending on the severity and consequences of the violation, the offender may be fined or imprisoned.

The progression of science in the last century has resulted in a significant amount of research aimed at determining the origin of maritime accidents. In many of them, the conclusion was reached that human error was one of the important factors leading to the maritime accident (Sánchez-Beaskoetxea, et al., 2021).

The rules for preventing collisions at sea are the same for everyone and must be followed by all participants in maritime navigation. Everyone must also be aware that at sea they must behave in accordance with maritime practice and the prevailing circumstances. During tourist season on the Adriatic coast, the number of participants in maritime traffic increases significantly compared to the rest of the year. Data for 2019, collected through the eVisitor system, for Zadar County show that the largest number of arrivals in the nautical charter was during June and August, followed by September and July (Croatian National Tourist Board, 2020). A survey of the attitudes and consumption of boaters in Croatia from 2017 showed that only 34% of vessels had a hired skipper onboard, while 66% of vessels operated without a hired skipper (Institute for tourism, 2017). At that time, there is a significantly larger number of people at sea, and not all of them are professional seafarers with years of experience, there are also recreational sailors who often do not have enough experience in sailing. It is extremely important that they all know the rules for preventing collisions at sea. In addition to knowing the rules, it is also necessary to apply them correctly at a certain moment, with the confidence that other participants will also behave according to the Rules.

Part C of COLREGs, which refers to lights and shapes, defines that rules of that part shall be complied with in all weather conditions and rules concerning shapes shall be complied with by day. Rule 25 paragraph e) of The International Regulations for Preventing Collisions at Sea (COLREGs), specifies that: "A vessel proceeding under sail when also being propelled by machinery shall exhibit forward where it can best be seen a conical shape, apex downwards". In addition to the rules for conducting maritime navigation, the technical characteristics of the equipment that ships must have in order to meet the requirements of the rules are also defined. The cone shape shall be black and have a base diameter of not less than 0.6 meter and a height equal to its diameter. In vessels of less than 20 meters in length shapes of lesser dimensions but commensurate with the size of the vessel may be used. These rules, as well as other rules concerning the need to exhibit shapes during daytime navigation, form an integral part of COLREGs. The rules on exhibiting shapes during navigation are no less binding than other rules contained in COLREGs so seafarers shouldn't choose whether to exhibit a certain shape or not.

During the tourist season, when there is a highest density of traffic, it can be noticed that the rules regarding exhibition of day shapes are often ignored. Likewise, within those rules from part C of COLREGs, which define the obligation to exhibit day shapes, there are some rules that are more often ignored than others, so it can be seen that paragraph e) of rule 25 is never obeyed. Proving that statement was the main goal of this paper.

LITERATURE REVIEW

The distribution of search and rescue (SAR) operations during 2021 indicates an established regularity compared to 2020, as well as to previous years. The largest number of SAR operations has been registered in the summer months, during the tourist season, because of a significant increase in maritime traffic of vessels intended for sport, pleasure, and recreation (Administration for Safety of Navigation, 2022).

As can be seen in the article The Role of the Human Factor in Marine Accidents (Hasanspahić, et al., 2021) a maritime accident can have several categories of causal factors based on human error. The most important category for this research is the category of unsafe actions, which includes, among other things, rule-based mistakes and knowledge-based mistakes. Rule-based mistakes include mistakes due to the choice of wrong rules due to the wrong perception of the situation or mistakes caused due to not applying the correct rule at all. Knowledge-based mistakes include mistakes that happen due to lack of knowledge of the person operating or inadequate application of knowledge acquired.

As stated in nautical tourism development strategy of the Republic of Croatia, the largest number of accidents at sea occur because of insufficient nautical experience, poorly equipped vessels and crew behavior that is not in accordance with maritime regulations and rules (Ministry of the Sea, Transport and Infrastructure; Ministry of Tourism, 2008).

The results of the analysis presented in the article by Mohović et al. (2016) show that students of nautical studies, those who will in the future take the role of deck officers, have certain deficiencies in their knowledge of COLREGs. The authors also concluded that officers and navigators who are in charge of navigational watches, regardless of their experience, do not fully understand all the rules of COLREGs. They also noticed that only a small percentage of seafarers try to perfect their knowledge through further training at COLREGs courses and thus improve their understanding of COLREGs.

Acar et al. (2012) claim in their paper that 85% of all accidents are either directly initiated by human error or are associated with human error. Mistakes are usually made because the regulations which are in force are often ignored by seafarers. The authors state that, according to the IMO, inadequate education, and training of seafarers, as well as deliberate disregard of adopted laws and procedures, are frequent causes of maritime accidents.

The Marine Accident Investigation Branch (2004) in its Bridge Watchkeeping Safety Study concludes that the basic principles of collision avoidance rules are not well understood and are then incorrectly applied in practice at sea. That study signals that collision regulations are either not understood or ignored, even though COLREGs provides a primary set of rules for taking actions to avoid collisions (Suhrab, 2016).

RESEARCH METHODS

The research was carried out in the Zadar County area during 3 summer months when number of sailing vessels is at its peak. Research consisted of visual observation of maritime traffic and by conducting a survey. Data collection by visual observation of sailboat traffic took place at Zadar channel in period from June 1 to August 31, 2022. The second part of the research focused on collecting data by distributing a survey questionnaire among seafarers, sailors, skippers and staff in marinas.

Visual observations

The visual observation has been carried out over a length of approximately 3 nautical miles on both sides of the Zadar channel, from the mainland side and from the island of Ugljan. The representation of the research area can be seen in Figure 1. On the mainland, observation stretched from the marina Borik in the north to the Gaženica port in the south. On the island of Ugljan, traffic of sailing vessels was monitored from the village of Lukoran to the passenger port in the village of Preko. The research was conducted by observing the traffic from a certain place on shore and from the sea using a boat. The boat was used so that, immediately after spotting a sailing vessel which is proceeding under sails when also being propelled by machinery, it would be possible to approach that sailing vessels while at sea and thus get in touch with the skipper in order to determine if he really had the obligation to exhibit the certain day shape at that moment. At certain periods, the speed of a sailing vessel was the key to determine if mechanical propulsion was used. If the ship was moving relatively fast while the sea was calm and there was only a light wind, it could be concluded that the ship was using mechanical propulsion along with the sails.

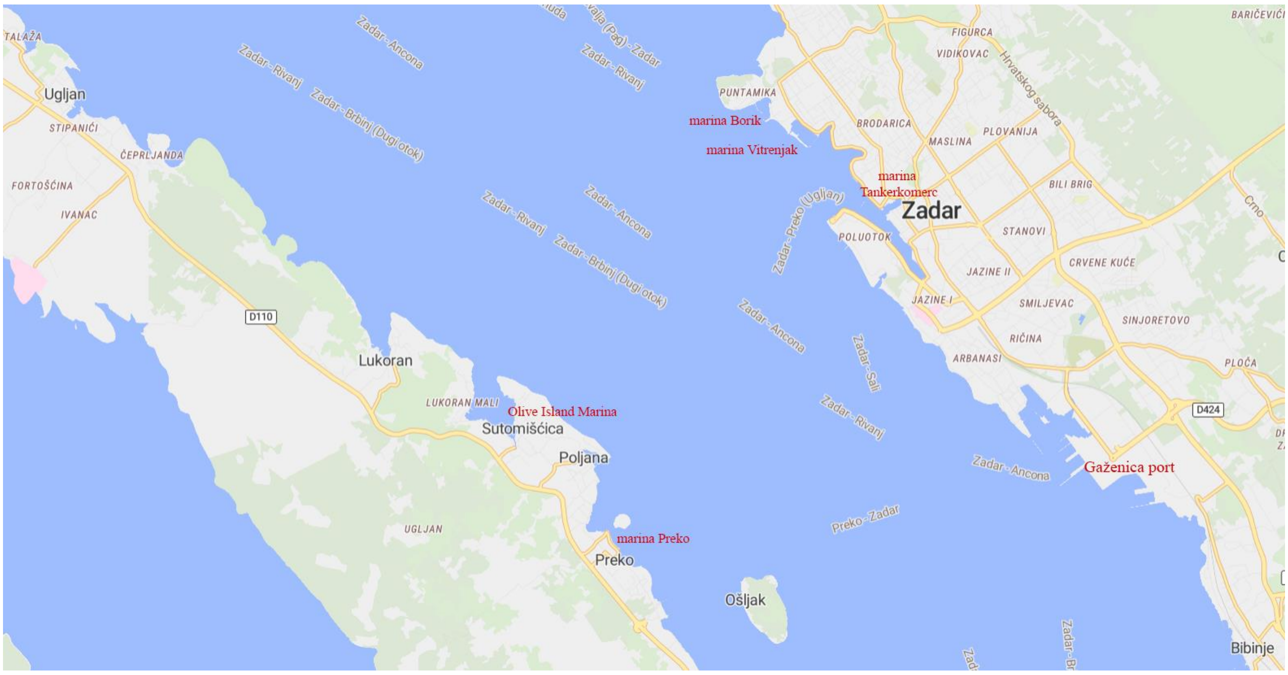

Figure 6. Research area in Zadar channel (Source: OpenMapTiles.org).

In the mentioned geographical area, at this time of the year, there is relatively dense traffic of sailing boats, and of various other types of vessels. In that area local and national passenger liner traffic takes place by Ro-Ro ferries and ships that connect the islands with the mainland, as well as international traffic with Italy, traffic of fishing boats from fishing areas to the fishing harbor in Gaženica, cargo ships to the cargo port in Gaženica, tourist boats for one-day excursions to tourist destinations that are moored in the old passenger port in the very center of the city on the Zadar peninsula. The number of arrivals of large cruise ships that call at the passenger port of Gaženica, as well as at the passenger port of Zadar, is also constantly increasing. With annual traffic of 2.4 million passengers and 350,000 vehicles, Zadar is one of the busiest ports in the Mediterranean (Zadar Port Authority, 2022). In the summer period, the traffic of vessels used for recreation in nautical tourism is especially increased, of which the traffic of sailing boats is most important for our research.

In the geographical area where the observation was conducted, there are as many as 5 modern marinas which can accommodate ships, yachts, and small boats. Marina Borik is located 1 nautical mile from the old city port and has a capacity of 177 berths. Just 400 meters south of the Borik marina is the marina Vitrenjak, which is well protected from wind and waves. Marina Vitrenjak is managed by a sailing club, and with 505 berths, many local seafarers and sailors have found a place to moor their boats. Furthermore, Tankerkomerc marina with a capacity of 300 berths is located at the very center of Zadar, in the old city port. On the other side of the Zadar channel, on the island of Ugljan, there are two more nautical marinas. One of them is Olive Island Marina in Sutomišćica with enough place for 225 boats. South of Olive Island Marine is the marina Preko, which is located in the center of the village Preko and can accommodate 87 boats. Apart from the mentioned marinas that are located directly in the research area, a large part of the traffic that passes through this area gravitates towards the marina Dalmacija, which is located approximately 4 nautical miles south of Zadar, between the towns of Bibinje and Sukošan. With a capacity of 1,200 sea berths and 300 dry berths, the marina Dalmacija is the largest marina on the Croatian coast and one of the best equipped marinas on the whole Adriatic. Including the marina Dalmacija, it can be seen that in the marinas in Zadar area, within a range of 7 nautical miles, there is a possibility to moor about 2,500 vessels. This information tells us that in the summer period during the tourist season, a larger number of sailing boats can be expected in this area.

Legislative Act on Boats and Yachts defines in Article 4, Paragraph 5 that sailing boat means a boat or yacht which, as a propulsion device, has sails of sufficient surface with which it can move on the sea or inland waters, and this term does not exclude boats or yachts that, in addition to sails, also have a mechanical propulsion device (Ministry of Sea, Transport and Infrastructure, 2020).

The same Act specifies that boats must be equipped with day shapes (signal marks) as follows:

- Boats for personal needs that sail in Area of navigation I[15] and II[16];
- Boats for commercial and public purposes with a length of more than 10 meters, regardless of the Area of navigation;
- Boats for commercial purposes, regardless of length, when sailing in Area of navigation I, II and III[17].

In accordance with this Act, in research were included only sailing boats that could be positively identified to belong to one of the categories, given that they are required to be equipped with day shapes (signal marks). This was determined by direct conversation with the boat skipper during the voyage or after docking in the marina.

Survey questionnaire

During visual observation of the traffic in the Zadar channel, research was also performed among the participants of maritime navigation. To collect data on knowledge and compliance with the COLREGs, a survey was conducted among seafarers using a survey questionnaire. The time for completing the questionnaire was not limited. Method of a survey questionnaire was selected in order to be able to analyze as many seafarers, skippers and sailors as possible over a period of time with the purpose of obtaining the most representative sample possible. This questionnaire was supposed to indicate the knowledge of the provisions from rule 25 e) of COLREGs among the selected group of respondents. Besides obtaining data on knowledge of COLREGs provisions, the purpose of the questionnaire was to get information on the frequency of application of the provision on exhibiting the conical shape with apex facing downwards when using sails with the simultaneous use of the machinery. The questionnaire also served to provide an answer to what is the reason that sailors do not comply with rule 25 e) in cases where they should. Survey was conducted in the period from the beginning of June to the end of August 2022 among sailors whose vessels docked in the marinas and among professional seafarers and recreational sailors. In that period, 166 respondents of various nationalities and from different countries completed the survey. Among the participants, 16% are professional seafarers, 11% have a license for professional skipper, 73% of people hold a license for recreational sailor e.g., boat leader. The percentage of respondents according to the license they possess is shown in figure 2.

[15] Navigation area I – includes international navigation on all seas and waters accessible from sea.
[16] Navigation area II – includes international navigation on all seas and waters accessible from sea limited to the 20 NM from the closest shore or island.
[17] Navigation area III – includes international navigation on all seas and waters accessible from sea limited to the 12 NM from the closest shore or island.

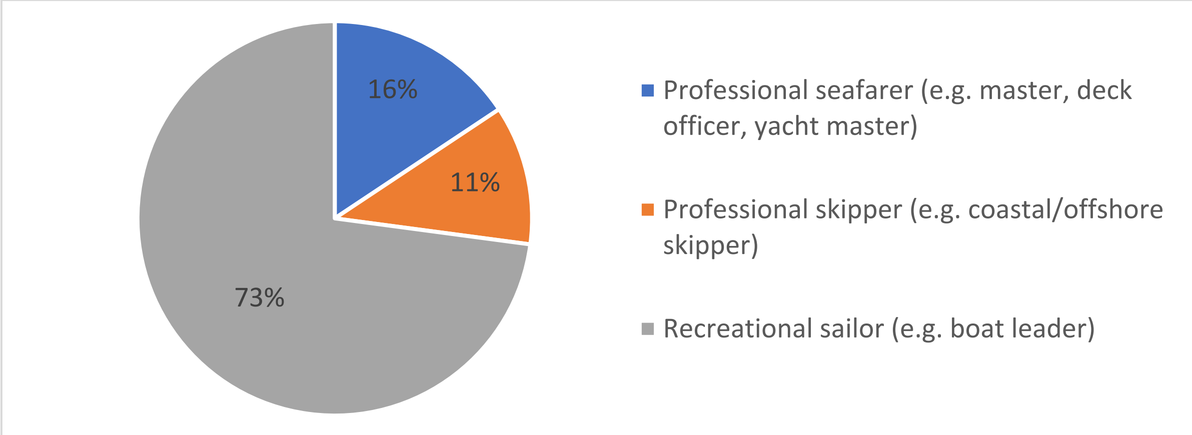

Figure 7. Type of license you possess.

It is significant or the research that 95 respondents, or as many as 57%, have 21 or more years of experience at sea. The entire percentage of respondents according to the number of years of experience at sea can be seen in figure 3.

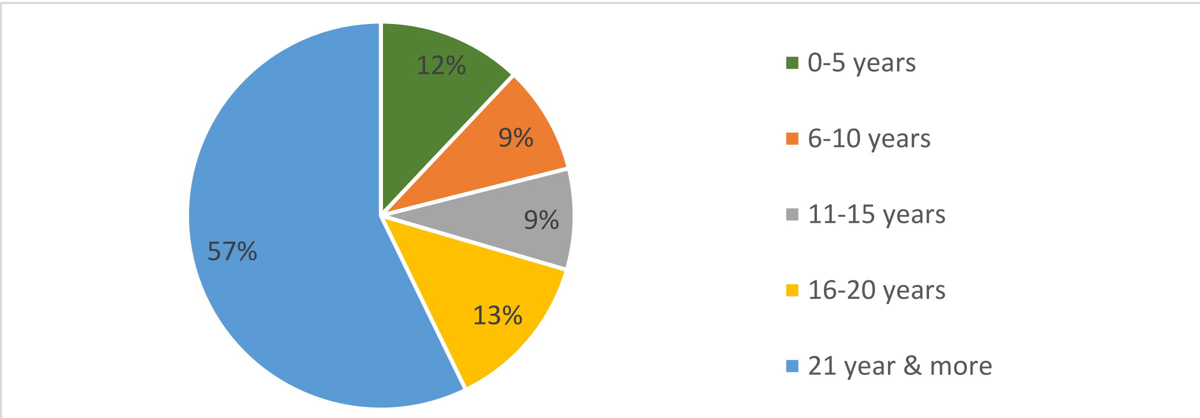

Figure 8. Years of navigational experience.

One of the questions from the questionnaire asked the participants to self-assess their knowledge of the shapes that COLREGs mandates to be exhibited on sailing boats during the day. Only 30% of the respondents rated their knowledge as excellent, which would suggest that less than one third of the people in charge of navigation consider themselves to be fully familiar with the regulations. A detailed assessment of the respondents' own knowledge is graphically presented in figure 4.

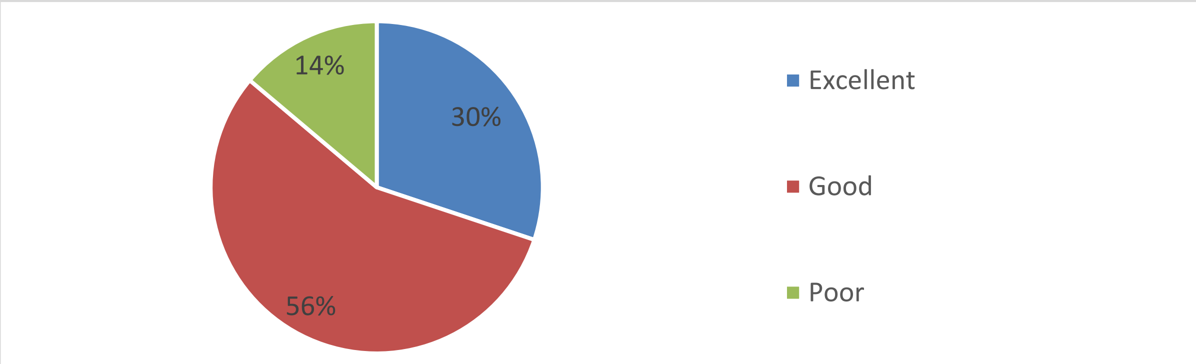

Figure 9. Assess your knowledge of the shapes which are to be exhibited on sailing vessels as required by COLREGs.

RESEARCH RESULTS

During 3 months of observation in the Zadar channel area, 83 sailboats were observed, where it could be reliably determined that at some point they were proceeding under sails and simultaneously were propelled by machine engine. None of these sailboats had exhibited a conical shape with apex downwards as defined by COLREGs in that situation.

Results obtained from the questionnaire can be divided into 3 parts. The first part of the questionnaire indicates knowledge of COLREGs rule 25 e). The second part refers to the frequency of application of COLREGs rule 25 e) during navigation. Third part of the survey questionnaire gives us an insight into what would be the reason why navigators do not respect the regulation of exhibiting conical shape with apex downwards while proceeding under sails and at the same time are being propelled by an engine.

The most important question in our research naturally refers to whether the participants know which shape shall be exhibited by a vessel that is proceeding under sails when also being propelled by machinery. The survey questionnaire revealed, as can be seen in figure 5, that only 44% of respondents answered correctly. Results also showed that 32% of the respondents did not know the answer to which shape to exhibit in that case, while 24% of the respondents gave the wrong answer. Respondents who offered the wrong answer, decided to exhibit a conical shape with apex upwards, meaning that they oriented the cone incorrectly. None of the respondents chose the other answers that were offered

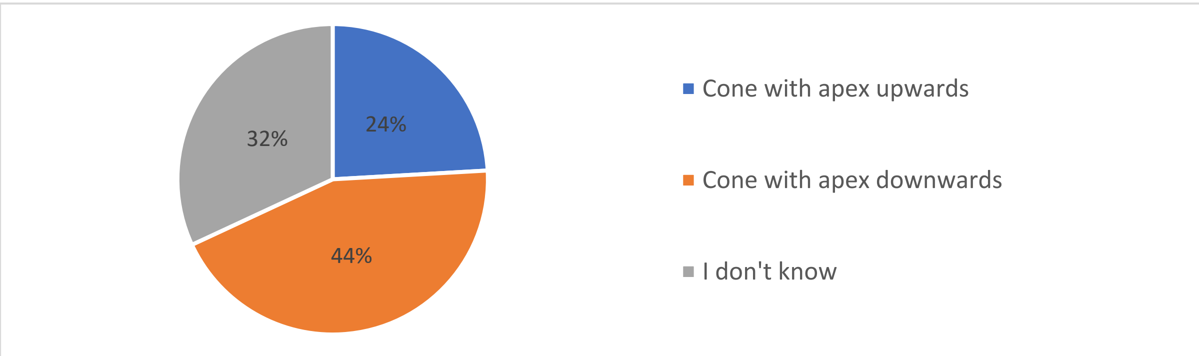

Figure 10. What day shape shall exhibit a vessel proceeding under sail when also being propelled by machinery?

Furthermore, the respondents were asked to declare "How many times have you proceeded under sails and at the same time also been propelled by machinery, but you didn't exhibit a conical shape with apex downwards on your vessel?" It is troubling that 84% of them answered that they had multiple times proceeded under sails and at the same used the machinery, without exhibiting the shape defined by COLREGs in rule 25 e). The results are shown in figure 6.

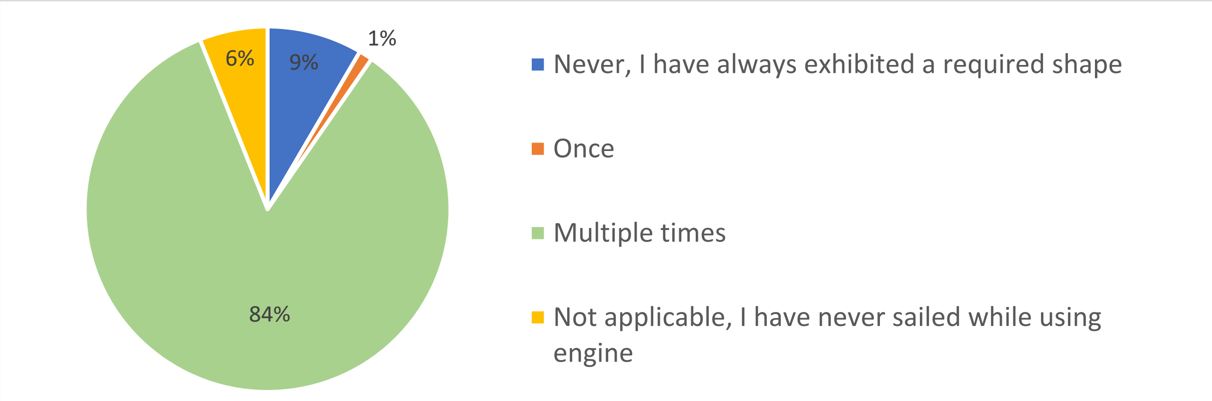

Figure 11. How many times have you proceeded under sails and at the same time also been propelled by machinery, but you didn't exhibit a conical shape with apex downwards on your vessel?

In the survey, the respondents had the opportunity to state in their own words one key reason why they do not exhibit the conical shape with the apex downwards when the vessel is proceeding under sail and simultaneously using machinery as required by rule 25 e) of COLREGs. The most common reasons for not exhibiting the required shape are visible, in percentage, on figure 7.

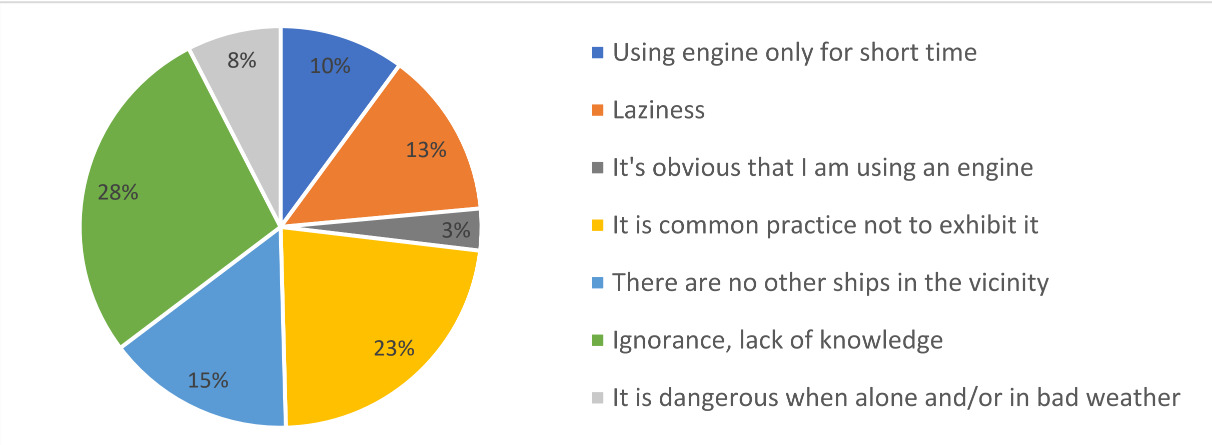

Figure 12. Reason for not exhibiting a conical shape with apex downwards when you had to as per COLREGs.

The results that were collected by visual observation in the Zadar channel evidently show non-compliance with the provisions of COLREGs, and the data obtained from the survey questionnaire indicate that these rules are violated mostly due to lack of knowledge, but also intentionally.

DISCUSSION

The results of the survey show that the skippers and boat leaders have insufficient knowledge of the provisions of COLREGs rule 25 e). Although there are no data in the Croatian national statistics indicating that non-compliance with rule 25 e) was the cause of the maritime accident, research on human errors in the maritime industry shows that insufficient knowledge and lack of experience in ship management are one of the causes of maritime accidents (Wang & Zhang, 2000).

One way to correct this is to work on improving the education of people who are in charge of navigation. The easiest way to achieve that would be to give more importance to COLREGs during the education process. Also, the inspectors who are conducting examinations to acquire a license for skippers, yacht masters and boat leaders should value knowledge of COLREGs more significantly. Better knowledge and understanding of the rules for preventing collisions at sea would consequently lead to more frequent and better compliance with them. Better compliance with the rules would also result in a reduction of maritime accidents, which would naturally increase the safety of navigation.

As the results of the survey indicated, lack of knowledge of the rules for preventing collisions at sea is the main reason why they are poorly adhered at sea, however, that is not the only reason. On average 56% of participants in the survey did not know that when a vessel is proceeding under sail and at the same time is being propelled by machinery, shall exhibit forward where it can best be seen a conical shape, apex downwards. However, at the same time, more than 84% of participants, admitted that they had repeatedly violated the stated rule of COLREGs. This indicates that non-compliance with the rules does not occur only due to lack of knowledge or misinterpretation of rule 25 e) but also due to negligence, i.e., intentional and conscious violation by the navigator. One of the reasons for such behavior, as stated by navigators, is that no one else adheres to that particular rule, and thus it has become a common practice at sea. From such results, it can be concluded that in addition to education, more active action should be taken, perhaps through more frequent controls during navigation and punishment of violators, in order to change people's habits and attitudes. Apart from that, maybe it should be considered to change the rule 25 e), that is, maybe it should be modernized in some way. A certain number of seafarers also think in this direction. They consider that there is no need to exhibit conical shape when they already use an AIS device on their vessel, on which they have clearly indicated the navigation status "Under way using engine". The use of AIS devices certainly contributes to increasing maritime safety, as it helps to identify vessels more easily and monitor traffic in the area. However, the problem with indicating the navigation status with an AIS device is that the obligation to carry AIS device on board applies only to ships of 300 GT and more in international navigation, cargo ships of 500 GT and more, and to all passenger ships regardless of size. So most recreational vessels that are at sea, such as sailboats, especially during the tourist season when the traffic is the densest, do not have the obligation to carry an AIS device. Therefore, such vessels, which formed the core of our research, are not visible to other vessels that may have an AIS device installed on board. This problem could be solved by extending the obligation to install AIS devices to smaller recreational vessels. However, this is difficult to expect in the near future, primarily due to the not very small financial resources that vessel owners would have to allocate additionally for the purchase and installation of an AIS system.

CONCLUSION

The results of the observation conducted during the tourist season confirmed the hypothesis that seafarers in charge of navigation on vessels do not obey rule 25, paragraph e) of COLREGs at all. During the research, a large number of sailing vessels were observed while proceeding under sail when also being propelled by an inboard engine or an outboard motor. However, none of these sailing vessels had exhibited a conical shape with apex downwards, as defined by COLREGs. By exhibiting that shape, they would indicate their navigational status to other participants in maritime traffic. If they followed rule 25 e) properly and exhibit conical shape with apex downwards they would "declare" themself as a power-driven vessel, regardless of the state of their sails, and must behave accordingly at sea. The reasons this does not happen in practice were determined by conducting a survey among the seafarers, namely professional seafarers, skippers, and recreational sailors. The results of the survey show that inexperience is not one of the main factors in non-compliance with regulation 25 e). It was found that lack of knowledge of rule 25 e) is the main reason for not exhibiting the conical shape, apex downwards. From that we conclude that it is definitely necessary to place greater importance on education and more efficient learning of the rules for preventing collisions at sea already in the first steps of seafarers' education. A way must be found to learn the rules in more detail, whether it is learning in naval schools or in courses at naval academies. In addition to the educational institutions, the port authorities should also place more emphasis on better knowledge in the field of COLREGs when conducting the examination to acquire a license for officers, skippers, yacht masters and boat leaders. In the entire process of raising awareness about the importance of exhibiting day shape when sailing, the role of the maritime police is also important. Maritime police should enforce more consistent compliance with the regulations through more frequent controls and eventual punishment of violators.

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Anchoring Semisubmersible Platforms

Marijan Zujić, Ivica Skoko, Zlatko Boko, Toma Kuzmić

Anchor handling is a complex and dangerous job that involves stretching anchor chains, dropping and lifting, and lifting multiple anchors, sometimes in bad weather conditions. Complex operations with anchors can be done successfully only by people with experience in these jobs. Any error when anchoring platforms can have disastrous consequences, cause extensive material damage, cause environmental disaster, and lead to human casualties. This paper explains the procedures for anchoring semisubmersible platforms for exploiting gas and oil from the seabed.

Some platforms are anchored with a dozen or more anchors, which requires anchor handling operations to be performed by two AHTS (Anchor Handling Tug Supply) ships simultaneously, with mutual coordination and cooperation with the crew on the platform, release or heave anchor lines (wire lines). In this demanding job, routine, experience, and safety are achieved over time in these complex operations.

KEY WORDS

Anchoring, Mooring, Towing, Semisubmersible platform, Anchor, Anchor handling tug supply vessel

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INTRODUCTION

In search of natural energy sources, oil and gas exploitation from the mainland gradually shifted to the coastal belt and then to the sea. The development of technology and the idea of oil platforms initiated the exploitation of oil and gas from the seabed. Distinct types of vessels involved in offshore oil field operations are Anchor Handling Tug Supply (AHTS), Platform Supply Vessels (PSV), Fast Supply Vessels (FSV), Dive Support Vessels, Pipe Lay Vessels, Crane Vessel, Seismic Vessel, Well Intervention Vessel and Multi-Purpose Offshore Support Vessels (Boko et al., 2022).

From the beginning of oil rigs and their arrival in the drilling area, the question arose of keeping the platform in the desired position, despite the changing hydrometeorological influences. With the development of anchoring technology, ships, and anchor handling equipment, positioning and anchoring platforms became safer and easier. Powerful winches were installed on ships, and steel foreheads were equipped. Spacious decks for handling anchors and platforms were installed on their construction with the cranes, anchor chains, and winches.

With the technology progress, the art of anchoring platforms was also developed. The large, powerful, massive anchors and the platform anchoring business led to increased platform safety while docked. In anchor handling operations, there must be no shortcomings and temporary improvisations because even the slightest mistake can lead to threats and disasters (Hancox, 1992).

Anchoring drilling rigs and exploiting oil and gas from the seabed is a dangerous and complex job that involves knocking down, stretching, or lifting many anchors, at a distance of up to several hundred meters, often in bad weather conditions. Well-trained seafarers with extensive knowledge and experience can successfully perform these operations. Any mistake can have disastrous consequences, cause a significant environmental disaster, lead to extensive material damage, and in the worst case, human casualties can occur.

The platforms are anchored with several anchors, depending on the type and size of the platform and the area of work and weather conditions. These operations with anchors are usually performed in pairs by two AHTS ships, with good mutual coordination and cooperation with the platform crew, which must do its part on time, wind, and release anchor wire lines. It takes extensive experience to make the right decisions promptly when anchoring platforms.

Figure 1. Deepsea Delta semisubmersible oil rig in the North Sea.(Source: https://en.wikipedia.org/wiki/Semi-submersible_platform)

PLATFORM ANCHORING EQUIPMENT

Equipment for anchoring platforms must be extremely sturdy and made of solid materials. The forces acting on the equipment are pretty significant. If the platform is not anchored correctly and if the appropriate equipment is not used, rupture and damage to the anchor equipment may occur. Essential anchor equipment consists of anchors, steel foreheads, buoys, windlass, anchor chains, shackles, wire lines, etc. The equipment is loaded onto a tugboat or "AHTS" ship that does the anchoring maneuver, and the rest is on the platform.

The anchor must have shape and size according to the purpose for which it is used, aligned with the size of the anchored object. It is not enough that the anchor is dropped down and lies on the seabed. To keep the floating object in the selected default location, the anchor must be dug into the seabed and buried during the object's stay in the given position.

The platform anchoring system consists of several anchor lines designed to maintain the platform in position. Anchor lines can be simple or homogeneous, consisting of a single steel forehead, chain, or combined. They could contain a wire part and a chain part near the anchor.

The anchor line contains a winch, a guide rail, a steel forehead and chain, links, anchor shackles, a tripping line, and a pennant buoy.

Anchor winch

Winches are used to retract or pull anchor chains found on cable lifters. Winches differ in size, power, and mode of drive, and they can be electric or hydraulic winches. The person handling the winch must know the following:

- Storage capacity of steel collar or chain and the speed and resistance ratio of the anchor line:
- high speed at low resistance (about 3 m/s),
- the medium speed at medium resistance (from 1 to 2 m/s) and
- Low speed at high resistance (from 0.3 to 0.5 m/s).

To allow the platform to anchor in a specific position, ensuring that the winches meet the requirements and that their maximum resistance capacity is sufficient for anchoring tests conducted under a particular load is vital. Winches are arranged on the platform, and their management should be performed in one room.

Consoles should also allow the constant display of drums (across the screen), a line tension indicator (tensiometer), and an indicator of a drawn steel forehead or chain. All accessories at the ends of the rope used in anchoring operations shall comply with the requirements of the classification society. It is forbidden to use improvised made ends of a rope which was often done by the crew before.

Figure 2. Socket (Source: https://www.certex.co.uk/products/steel-wire-rope-accessories)

Pennant (Tripping line)

Pennant is a steel rope tied to the anchor’s end, allowing anchors to be heaved and extracted from the sea by AHTS boat. Pennant must have the same features as the anchor line. Its length shall be equal to the depth at which it is located, with the addition of 30 to 40 m and an addition to the deck length of the AHTS ship. This type of steel rope must withstand the heavy loads of the deeply buried anchor. Therefore, it must always be in good condition because the cracking of the pennant would lead to a tremendous waste of time and sometimes even the loss of the anchor.

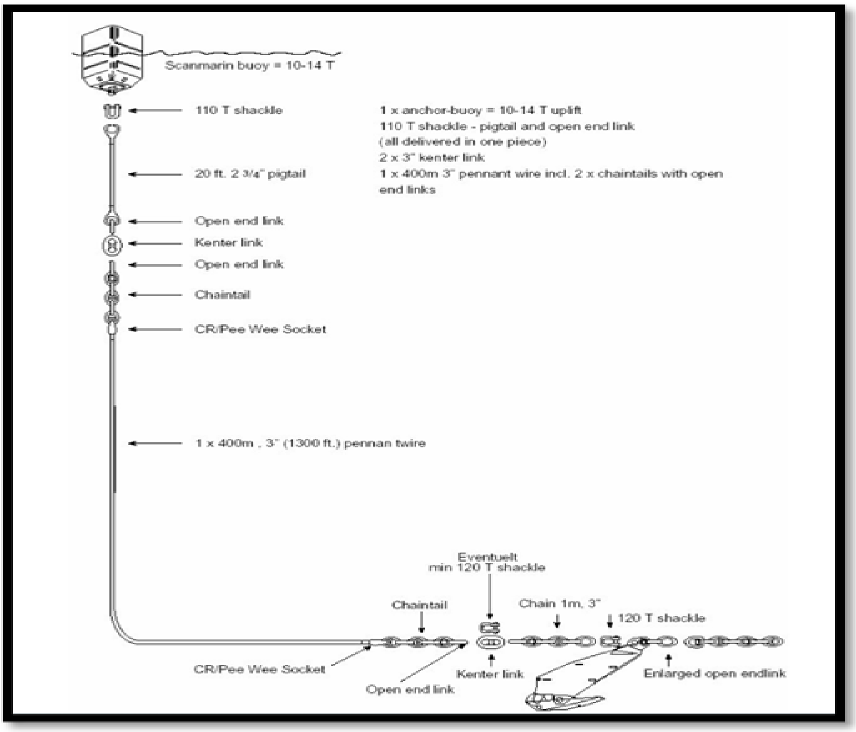

Figure 3: Pennant line (Source: authors)

Pennant buoys

This type of buoy maintains a pennant steel rope on the surface of the sea and, at the same time, marks the position of the anchor. The dimensions of the buoy depend on the steel rope attached to it, while about a third of the buoy is above the sea surface.

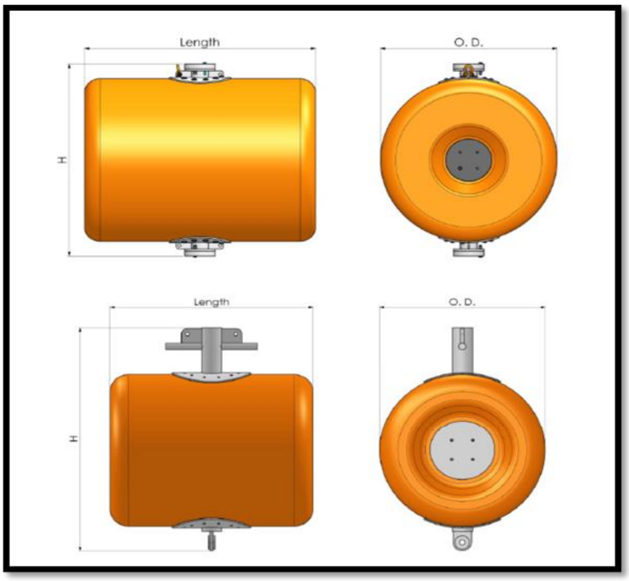

Figure 4: Pennant buoy. (Source: https://www.floatex.com/product/anchor-pennant-buoys/)

Chaser

Chaser is a ring placed on the anchor line for handling and extracting the anchor from the sea. It is connected to the vessel via a pennant rope.

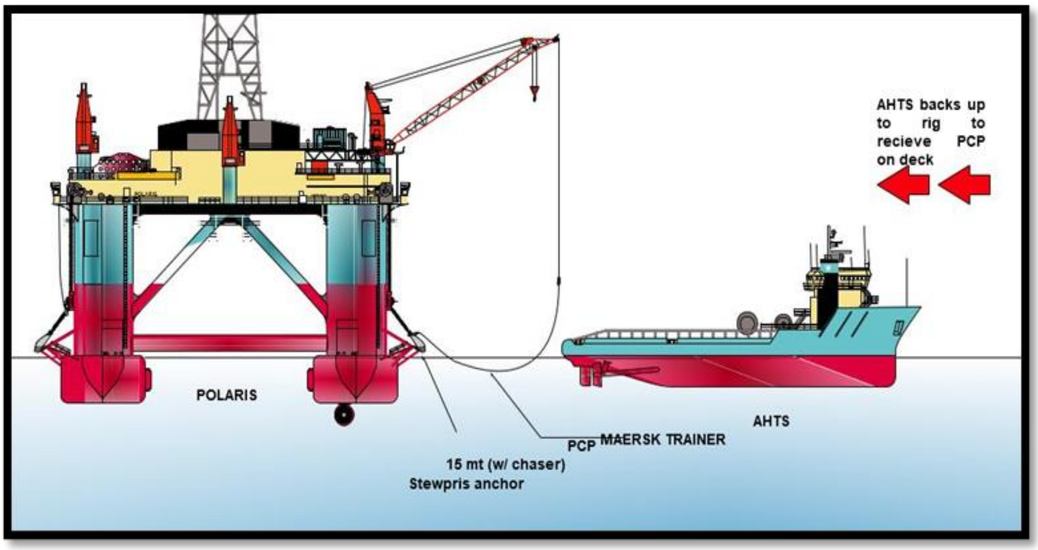

Figure 5: Returning chaser to the platform. (Source: https://studfile.net/preview/5155240/page:40/)

After anchoring, the line is slightly tense, and the supply ship transfers the “chaser” to the platform. To extract the anchor from the sea, the supply ship slips the chaser along the line to the anchor and pulls it out by pulling the line. Chaser must gently slide over the chain and rotating links to not damage the line.

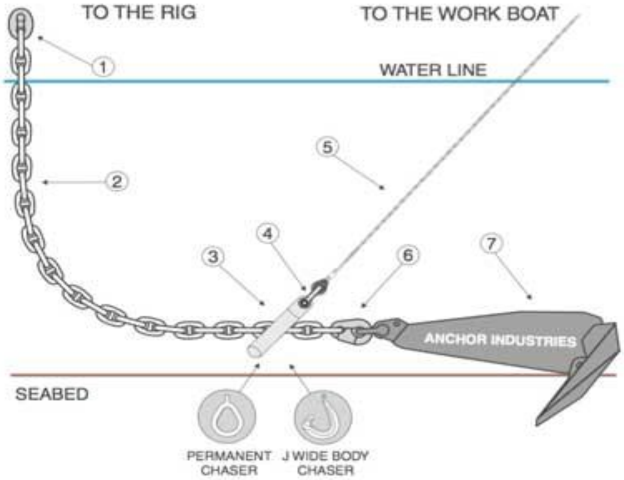

Figure 6: Anchor equipped with a chaser ring. (Source: https://anchors.co.za/)

Anchors

Figure 7 below shows the types of anchors which are most commonly used in the offshore industry. Regardless of the variety in shape and use of anchors, all anchors have some standard features, so each anchor has a shank, crown, arms, and shovels.

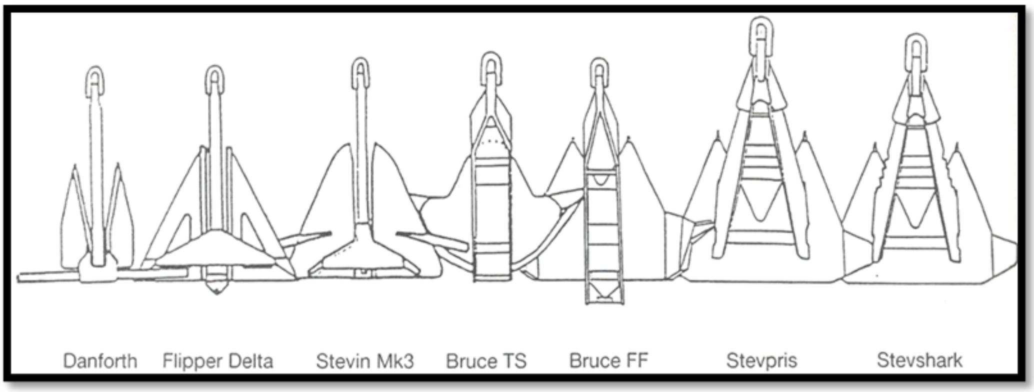

Figure 7. Types of anchors often used in the offshore industry. (Source: http://1.bp.blogspot.com/)

AHTS (Anchor Handling Tug Supply) ships

The AHTS has three main roles in the oil industry. It is equipped with a winch and work wire that enables the vessel to run anchors for semi-submersible oil rigs, pipe laying barges, accommodation barges, FSOs, FPSOs, as well as to tow rigs, barges and tankers during export operations. Moreover, the AHTS vessel has a cargo deck and below deck storage space similar to the PSV as supplying required cargo. On today's market, most charterers require fire fighting, oil spill containment and Emergency Rescue and Recovery Vessel (ERRV) capabilities on the vessel (Skoko et al., 2013).

Many of these ships can withstand the harshest weather conditions in the North Sea and supply between shore bases and oil rigs.

AHTS ships differ from Platform Supply Vessel (PSV) ships in that they are equipped with strong winches for towing and maneuvering anchors, have an open stern to allow anchors to be lowered, and have a higher pulling power than conventional PSVs vessel (Skoko et al., 2020). Their machines are specially designed to operate with anchors.

Bollard pulls required to perform these demanding tasks dramatically affect the ship's design because it defines the power of the engine needed, the size of the screw, the shape, and the submersible stern that allows the screw to be located at the required depth (Ajay Menon, 2021). The width and shape of the hull provide the AHTS vessel with good stability, primarily when heavy ropes/chains and anchors descend from the stern into the sea.

Handling anchors requires high engine power, winch capacity, place on the aft deck, chain lockers, and auxiliary equipment for anchor handling. A stern roller on the ship's aft facilitates the passage of wires and anchors over the vessel's stern during anchor handling operations.

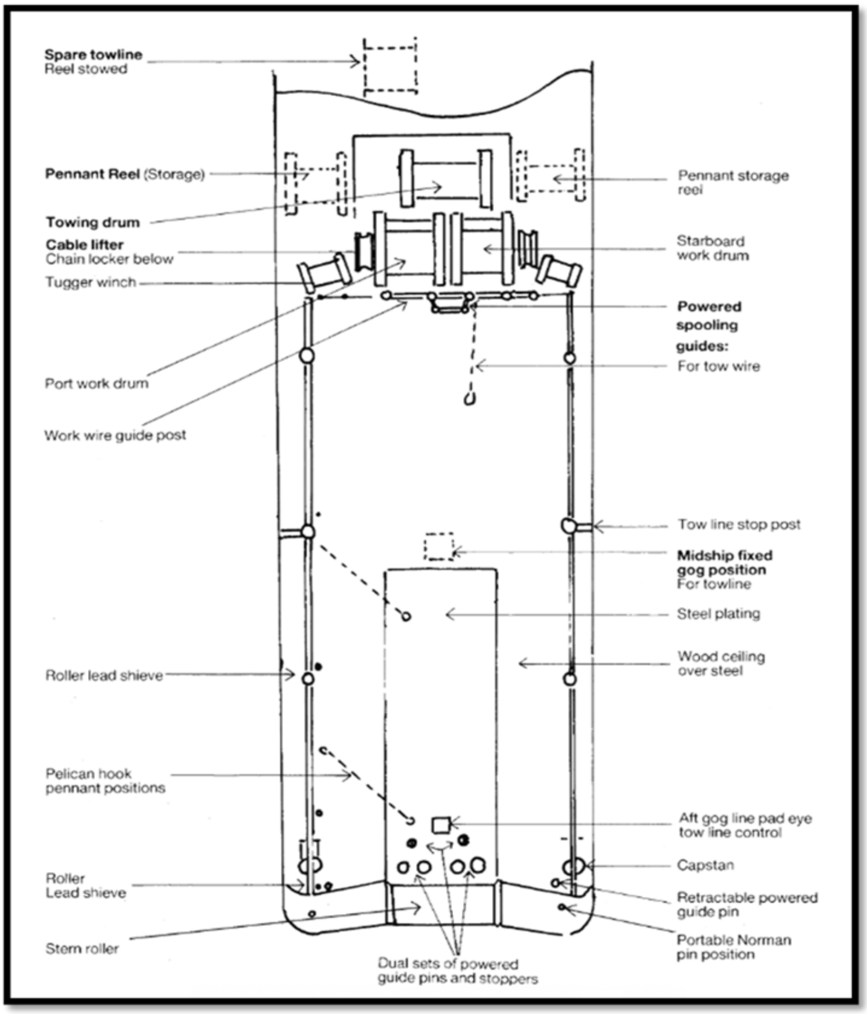

Figure 8: Arrangement on the deck of a large AHTS ship. (Source: Hancock, M 1994.)

The main features of AHTS ships are:

- Extremely high traction power and the degree of engine utilization required for handling heavy anchors,

- equipped with a combination of multiple thrusters (bow and stern) with dual-screw CPP (Controllable Pitch Propeller) systems, which gives them good maneuverability and allows AHTS ships to operate in all weather conditions,
- reinforced deck on the stern allows the handling and stacking of the largest anchors, heavy steel foreheads, chains, buoys, and similar equipment,
- a robust multi-drum system uses two winches, one for towing and the other for anchors. Also, each of these main vitals and drums contains auxiliary drums and winches for towing and handling anchors at great depths (Lamas Pardo et al., 2017),
- chain lockers are of high capacity, so there is a large amount of anchor chain on board, and
- AHTS ships are multipurpose ships and can be used as platform supply ships.

Figure 9: AHTS Skandi Vega. (Source: https://www.shipspotting.com/)

ANCHORING PLATFORMS

Anchoring analysis

The anchoring analysis aims to estimate maximum values, such as full loads on anchor lines, forces on anchors, and shifts of an anchored object, which can occur in adverse weather conditions. These maximum values shall be less than permitted in the project to ensure sufficient safety of the system in the event of overload and a satisfactory distance from other maritime facilities.

The maximum displacement must be checked for the conditions of the strongest storm the rig must endure during drilling operations. The displacement depends on several factors, such as water depth, environmental forces, and the anchoring system of the object being analyzed (Hancox, 1992).

Operation planning

Anchor handling operations are agreed upon between the platform, the AHTS ship, and all related parties. In practice, no universal method is applied to all anchor handling operations. Which way will be used depends on the weather conditions, the depth of the sea, and the equipment available to the platform and the AHTS ship.

When the requirements of anchor handling operations are determined, it is necessary to carry out a process according to the state of the oil field. All parties involved in operations shall be informed and prepared with the essential information and materials necessary for the successful execution of the anchor handling operation.

The operating team of the platform performs a risk assessment in the anchor handling operation. Situation checking includes the general condition of the platform, weather conditions, availability of equipment on the platform, and risks that can be predicted, as well as hidden risks.

Before carrying out the anchor handling operation, a platform relocation meeting should be organized. Participants shall be informed of their roles in the platform relocation and given sufficient time to review the rig move plan. Weather conditions during the task should be considered, and the weather forecast for three days from the start of the anchor handling operation. The wave height and wind power shall not exceed the planned expected values.

Anchoring procedure

Semisubmersible oil platforms are equipped with anchoring systems (anchor-winch, anchor lines-chains, steel and synthetic ropes, anchors, and other elements such as canter connecting links and bollards).

Depending on the construction of the semisubmersible platforms, each usually has between six and eleven anchors by which they are maintained at the drilling position. There are several models of anchoring (Fig. 10), and they mainly depend on the performance of semi-submerged platforms.

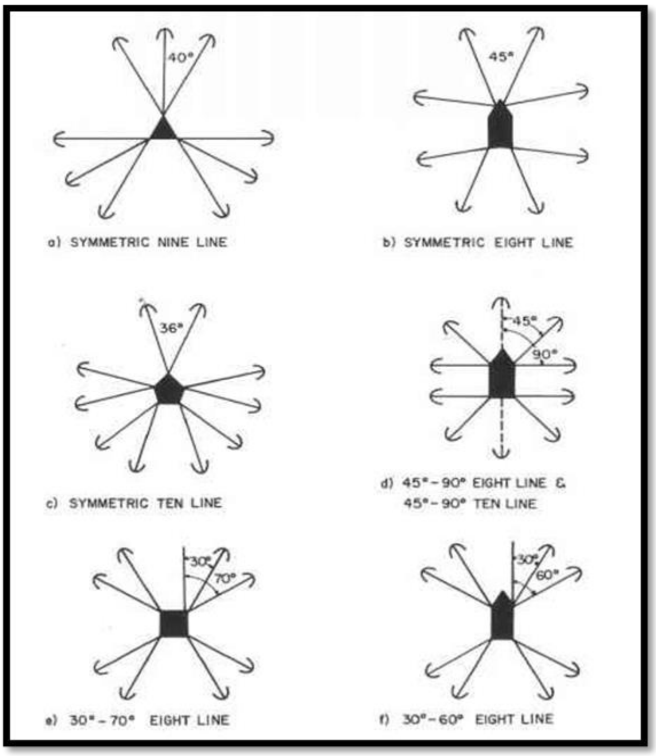

Figure 10: Typical anchor line layout. (Source: https://www.rigworker.com/)

(a - nine symmetrical anchor lines, b - eight symmetrical anchor lines, c - ten symmetrical anchor lines, d - eight anchor lines, angles 30º and 70º, e - eight anchor lines, angles 45º and 90º and dashed ten anchor lines, f - eight anchor lines, angles 30º and 60º).

Oil rigs need to be towed and anchored at the final position. The number and type of the anchors, pennants, and buoys depend on the platform type. When the platform approaches the position designated for anchoring, the "AHTS" ship approaches the platform and takes over the ploy and buoy. AHTS vessel load all equipment, including anchors and pennants, before departure from the port.

Anchor is connected to the working wire, and each line will be later stretched on the main deck as per the agreed sequences. At the same time, the platform drops the chain. The anchor is placed next to the stern of the tug. The length of the line is prepared in advance and should be increased by 30 % concerning the depth of the sea. Upon arrival at the anchoring point position, the platform crew is notified.

The anchor is gently lowered to the seabed, and the entire pennant is discharged. The strength of the wireline pennant must withstand a load from 8 to 12 times that of the anchor itself.

The process begins when the anchoring analysis is completed and an anchoring plan is made. The platform is brought to the anchoring position, and the AHTS transfers the anchor to the position determined by the anchoring plan. The following Figure 11. shows the ship in the process of anchoring the platform.

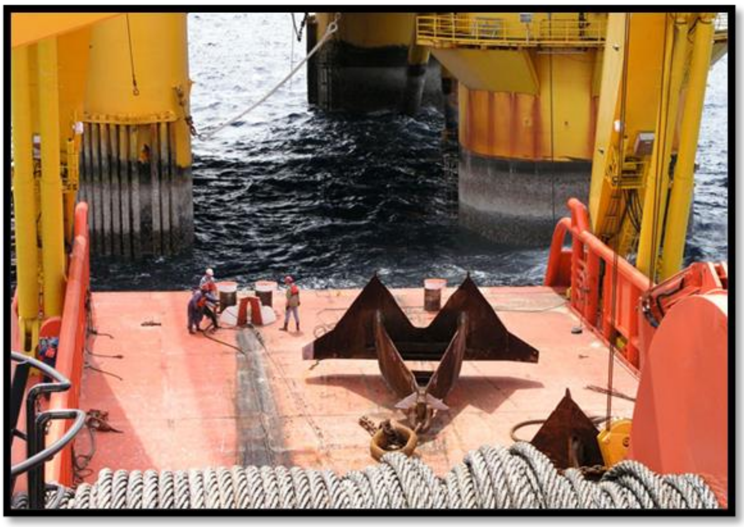

Figure 11: AHTS (Anchor Handling Tug Supply) in the platform anchoring process. (Source: http://www.oedigital.com/)

Receiving pennant from the platform

The Master of the AHTS ship maneuvers the ship with great care and brings it close to the platform. During the approach, AHTS must always have a boat ready for the descent, as the crew operates on an open deck at the ship's stern.

Due to the complexity and high risk of anchor handling operations in the deep sea, two, three, or more AHTS ships are used. The main AHTS comes to a position where the distance from the rig is suitable for towing operations or in case of any emergency.

When the AHTS ship reaches the vicinity of the platform and is ready to take over the pennant, the vessel and the crane on the platform must communicate well and clearly to harmonize the work to avoid dangers and injuries to the crew members of the AHTS ship.

The crane places the pennant above the AHTS ship and slowly lowers it according to the orders of the first officer or deck leader. The Master keeps the boat in place until the crew secures a pennant and work rope. The team at the stern of the AHTS ship must be careful and avoid being hit by a pennant or a crane hook.

When the pennant is lowered on the vessel, it is secured by a shark jaw system and connects to the work rope. The rope attached to the pennant line is pulled on the deck of the AHTS and links to the tow rope of the AHTS. The crew leaves the vicinity of the tense pennant as soon as possible because there is a risk of cracking due to overload.

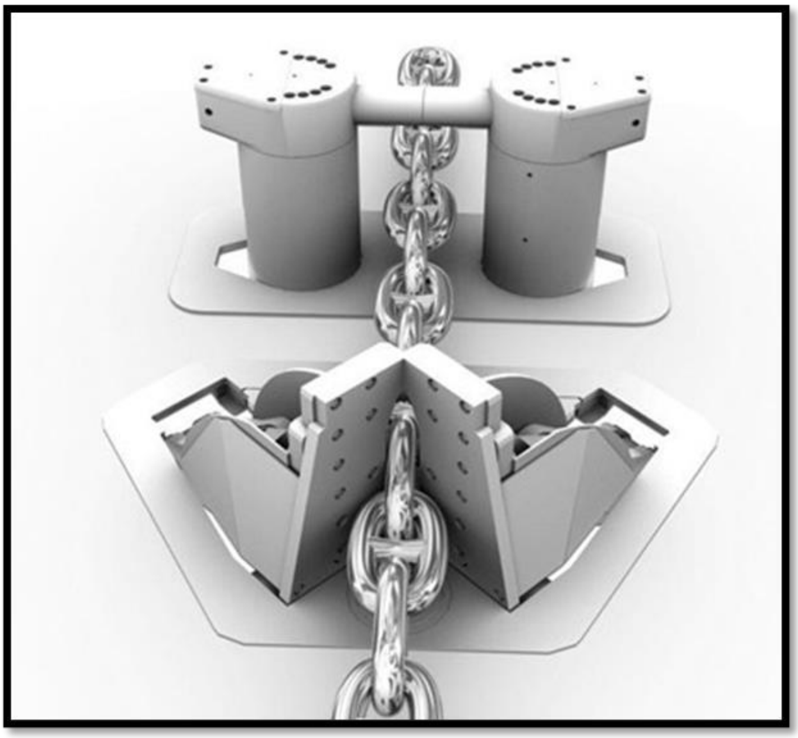

Figure 12: Shark jaw system. (Source: https://www.macgregor.com/)

AHTS places the anchor and chaser on the deck and pulls the work rope from the platform. The working string should be held between the shovels of the anchor during the process of paying out the anchor line. AHTS increases power while the anchor line's tension rises on the platform's winch tension indicator. The anchor line is drawn entirely with an anchor on deck or sometimes on a stern roller. When the central anchor is moved, second AHTS ships are positioned to accept part of the chain and thus reduce the load on the line and the possibility of damage.

As the tension reaches the expected value, the platform issues an order to lower the anchor, and AHTS pays out a tow line until the anchor comes to the roller on the stern. Chaser can also be located on the deck or the stern roller. In this case, the thrust of the screw passes under the anchor and does not affect the anchor.

AHTS reduces power when lowering the anchor over the roller after receiving the command from the platform and retains the “chaser” on the anchor head to control the anchor’s orientation and lowering.

When the anchor is located below the screw splash zone, constant tension is maintained to ensure the anchor does not fail through the “chaser”.

In some conditions, AHTS ships maintain the anchor hanging from the pennant line below the screw splash zone, about 60 to 80m above the bottom. This method requires less power on the winch during laying anchor.

Communication between the platform and the AHTS ship is essential, especially when the anchor hangs 10 to 15m above the bottom. AHTS stops the anchor dropping and notifies the platform, then orders AHTS to release the pennant line approximately 1.5 times the depth of the sea (Nilsson Marten, 2009). Then AHTS increases power until a rise in line tension is noticed on the platform. At this time, the platform gives the order to lay the anchor. AHTS immediately stops the engines and pulls back. It then pays out a line of pennants, and the anchor lies at the bottom until the line is stretched. The platform pulls the line to the required load, and the anchor is completely buried. The wear and tear between the chaser and the work line decrease when the working line is taut and the chaser can be pulled out with less friction.

Anchoring operation

The platform is brought to the anchoring position. The ship AHTS (Anchor Handling Tug Supply) first approaches the rig with the stern (Fig. 13) and connects the main anchor’s head or extra towing rope (Wu & Moan, 2017).

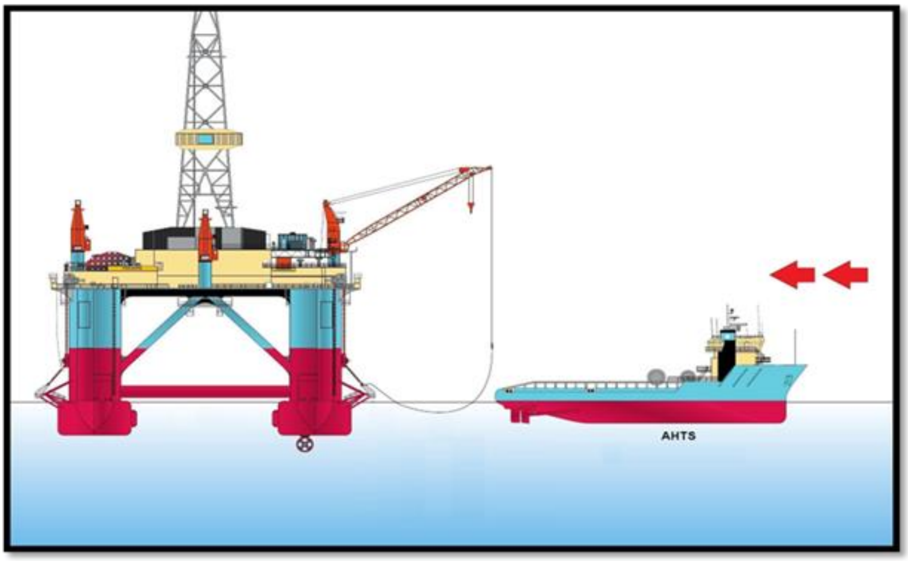

Figure 13: Approaching the ship to the platform to take over the anchor line. (Source: https://studfile.net)

The anchor is placed next to the stern of the tugboat (Fig. 14). pennant is prepared in advance depending on the depth of these. At the same time, the platform drops a chain or steel forehead with which the anchor is connected. The pennant must be longer than the depth of the sea by 30 %.

The sizing of the pennant must be such that it can withstand up to several times the force (eight to twelve times) than those produced by the anchor and the platform anchor line.

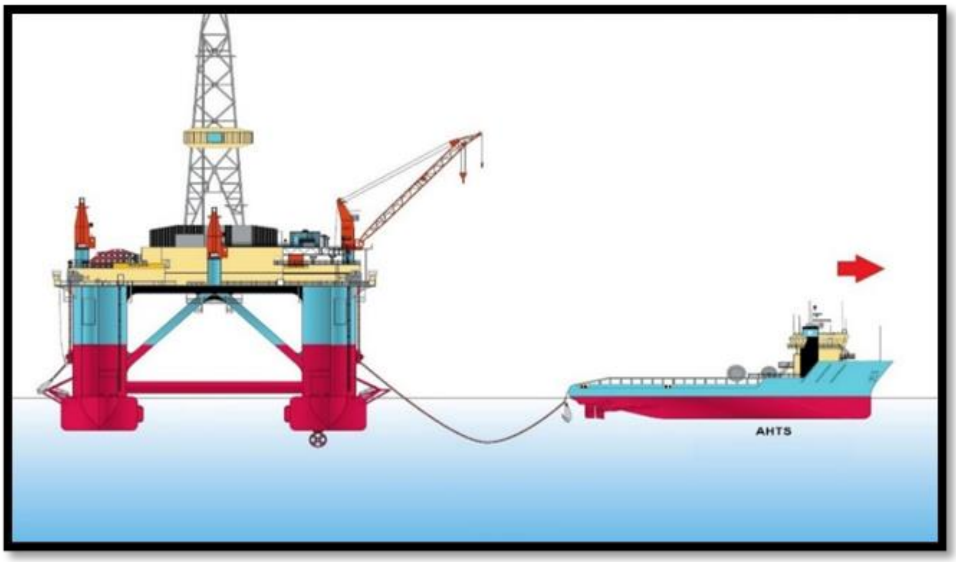

Figure 14: Setting the anchor along the stern of the tug. (Source: https://studfile.net/)

After the anchor is placed along the tug's stern, the same takes the course set by the anchoring plan (for this anchor line), driving forward to reach the anchor point (Figure 15).

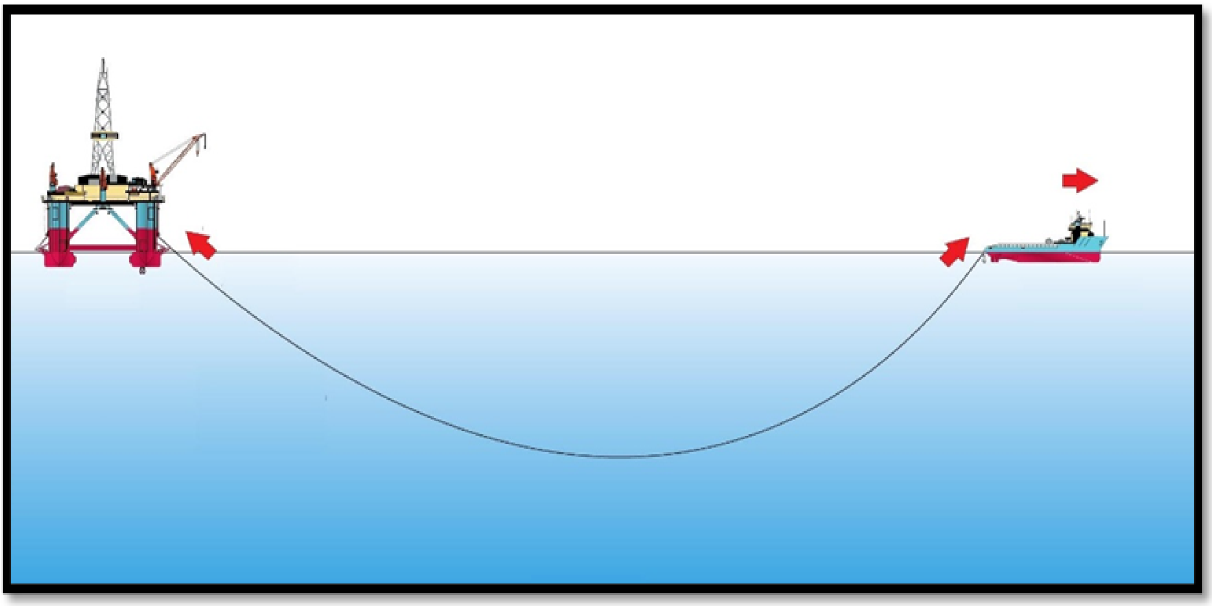

Figure 15. Stretching the anchor line to the anchor point. (Source: https://studfile.net/)

An anchor is placed on the seabed (Fig. 16). pennant has two parts, one on the anchor and the other on the buoy (which indicates the position of the anchor). While the lower part of the pennant is on the AHTS deck, the winch stops, the slip hook is connected, the towing rope is released, the buoy is connected, then the slip hook is released (slipping), and the buoy slides into the sea. The process is repeated for other anchors according to the anchoring plan.

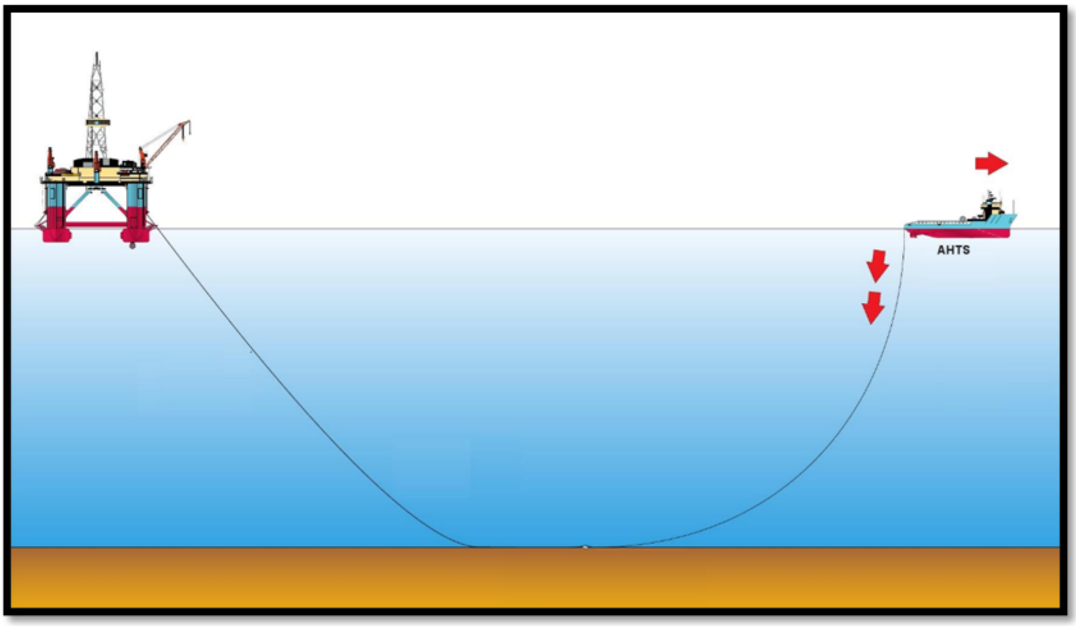

Figure 16: Placing the anchor on the seabed. (Source: https://studfile.net)

Piggyback with two Stevpris anchors

When one anchor is not safe enough to anchor, the so-called PIGGYBACK method with two anchors is used. When two Stevpris anchors are used in piggyback, the holding capacity of this combination may be equal to or greater than the sum of the individual anchor holding powers. The installation process of two Stevpris anchors is as follows (Hancox, 1992):

- The main Stevpris anchor is dropped, with a mooring rope connected to the anchor link and a pennant line (steel rope for optimal performance and approximately three times longer than the waist of the first Stevpris anchor) connected to the eye behind the anchor's shackle.
- Connect the other end of the steel forehead to the link of the anchor of the second Stevpris anchor.
- To lower the second Stevpris anchor to the seabed, the second line of the pennant is associated with the eye behind the anchor shackle.
- Using the second pennant line, Stevpris anchors descend to the seabed and position.
- Stevpris anchors are then dug in by drawing a mooring line (Hancox, 1992).

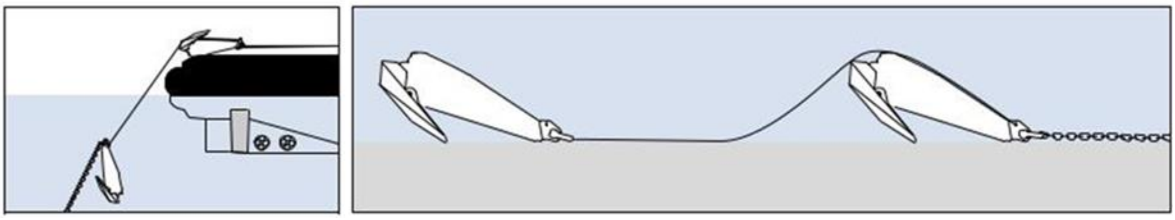

Figure 17: Piggybacking with the use of a chaser. (Source: https://studfile.net/)

Piggybacking with the use of a chaser

Sometimes catchers are used to connecting the piggyback anchor to the first anchor, although a pennant line connected directly to the eye behind the main anchor is preferred. The connection process described for the two Stevpris anchors also applies when using the chaser (Hancox, 1992)..

Lifting anchor

Upon completion of the rig job on a particular site, moving the rig to a new location is necessary. After the preparations for "AHTS," the ship approaches the stern buoy anchors, which need to be raised.

AHTS ship maneuvers by approaching the buoy, indicating the platform anchor. The ship's first officer must deploy the crew to perform the agreed activities on deck. Before lifting on the deck, a crew member should prepare a lasso to catch the buoy. Lasso comprises a synthetic rope or steel forehead length of 10 to 15 meters.

The wire line's size and strength depend on the buoy's size. After everything is ready, the lasso is transferred over the buoy, connected to the towing rope, and tightened until the first part of the tailgate reaches the deck. The anchor is lifted from the seabed and swirling until it reaches the tug's stern.

The separation of the anchor must be carried out with the pennant longer than the depth of the sea at the place concerned. It is not recommended to pull the pennant vertically because there is a possibility that it will crack. It is best to heave up at an angle of 15 degrees to the perpendicular in the opposite direction from the action of the anchor chain (Wei Peng Dephne et al., 2013). All these actions are performed in constant contact with the rig's crew.

When the anchor is under the stern of the tug, the platform is notified, after which the platform twists the chain and pulls the stern of the tug to the platform until it reaches the position where the crane from the platform can take over the anchor pennant. This procedure completes the lifting of one anchor. The exact process is repeated for all other anchors.

Lifting the anchor, step 1.

The following figure shows the approach of AHTS to a semisubmersible platform. The system in the figure shows a typical way of mooring and lifting the platform anchor in which the vessel maneuvering approaches from the side and accepts the tension wire lines.

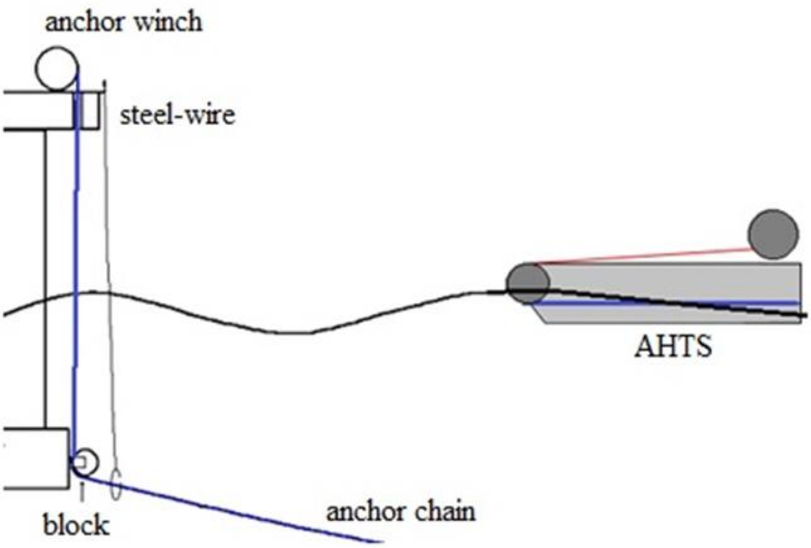

Figure 18: Approaching the "AHTS" of the ship to the side of the platform. (Source: authors)

Lifting the anchor step 2.

In the next step, the ship approaches the platform with a prepared mooring winch. The vessel has two mooring winches to handle anchors on the working surface of "AHTS" ships. Tensile wire lines are prepared and placed in winches and ready for tensioning. The crane on the platform's side holds the free end of the wireline and lays it towards the ship. The wireline is connected via the safety ring to the winch on board.

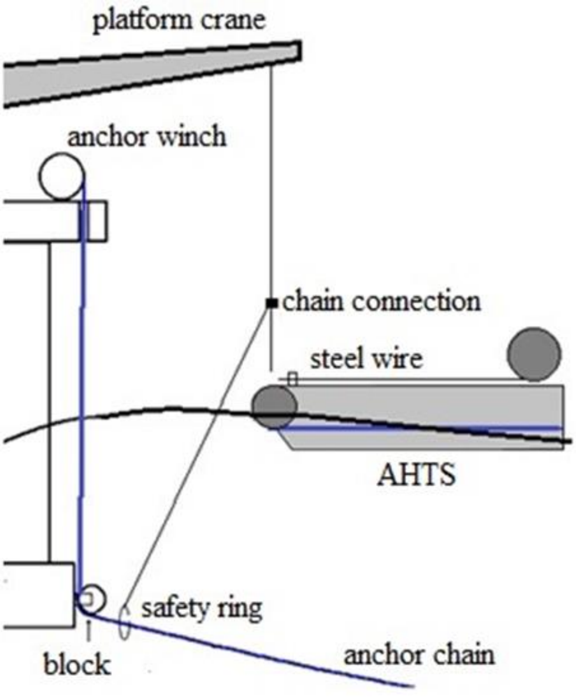

Figure 19: Merging the chain link and connecting to the tension steel cell. (Source: authors)

Lifting the anchor, step 3.

The crew of the "AHTS" ship takes the wireline and places it in a mooring winch. When the wireline is connected to the mooring winch and the rig crew begins to moor, the platform crew loosens all the force on the platform's crane that has tightened the wireline and redirects the complete moment of pressure to the mooring winch. Particular attention should be paid when heaving the wire because the mooring strength is immense, and the tension wire lines may be cracking.

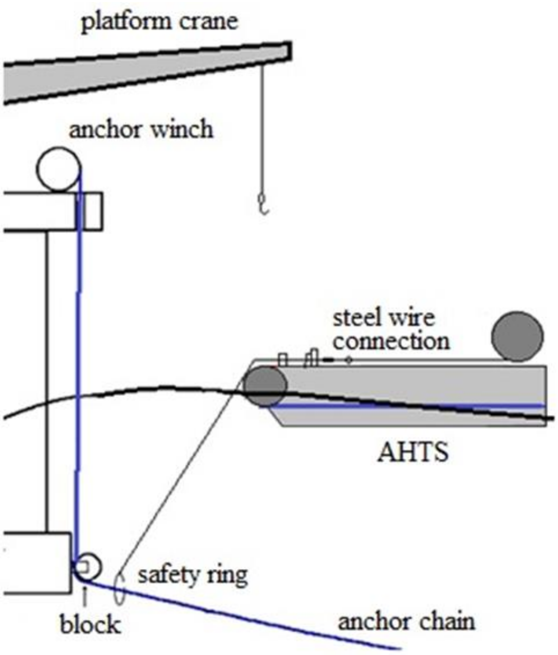

Figure 20: Connecting the safety ring and wireline. (Source: authors)

Lifting the anchor step 4.

The AHTS ship is pulled along the anchor chain and winds only the anchor until it reaches a favorable position for extraction on the working deck of the vessel.

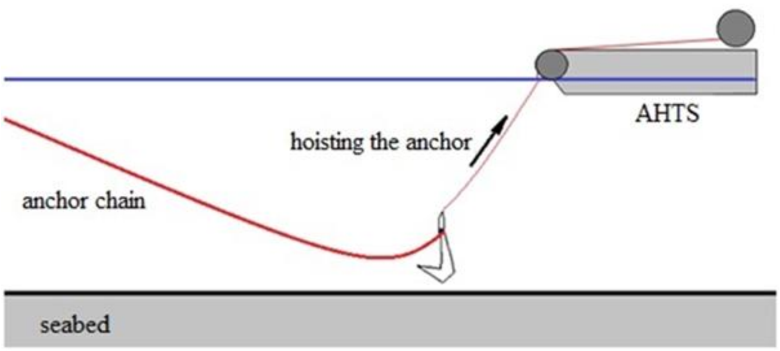

Figure 21: Drawing anchor. (Source: authors)

Lifting anchors using a chaser

Sometimes when lifting anchors, chasers are used. The crew receives the “chaser” from the platform and connects it to the work rope. AHTS is maintained in place, and sudden movements should be avoided during the performance of this operation. To reduce the wear and tear of the working rope, the necessary tension of the rope should be provided before pulling the chaser. The length of the chaser pennant line should be at least 1.5 times the depth of the sea to achieve safety requirements for particular operations.

As the chaser approaches the anchor on the seabed, the tension of the pennant rope rises and needs to be controlled until the anchor line’s weight exceeds the anchor’s weight. When the anchor rises to the deck, it passes over the stern roller and creates a great force that can lead to the cracking of the anchor line, so for safety, the crew must leave the aft deck. The Master of the AHTS ship manages the ship’s speed and tries to avoid sudden jerks on the pennant while the anchor is still at the bottom.

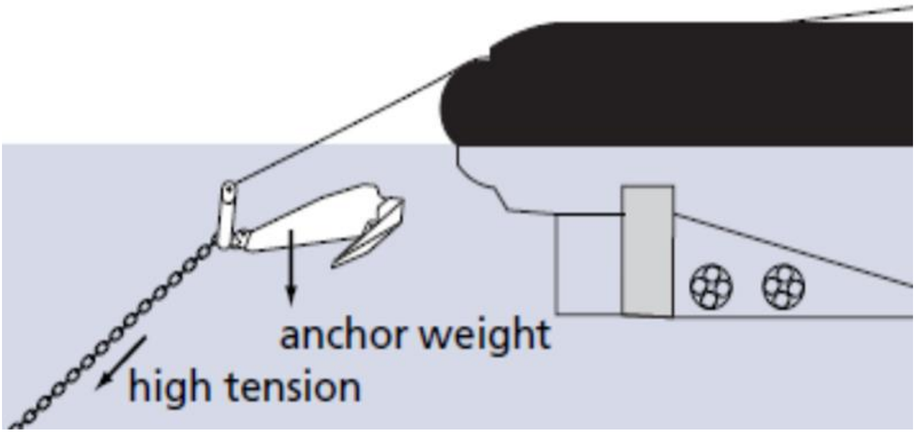

Figure 22: Lifting the anchor in the opposite direction from the installation of the chaser. (Source: https://studfile.net//)

Release “plucking” anchors from the seabed

When a buried anchor is “plucked”, one should slowly increase the power in the direction from the well (pull the anchor backward) to the “release force” and then hold that strength to allow the under pressure or “suction force” to be reduced/equalized to facilitate plucking/extraction of the anchor. If the anchor does not loosen after 30 to 40 minutes (a matter of expected assessment), slowly increase the power by 10% and repeat the process. One should have patience when removing anchors, not rush, be gentle with equipment, keep the pennant under specific tension, and the anchor will loosen. Anchors in very soft clay can be dug very deep (Hancox, 1992).

CONCLUSION

This paper describes the anchoring of semisubmersible platforms and equipment used in anchoring, including AHTS ships, wire lines, pennants, chasers, buoys, and accessories at the ends of the rope. It presents some of the types of anchors that are often used in the offshore industry. The equipment of the AHTS ship and the procedures of lowering and lifting anchors using the AHTS ship are described, and the piggyback method is included.

Danforth, LWT, and Moorfast were used as the first offshore operations anchors. The development of technology has also developed anchors of Flipper Delta, Stevin, Stevfix, and Bruce, which have been used for many years in platform anchoring. Today, mainly Stevpris and Stevshark anchors are used, whose characteristic is a firm grip to the bottom, even at high loads, which is very important for platforms exposed to strong winds and waves in the North Sea and Gulf of Mexico areas.

Towing and anchoring services are the maritime industry's most demanding and complex tasks. Shippers and oil companies aim to do the towing and anchoring work as quickly, safely, and efficiently as possible. With the development of technology, platform anchoring has also developed from the first tug boats that performed only the basic activities of port towing to today's modern AHTS ships.

The platform anchoring operations should be approached meticulously and maximally prepared. At the moment when the anchoring itself begins, everything must be worked out in advance. In anchoring preparation, possible errors are foreseen, external influences are determined, crews are organized and prepared, and equipment must be ready and checked. Anchoring operations are demanding and require maximum readiness and training of the crew (Wu & Moan, 2017).

Maneuvering is a skill for which it is necessary to know and apply theoretical principles in practice. Good knowledge of the ship's maneuvering characteristics and the forces generated by the action of screws, rudders, ropes, anchors, wind, and sea currents, is a prerequisite for a proper and safe anchoring maneuver. Experienced seafarers will know how to use the action of these forces when performing maneuvers by ship and facilitating the maneuver. During anchoring, the boat is constantly exposed to the action of external forces so that human error can put the vessel itself and the crew in danger.

The anchoring process of semi-immersive platforms begins when the anchoring analysis is completed and the anchoring plan is made. Unlike anchoring ships, anchoring platforms require greater precision in bringing to the exact anchoring position and maintenance at the given location. Adverse hydrometeorological conditions are often in areas with rich oil and gas deposits. For this job, specialized classification societies are mainly engaged. Currently, in the world, Norwegian Det Norske Veritas (DNV) and Germanischer Lloyd (GL) are leading. With the merger of the Norwegian and German companies, the unique company GL DNV appears on the market today. How demanding and responsible is the job of creating an anchoring plan says that few registered companies specialize in that task.

In addition to anchoring, maintaining the platform at the desired position can be performed with a dynamic positioning system. However, there are high costs and increased fuel consumption; therefore, the classic anchoring of platforms described in this paper is the most common method.

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Analysis of Operational Time and Costs of Offshore Vessels and Correlation with the Crude Oil Price

Ivica Skoko, Marijan Zuijć, Zlatko Boko

The offshore oil & gas industry is one of the fastest growing industries in the world and high demand for such type of energy has moved exploration beyond shallow water to deep water. Offshore supply vessels (OSV) are an indispensable part of exploration, drilling, production, and finally reloading of newly discovered and produced crude oil. Proper planning of the offshore fleet is an essential part of the offshore logistics chain and has a direct impact on a Company's projects and as such a significant impact on the project budget. With available data from the real sector in the work is given the actual operational use of the vessels in comparison with their monthly and annual costs. The analysis will be carried out for the two main types of offshore vessels, Anchor Handling Tug Supply (AHTS) and Platform Supply Vessels (PSV). The correlation between a crude oil price and an AHTS daily hire rate will also be presented.

KEY WORDS

Offshore vessels, Operational time, Offshore activities, Hire costs, Crude oil

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INTRODUCTION

With growing global energy needs, offshore oil production has become an attractive energy source (Skoko et al., 2013). Preparation, loading and delivering the required supplies to various types of offshore installations is the utmost important challenge for the logistics department of any oil company. One of the most critical logistic links is offshore supply vessels. Bearing in mind that one of the most expensive segments of that chain is offshore vessels, the technical selection, number and type of these vessels are crucial factors for planning annual or project budgets. Sometimes due to various unpredictability in the oil and gas industry, companies hire a large number of offshore vessels to avoid problems with the delivery of cargo and possible downtime to offshore installations. This downtime can cause a loss of several million dollars in drilling or production on the oil field. Therefore, it is indispensable to provide the requested cargo and maritime service activities to offshore installations without disturbance. Using the method of analysis and comparison from the vessel's logs, then dividing them into different activities, it is possible to obtain precise data on where two representative vessels were employed during the year and the exact time of employment for specific activities. Also, the time when the vessels are on standing by waiting for the next order. The obtained results should give us an overall situation of the percentage of working time for 24/7 paid vessels according to the usual BIMCO (Baltic and International Maritime Council) contract and the need to create a mathematical model that would define the required fleet according to the number and structure of a vessel.

OFFSHORE SUPPLY VESSELS AND OFFSHORE INSTALLATIONS

Offshore supply vessels (OSV) come in different types, sizes and designs and are the most important factor in the offshore logistics supply chain (Skoko et al., 2020).

Compared with many cargo vessels, offshore operations support vessels are rather small in size and have low cargo capacity. But these vessels normally operate close to their shore base and frequent trips are more important than high cargo capacity. The capability to perform their mission in heavy weather is also very important and the vessels must have good seakeeping and maneuvering performance (Erikstad and Levander, 2012).

OSVs are specially designed for the logistical servicing of offshore platforms and subsea installations, from installation through the full-service life of offshore fields (Eknes, 2023). As the search for oil and gas moves into deeper, more exacting environments, operators are contracting multipurpose OSVs as a cost-effective tool for carrying out specialized services on platforms, offshore facilities and piping equipment and systems. Today's OSVs are carrying out inspection, maintenance and repair and are equipped with larger accommodation spaces, heavy lift cranes, helidecks and streamlined bow forms for harsh-environment operations (ABS, 2023). In addition to their regular jobs, the OSVs are engaged in oil spill recovery and rescue operations, firefighting and emergencies.

In recent years, a new generation of offshore supply vessels entered the market, usually equipped with Class 1, Class 2 or Class 3 Dynamic Positioning System (DPS). A DPS is a piece of automation that helps the vessel to maintain its position by analyzing data received from wind, current and motion sensors and then sending a signal to thrusters and rudders (Sanchez-Varela et al., 2022). Which DP class the vessel will have depends on whether it has no redundancy (Class 1), has redundancy (Class 2), or has to withstand fire or flood in any one compartment without the system failing (Class 3).

Constructional and purpose built, they can be divided into two basic types of offshore supply vessels, Anchor Handling Tug Supply and Platform Supply vessels.

Anchor Handling Tug Supply Vessel

Anchor Handling Towing Supply (AHTS) vessels have been an inseparable part of the offshore oil industry since the exploration of oil from seas first began. This oil & gas industry's utmost important vessels are built to perform many different solid and liquid cargo operations and to deploy and recover mooring systems for Floating Production Storage and Offload units (FPSO), drilling rigs, barges, and support subsea construction activities. Towing and relocation of different offshore units as well.

AHTS vessels differ from PSVs in being fitted with winches for towing and anchor handling, having an open stern to allow the decking of anchors, and having more power to increase the pulling power of winches (Figure 1.).

Figure 1. AHTS vessel running anchors (Source: https://www.shutterstock.com/)

The pulling power of winches is expressed through Bollard Pull (BP) certificate and is recorded in metric tons or kilo Newtons (kN). The BP is defined as the maximum average of the recorded tension in the towing wire throughout 1min at a suitable trial location.

To obtain the BP certificate each AHTS has to pass trials which are not performed in typical operating conditions. The conditions must be as close to ideal as possible where the environmental and external effects are minimized. The criteria for the length of the tow wire and water depth are prescribed and must be followed during the test. In an ideal BP test the following criteria are to be met (Arun, 2018):

- lower and straight hawser (no sag and no angle)
- larger water depth (three to four times draught with a minimum of 50m or more).
- minimal current (<0.5 knots)
- minimal wind (<0.5m/s)
- good trim and sufficient draught for propeller immersion.

The test shall be witnessed in the presence of the recognized International Classification Societies (CS) surveyors such are Bureau Veritas (BV), American Bureau of Shipping (ABS), Lloyd's Register (LR), Det Norske Veritas (DNV), etc and measurement should be taken using a calibrated dynamometer or a mechanical load gauge (Figure 2.).

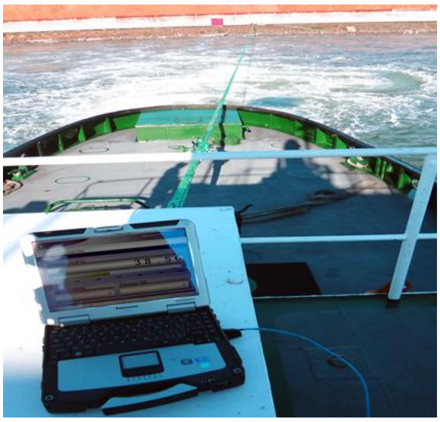

Figure 2. Bollard Pull test (Source: https://www.oedigital.com/)

Typical AHTS vessels range from 8.000 to 15.000 BHP (Seacormarine, 2023) and deadweight from 1.500 up to 3.500 tons. It is worth mentioning that in some cases related to certain specific projects, particularly in the North Sea area, BP requirement can go over 350 t and the main engine power over 30.000 BHP (Boko et al., 2022). In addition, the typical AHTS can also act as a rescue vessel for other vessels in times of emergency and can be used as an effective tool to prevent oil rig capsizing and other mishaps that might occur in stormy weather and rough sea.

Platform Supply Vessel

PSV vessels for the supply of oil platforms and installations (Figure 3.) are specialized exclusively for the supply of oil platforms and offshore installations in general. These vessels do not have winches or steel ropes, and their sterns are closed. On this type of ship, priority is given to the space for the accommodation of deck cargo, as well as liquid and bulk cargo in the lower deck, which are necessary for underwater oil exploration.

Figure 3. Platform Supply Vessel UT 755 L class (Source: https://www.offshore-energy.biz/)

PSVs transport the same type of cargo as AHTS, but due to the lack of winches, which occupy a certain space, they can load larger quantities of deck cargo. The cargo that is transported below the deck is fuel, drill water, oil or water base mud, brine, cement, barite, etc. PSVs are the main carriers of the supply of oil installations, and have great autonomy and supply oil installations that are sometimes over 200 nautical miles away, and are built to withstand extreme weather conditions. The size of this type of ship ranges from 45 meters to 105 meters in length and is used to supply installations in deep water, and can accommodate up to 36 offshore workers (Skoko et al., 2013).

Offshore installations

Offshore installation means fixed or floating platforms including drilling rigs, floating production storage and offloading facilities used for the offshore production and storage of oil or noxious liquid substances, and floating storage units used for the offshore storage of produced oil (Gov.UK, 2018).

An offshore oil field is composed of several types of oil and other installations or facilities that are divided into fixed, floating/semi-submersible and underwater and are used for exploration and production activities. The appearance and description of some of the deepest and largest are shown in Figure 4.

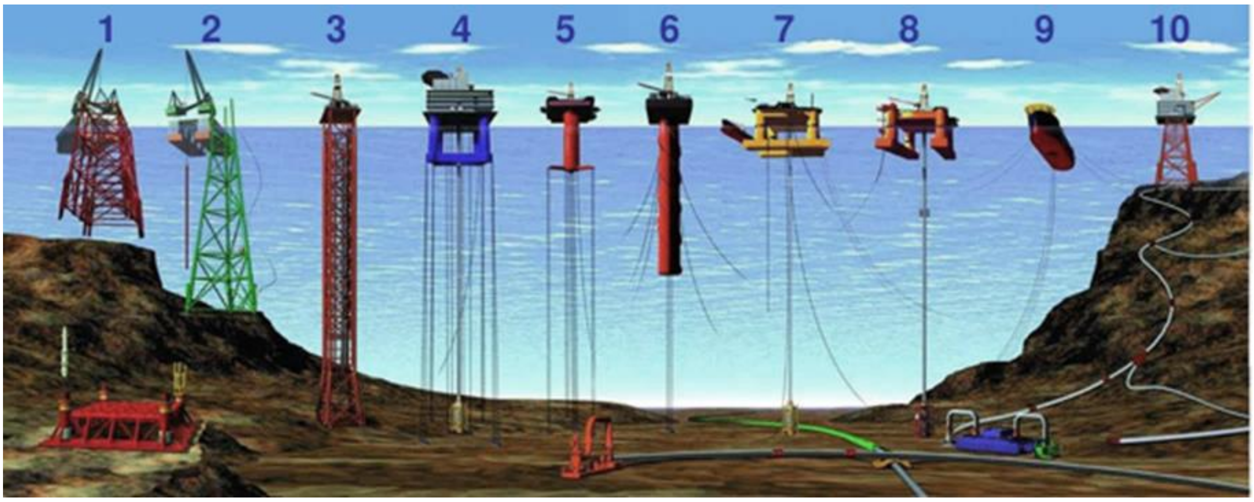

Figure 4. Offshore oil & gas installations (Source: NOAA Ocean Explorer, 2010).

Figure 4. shows the installations as follows: 1 and 2 are conventional fixed production platforms while platform number 3 is production compliant tower. Platforms 4 and 5 are vertically moored tension leg and mini-tension leg platforms. The Spar platform is under number 6. In deep water are very common movable semi-submersible platforms with an anchoring system and is shown under 7 and 8.

Floating Production Storage and Offloading (FPSO) facilities under 9 are typically converted old VLCC or ULCC tankers moored far from the shore where crude is stored and later on transferred to the export tankers and finally, sub-sea completion and tie-back to the host facility are shown under 10 (NOAA Ocean Explorer, 2010).

CORRELATION OF THE CRUDE OIL PRICE AND DAILY RATE OF AN AHTS VESSEL

The main criteria for the availability and daily rate of offshore vessels are based on supply and demand but also on political stability in oil-rich economies (Skoko et al., 2013). Geopolitical events and economic downturns can disrupt supply or decrease demands driving prices up or pushing prices down. The Figure 5. show's oil price trends from 1970 to 2022., and indicate that the price of crude oil changes mostly depending on the geopolitical situation in the world and recently the Coronavirus disease (COVID-19) starting in 2020. Crude oil reached an all-time high of 147.27 USD/barrel (USD/bbl) in July 2008 (Trading Economics, 2023).

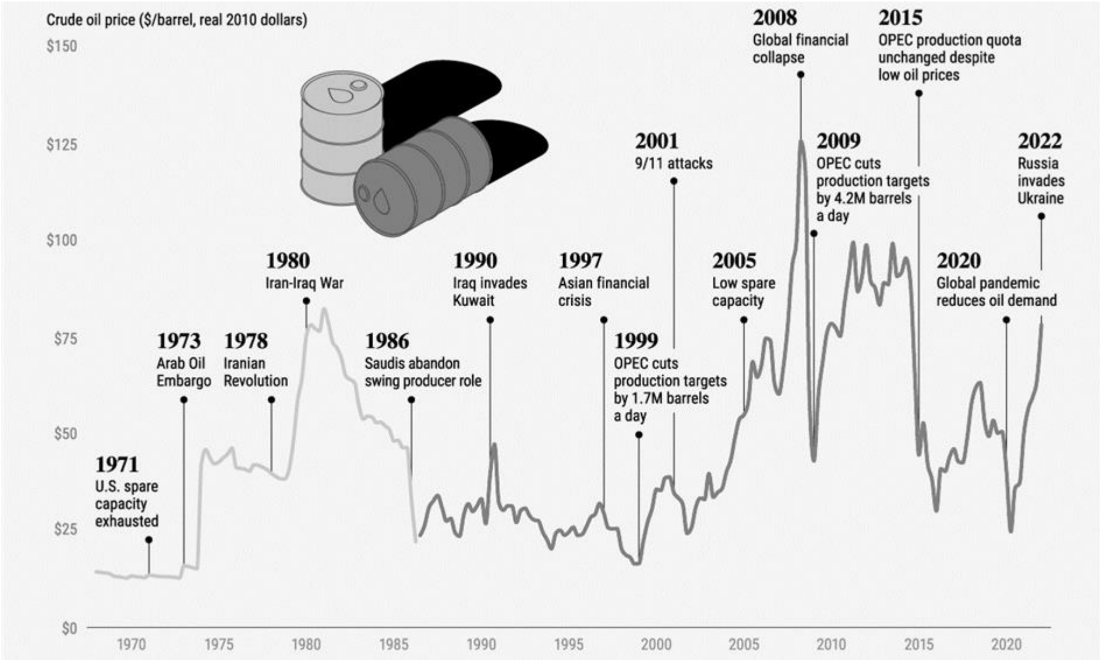

Figure 5. The price of oil in response to various events (Source: https://advisor.visualcapitalist.com/)

Consequently, the increase or decrease in oil prices is followed by a decrease or increase in the hire rate of OSV. In principle, offshore vessel charter follows changes in the crude oil market. Certainly, not daily based on which crude oil prices change because, in the case of the offshore fleet, the contracts are still concluded for a longer period.

Figure 6. present a day rate of one typical 11.000 BHP-130T BP AHTS compared with crude oil price history in USD/bbls, in the period of 2001 – 2012 (Skoko et al., 2013). In that period during 2009, the global recession, triggered by the world financial crisis, was by far the deepest and most synchronized compared to other recessions (Kose et al., 2020) and brings the crude oil price to the highest in history.

From the research is a visible similarity in the movement of the crude oil price and a day rate but in the oil price the changes are more significant than an AHTS day rate due to the vessel's long terms contracts and conditions where terms cannot be changed before the contract expired.

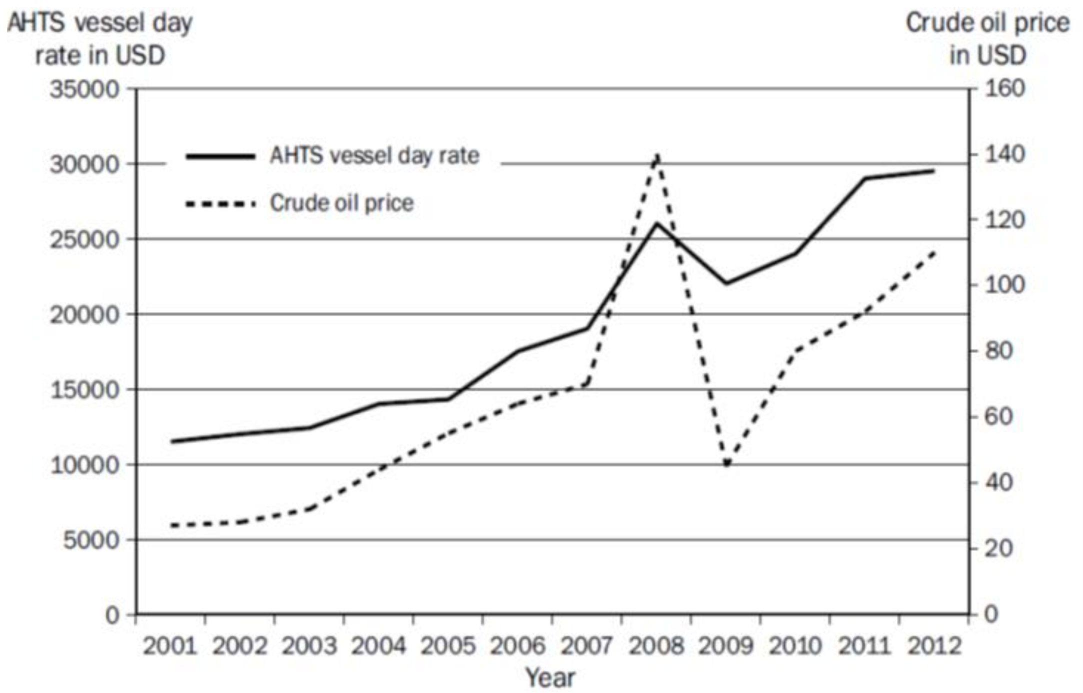

Figure 6. Average crude oil and AHTS vessel day rate 2000-2012 (Source: Skoko et al., 2013)

As a result of the price and level of exploration activities in the oil field, oil companies hire a certain number of offshore vessels, PSVs and AHTSs. To avoid any downtime on the platforms during exploration or production, the department in charge of exploration or production activities generally requests a more significant number of vessels regardless of their actual needs to cover the potential lack or failure of any equipment on OSVs that is required during these activities. Considering that the daily rate of the rigs or drill ship can vary from 100.000 USD up to 400.000 USD in some cases, a day of loss of drilling or production activities can be financially equal to one month of OSV hire (Rose, 2011). In the following, real or average data for two typical types of offshore vessels, PSV and AHTS, will be presented with data related to the performance of activities in the oil fields of West Africa. The data processed are obtained from official vessel logs.

ANALYSIS OF OPERATIONAL TIME AND COSTS OF OFFSHORE VESSELS

The importance of OSV ships in the logistics chain of oil exploration and production has already been mentioned through several factors. Still, for a better representation of the role of this type of vessel, it can be seen in Figure 7. where the difference in the size of the two types of vessels is visible but AHTS with LOA 69 m; 2.380 DWT; 10.800 BHP and 133 t BP having the daily hire amount approximately equal to the daily hire of a VLCC vessel with over 300.000 DWT and LOA of 320 m. For both types of vessels, the daily hire rate is around 33.000 USD.

Figure7. AHTS 130t BP and VLCC vessel (Source: https://seacormarine.com/; https://commons.wikimedia.org/)

For hiring a VLCC vessel, the hire is paid only when the vessel is in principle working, while in the case of a typical AHTS vessel, by looking at the Logbook during one year, almost half of the hire time vessel is on standing by waiting for orders (Table 1.). In addition to the st/by period, the importance is also reflected in the commercial side of the contract.

Month	Marine service activities (day)	Port (day)	Sailing (day)	St/by (day)	Supply (day)	Total (day)
1	3.93	1.47	6.27	17.38	1.93	30.98
2	4.33	3.19	8.65	8.96	2.85	27.98
3	8.62	0.72	5.16	13.86	2.62	30.98
4	4.36	1.74	8.62	11.25	4.01	29.98
5	7.60	3.86	6.77	8.83	3.92	30.98
6	1.60	2.17	6.45	16.93	2.83	29.98
7	4.73		3.01	13.27	0.97	21.98
8	8.32	0.72	5.17	14.18	2.58	30.98
9	4.02	1.26	7.39	9.45	3.86	25.98
10	4.17	3.36	3.99	11.74	0.73	23.99
11	7.60	1.26	6.08	11.44	3.92	30.30
12	4.17	3.46	3.97	9.65	0.73	21.98
Average days	5.29	2.11	5.96	13.03	2.58	28.01
Total days per year	63.5	23.2	71.5	146.9	31.0	336
%	18.88	6.91	21.29	43.72	9.21	100

Table 1. AHTS operational time during a year

An extract from Logbook in Table 1. shows the number of days per month during a year where the activities of the representative AHTS are divided into marine service activities, time spent in port, navigation, st/by and supply. Due to AHT capabilities, marine service activities are only related to the AHTS type of vessels and not PSV vessels. These activities include anchor handling, towing, tanker lifting, rig move and relocation of different offshore units. It should also be emphasized that according to the analysis in all months during the year, the vessel could not operate fully every month due to technical difficulties or some other issues and as a result, it was some period out of hire. Table 1. shows a significant share of as much as 43.72% of the time the AHTS spends on standby and is operationally not used, even though the daily hire is paid in full. From a commercial point of view, it is considered a day rate which during the analysis period amounted to 32.500 USD causing a loss during an average month close to 400.000 USD and yearly over 4.7 mil. USD was paid when the vessel did not have any activities. Due to the depletion of oil in shallow seas as well as the advancement of technology, oil and gas fields move into deep and ultra-deep waters, and vessels will follow with more brake horsepower, larger deck size, and improved BP (Boko et al., 2022). It will consequently cause a higher hire rate and higher loss due to the time the vessels spend waiting and not in use.

In the case of PSV UTT755 class vessel which represents this type of OSV vessel by looking at the logbook during one year, almost half of the hire time vessel is on standing by waiting for orders. Due to the mentioned technical specification, the PSV vessel cannot handle the anchor and tow, but only performs supply operations, so only supply was considered and not marine service activities. But a capacity of 1600t of deck cargo, and over 7000^{3}m liquid and dry bulk cargoes rank this class of vessels as one of the most desirable on the PSV market (Golden Energy Offshore Management AS, 2023).

Month	Port (day)	Sailing (day)	St/by (day)	Supply (day)	Total (day)
1	3.42	3.18	15.32	2.34	**24.18**
2	3.62	7.43	6.69	4.42	**22.15**
3	3.62	8.54	8.23	5.00	**25.38**
4	3.49	9,85	12.49	4.14	**29.97**
5	3.64	7.43	15.07	4.84	**30.98**
6	3.12	10.87	10.9	5.09	**29.98**
7	4.42	9.91	12.81	3.84	**30.98**
8	3.03	11.48	13.09	3.36	**30.96**
9	3.08	5.70	18.28	2.91	**29.97**
10	5.38	4.24	19.84	1.17	**30.63**
11	12.77	5.83	6.77	4.61	**29.98**
12	3.13	2.92	13.74	2.20	**21.98**
Average days	**4.39**	**7.28**	**12.78**	**3.66**	**28.10**
Total days per year	**52.70**	**87.38**	**153.24**	**43.92**	**337.14**
%	**15.63**	**25.92**	**45.46**	**13.03**	**100**

Table 2. PSV operational time during a year

Given that this type of vessel does not perform marine service activities and has 45.46% of total time spent on st/by the loss of operational time is even more pronounced. Looking at the commercial side of this type of vessel with a day rate of 27.500 USD and an average of 28.10 days of hire during a year the loss because the vessel was not involved in operations causes payment of over 350.000 USD for the vessel being on st/by. On yearly basis, it amounts to over 4.2 mil. USD.

Taking the aforementioned and the total st/by time for both types of vessels with a percentage of almost 90% it can be said that one vessel was needlessly hired. The loss of over 750.000 USD per average month and close to 9 mils. USD per calendar year and the operational non-use of the vessels give a considerable amount of money that the oil company has to calculate in the project budget burden.

OSVs are hired according to the planned project, which is always for a longer period, year and more so the percentage of non-use of the vessel, as well as the loss in money, gives additional importance into account. Particularly where several OSVs are hired and not regularly used. The spot market prices are always higher than the long term-market prices by 10-15%. In emergencies, a vessel's day rate can increase by 20% or more (Skoko et al., 2013) and oil companies avoid this type of hire and take vessels on short-term contracts only if they are necessary or for a specific job.

In this research, it should be emphasized that only the amount of daily hires was taken into account, while port and fuel costs, agency fees, etc. were not considered, so the total amount of losses are higher.

In addition to operational and commercial losses due to the non-use of vessels, problems for the environment also come to the fore. OSVs regardless of the fact that they are not operationally involved, release harmful substances into the environment, thereby polluting the air and causing problems and expenses of another kind.

CONCLUSION

Offshore vessels are indispensable and one of the more expensive parts of the offshore logistics chain. Careful planning of the offshore fleet can save a large amount of money for the oil company, but also due to unexpected problems in exploration and production, not having a sufficient number of OSVs in the fleet to cover extraordinary cargo runs or marine service activities, can cause almost immeasurable losses.

When planning the budget, the size and duration of the project are considered, so accordingly a certain size and type of vessels are also taken. By analyzing the prices of crude oil, it was observed that it depends on geopolitical factors and has unpredictable even daily changes. Unlike the sometimes-sudden daily changes in the price of crude oil for OSV vessels, the price is mainly related to the contract duration.

Analyzing the hire rate of OSV vessels there are no sudden daily changes but the trend of tracking the movement of crude oil trend is certainly visible. Either in rising or falling prices.

The oil companies have problems when planning the hire of the fleet and the vessels spend almost half of their time waiting for instructions, causing great losses and pressure on the project budget. For the sake of security and maintenance of a continuous supply chain, companies hire a larger number of vessels, even though in principle they do not need them in that number.

From the analysis of two typical types of OSV vessels, it can be concluded that one vessel is practically not even needed, which is not the case in practice.

In a conclusion, it can be said that for future research and to get proper selection by size and type of offshore vessels, it is necessary to create a mathematical model whose operational data, and activities are taken from the logbooks of all hired vessels in the oil field, and according to the results obtained reduce or increase the type and number of vessels in the field.

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Application of Interpolation in Different Branches of Navigation and Cargo Handling

Zaloa Sanchez Varela, Marina Laušić, Tony Pinčetić, Ivan Pavić

Throughout history as well as today, the term navigation in itself comprises a whole set of skills needed for operating a vessel and safe handling of her cargo. Therefore, it could be argued that navigation consists of different branches – coastal, celestial and electronic. Cargo operations on the other hand embody cargo handling and ship stability. But all of the above-mentioned subjects share the same connection, which is that in their everyday use and different applications throughout the maritime profession they are based on different mathematical operations and methods. One such method used in data analysis is interpolation. The purpose of this paper is to explain and give a closer look at different methods for determining unknown values of a quantity using known values located within an interval defined by a discrete data set in which the laws of its changes are known. Interpolation is something that is in everyday use by deck officers on board vessels, and it is also one of the more complex methods with which the students of Croatian maritime schools and universities are acquainted with during their studies. By simply describing facts, processes and objects in in question or relation to the presented subject in question, as well as with its empirical confirmation and proof of relationships and connections, without much scientific interpretation and explanation the method of interpolation is shown at its theoretical and practical levels. The information sources that have been used are compiled trough reviewed scientific research work, with sufficient mathematical methods that describe the laws of the interpolating method. The paper shows that there are different methods in use, the use itself is essential in everyday work, and that the method in use determines the effectiveness and the accuracy of needed calculations. So, it is of vital importance that a level of significance and attention is put on appropriately mastering and using this method for the purpose of educating and creating competent future deck officers, as well as the emphasis for cross curricular cooperation.

KEY WORDS
Interpolation, Navigation, Mathematics, Function, Data set

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INTRODUCTION

The maritime transport industry, like any other branch of technical and natural sciences, tends to acquire of as much data as possible. For the person who observes the parameters of the object to better understand the process through which the observed object goes, it is important to have as accurate a set of data as possible. That is usually obtained by some kind of exact measurement or calculation, the accuracy of which we have convinced ourselves by different methods of proving it. These data vary in what they show, considering the countless possible subjects of observation and examination. But what connects them is that they always show the value of a certain parameter. That parameter value most often expresses a change of state. To state a change as such, a relationship is needed against which or concerning what that same parameter is changing.

Of course, the set of default values of the measured parameters is not infinite because if it were, the application and handling of such a set of data would be impractical, perhaps even impossible, but moreover unattainable. Therefore, the information handled by the user is given in formatted structures with a hold on probable cases and corresponding parameters, borderline cases and the predicted minimum and maximum values of these.

The methods that we encounter in the daily analysis and determination of the exact values of navigation and cargo handling parameters as maritime transport technology engineers derive from and are based primarily on the application of numerical mathematics. More specifically numerical analysis algorithms, with which we determine approximate values while solving mathematical problems that we encounter in daily work, management and handling of the ship and its cargo. Among these procedures and methods are numerical mathematics, numerical linear algebra, approximation and interpolation methods, numerical solving of non-linear equations, as well as the analysis of their errors which should be clearly distinguished.

INTERPOLATION

In a series of mathematical-analytical problems, in which the methods of solving are used to find the data of the associated functions that were previously determined by analytical or statistical tools and methods, and accordingly also the mathematical processing of these data into meaningful information, which, as has been shown in practice, at least in the case of maritime navigation, in most cases are crucial for the execution of navigational planning or cargo handling. Through such processing of the given data, we actually approach meaningful parsing and find patterns by which we arrive at required values based on a known parameter in relation to which others also change precisely according to that pattern. However, of course, the whole method fulfills the condition of its meaningfulness only if it meets the condition of understanding the nature of the change, i.e. by understanding the procedures by which complex or simple forms are used to arrive at simple and as exact results as possible.

Every seaman, or rather a navigations officer in the service of the deck, finds himself in a situation every day where he has to find or express some of the variable values by which his problem is demarcated by some mathematical method, most often by interpolation. Such problems can be calculations of changes in the height of high or low water in terrestrial navigation, calculation of some of the values from hydrostatic tables during the final calculation of the ship's stability, calculation of some corrective parameter in astronomical navigation, or calculations that electronic navigation systems themselves calculate as part of their software solutions in daily use.

As already mentioned before, interpolation, as a method of processing data within the interval of a discrete set, is applied when some of the required values are not given in the form of formulas, the application of which and the inclusion of other given parameters. If they are those necessary for solving the same, enable the solution given formulas, are already given as ordered members of the set of function values of the associated data. Hereby we pose a question about "the problem of approximation". Suppose some or more information is known about a particular function defined on some set X ⊆ R. Based on this information, we want to replace that function with another function φ on the set X, so that f and φ are close in some sense. The set X is most often an interval in the form of [a, b] (it can be infinite) or a discrete set of points (Rogina et al, 2003, p. 288).

Using an analytical approach, certain functions for calculating the required points in their formal forms are not practical for everyday use, such as in the question when we talk about the maritime profession. The approach of searching for such functions or determining their approximation functions is even more impractical. The most common situation is that end users (at least in the case of the profession in question in this paper) are not familiar with the methods of calculating such functions or using them. Therefore, instead of a function only as information, they are offered a set of measured points from whose measurements the changing pattern is clear and within whose interpolation nodes the required values can be calculated using different interpolation methods. When it is necessary to interpolate only the function values of a given function (polynomial), we most often use the so-called Lagrange interpolation. We use this polynomial when we need to calculate the value of a function f at some point x ∈ [a, b], x 6 = xi, i = 0, 1, 2, ..., n (Ujević, 2004). The interpolation polynomial p_n is:

$$p_n(x) = \sum_{i=0}^{n} f_k l_k(x) \quad (1)$$

Where: $l_k(x) = \frac{(x-x_0)\dots(x-x_{k-1})(x-x_{k+1})\dots(x-x_n)}{(x_k-x_0)\dots(x_k-x_{k-1})(x_k-x_{k+1})\dots(x_k-x_n)} = \prod_{\substack{i=0 \\ i\neq k}}^{n} \frac{x-x_i}{x_k-x_i} := \frac{\omega_k(x)}{\omega_k(x_k)}, \;\; k = o, \dots, n.$ (2)

If we require interpolating the given values of the function and its successive derivatives, we use Hermite's interpolation (Rogina et al, 2003, p. 316).

However, in day-to-day navigational practice, solving a polynomial higher than the first degree is rarely approached; therefore, the so-called Newton's method is most often used.

NEWTONS METHOD

The Lagrange form of the interpolation polynomial is not suitable for adding nodes, that is, for gradually increasing the degree of the interpolation polynomial, which we rarely encounter. We will use Newton's form of the interpolation polynomial, which can be performed by adding new interpolation nods to the interpolation polynomial, that is, which allows us to increase the degree of the interpolation polynomial (Singer, 2019, p. 5).

We look for the interpolation expression from Newton's formulation;

$$P_n(x) = a_0 + a_1(x - x_0) + \cdots + a_n(x - x_0)(x - x_1)\dots(x - x_{n-1}) \quad (3)$$

and coefficients $a_0, a_1, \dots a_n$ are calculated using the finite difference method from which the expression (3) becomes;

$$P_n = f[x_0] + f[x_0, x_1](x - x_0) + \cdots + f\left[x_{0,}x_1 \dots x_n\right](x - x_0) \dots (x - x_{n-1}) \quad (4)$$

in which the following are;

$$f[x_0, x_1 \dots x_n] = \frac{f[x_1, \dots, x_n] - f[x_0, x_1, \dots, x_{i-1}]}{x_1 - x_0}, \quad i = 1, \dots, n. \quad (5)$$

When interpolating a parameter whose change value is linear, for example, in the case of speed and distance traveled, Newton's method certainly seems to be the simplest and most practical numerical method of interpolating a polynomial of the first degree, i.e. a line passing through points/coordinates (x_0, x_1) and (y_0, y_1);

$P_1(x) = a_0 + a_1(x - x_0), a_0 = f(x_0), \quad (6)$

where according to the first finite difference, it follows that they are;

$$a_1 = \frac{f(x_1) - f(x_0)}{x_1 - x_0}, \;\; f(x_1) = y_1; \;\; f(x_0) = y_0, \quad (7)$$

and it is finally;

$$P_1(x) = y_0 + \frac{y_1 - y_0}{x_1 - x_0}(x - x_0), \quad (8)$$

If the values included in expression (8) come from a set of data whose value has the nature of a change that is linear, i.e. if it changes "along a straight line" in a coordinate system, then the final value is not an approximation but an exact result that, due to the application of the method of its numerical calculation, was not obtained with an error.

APPLICATION - EXAMPLES

Costal (terrestrial) navigation

Perhaps the most frequent example in which we can clearly recognize the need for simple interpolation methods is the classic task of reducing the measured depth of water to the level of the water surface from which depths are shown on a nautical chart (chart datum) for primary (with indicated water depths for chart datum) and secondary ports (with corrections in relation to primary ports). The calculation of the current depth of the sea for the corresponding chart datum or at what time the indicated depth will be at a certain position. Newton's method can demonstrate its purposefulness in all of the aforementioned applications.

The given data that we use is tabulated using The Admiralty method (see table 1.), on the basis of which Tide tables are created. Three phases are distinguished in the reception of harmonic analysis for the calculation of Tide Table elements: determination of the appropriate number of component waves for the most accurate approximation to the real wave of the main port, extraction of components such as the amplitude component or delay phase and the drawing of the diagram of sea changes to determine the occurrence of high and low water (Simović, 2001, p. 175).

In such a task, which is really simple, but even more important, the everyday work of an officer, attention and precision are much required considering the fact that such a calculation is of sensitive nature, or rather the information on time and height of water is of significant importance for the safety of navigation. In such a task, it is necessary to interpolate several times. In order to finally obtain the results of the requested parameters, i.e. the first and second high and low waters and finally calculate the requested reduction, it is necessary to pay attention to the fact that many of these input parameters are given in a table. The requested parameters that we obtain via at least one known value are usually between given data.

If the corrections for the time differences between the main and secondary ports are given in periods and not in the final correction, then the same should be calculated, that is, obtained by one of the interpolation methods, most practically by Newton's method and formula (formulation 8.).

	Time differences			
	High water		Low water	
Main port	0300	0800	0300	0900
MP seasonal change	1500	2000	1500	2000
Secondary port SP seasonal change	-0025	-0035	-0010	-0020

Table 1. Tide tables – example (prepared by the authors)

Where if we assume that time of high water is at 05 hours and 28 minutes, and after the same time of the first high water had been corrected for the value of the seasonal change, if the seasonal change exists for the particular port, we proceed to finding in which of the given intervals of the high water time differences our given value falls in (see table 2. and 3.).

0300	-0025
0528	?
0800	-0035

Table 2. – extraction of the given values (prepared by the authors)

x_0	0300	-0025	y_0
x	0528	?	$P_1(x)$
x_1	0800	-0035	y_1

Table 3. – assigning of values identities (prepared by the authors)

$$P_1(x) = y_0 + \frac{y_1 - y_0}{x_1 - x_0}(x - x_0) = -0025 + \frac{-0035 - (-0025)}{0800 - 0300}(0528 - 0300) \approx -0030 \quad (9)$$

Since we are showing here the principle of the method being used, this example is sufficient to show the operational principles. However, we cannot help but say that during this very task (the calculation of time or height of high and/or low water) there are but a few other moments in which interpolation is needed. Such is, for example, the interpolation of the height difference when using values of mean high/lows of water springs/neaps, or when in the tabulated form of solving the problem the values with which we find the change of amplitude are not exact or close (regarding the margin of error) to the before calculated values. The examples are numerous and can be found throughout the branch of coastal (terrestrial) navigation.

Vessel's stability

The primary source of information for handling cargo whilst achieving, or better to say maintaining vessel's stability is found in the stability booklet, which is one of the most important books onboard that we use in the daily exploitation of the vessel, especially before, during and after or upon completion of cargo operations. The stability booklet contains the capacity plan of the ship, the hydrostatic tables, calibration tables showing the weight and volume values of individual tanks and volume values of individual storage spaces (capacity for bales and grain) (see table 4). Other data presented are the tables of moments of inertia of liquids in tanks, important for calculating the influence of free surfaces, a diagram of the change of trim for a certain value of loaded or unloaded cargo, the cross curves of stability, which are also extremely important for calculations of GZ curves.

Hydrostatic Particulars

DRAFT	DISPL.	TPC	MCTC	LCB	LCF	KB	KM_L	KM_T
(m)	(tonnes)	(tonnes/cm)	(tonnes.m/cm)	(m)	(m)	(m)	(m)	(m)
	SW (RD 1.025)	SW (RD 1.025)	SW (RD 1.025)	FOAP	FOAP		Above base	Above base
10,40	33190	35,31	415	85,74	82,16	5,38	216	9,53
10,50	33540	35,38	418	85,70	82,08	5,44	215	9,55

Table 4. – Hydrostatic particulars (tabulated - example vessel - M/V Almar) (prepared by the authors)

The stability booklet also contains diagram sheets of the vessel, also known as hydrostatic curves that graphically show various geometric sizes of the vessel. All curves are valid for mean drafts. A chart sheet usually has twenty curves with different scales for different sizes. The starting point of each of them is the mean draft whose values are on the ordinate. Some of these curves refer to the curves of the height of the center of buoyancy for a given displacement from the keel (KB), the curve of the moment of trim for a draft difference of 1 cm (MCTC), the volume scale, the displacement scale or the carrying capacity scale, the curve of the surface of the water lines, the height of the metacenter above the keel (KM), the longitudinal center of buoyancy (LCB), the center of gravity (LCG), tonnes per cm immersion (TPC), center of flotation (LCF).

Table method

So, how to interpolate using the indirect Newton method knowing only one parameter? Let's assume that we accurately know the vessel's draft, which can be quite easily obtained only by reading the vessel's draft marks. With the obtained mean draft, we would search the other closest values to that which is given to us, or which we had read and corrected if necessary. Other tabulated values of the mean draft will be given, as it is said before, in the hydrostatic tables (see table 4.) So, the values we are looking for have to correspond with the given parameter whose value is known to us, in this example – the mean draft (see table 5.).

Draft	Displ.	KB	MCTC
10.30	32840	5.33	413
10.34	?	?	?
10.40	33190	5.38	415

Table 5. – table for interpolating required values (prepared by the authors)

The method consists of five steps.

1. Calculating the difference between the higher and the lower value. This step has to be repeated for all of the required parameters; in this example draft, displacement, KB, and MCTC. In this example:

$$\Delta draft_1 = draft_2 - draft_1; \quad \Delta draft_1 = 10.40 - 10.30; \quad \Delta draft_1 = 0.1\ (m) \ \ (10)$$

2. Calculating the difference between the given draft and the lower draft value. This step is carried out only with the parameter whose value is given or otherwise known to us. In this example, that parameter is the draft.

$$\Delta draft_2 = draft - draft_1; \quad \Delta draft_2 = 10.34 - 10.30; \quad \Delta draft_1 = 0.04\ (m) \ \ (11)$$

3. With the above data, division of the draft differences is formulated out of the Newtons method where by substituting the values in (9) we obtain:

$$draft\ division = \frac{(x - x_0)}{x_1 - x_0} = \frac{\Delta draft\ _2}{\Delta draft_1} = \frac{draft_2 - draft_1}{draft - draft_1} = \frac{10.34 - 10.30}{10.40 - 10.30} = \frac{0.04}{0.1} = 0.40 \ \ (12)$$

4. Calculating the difference between the required and the lower values is performed through the multiplication of draft division (step 3.) and the difference between the given higher and the lower values:

*Displacement

$$\Delta displacement_1 = displacement_2 - displacement_1; \quad \Delta displacement_1 = 33190 - 32840; \quad (13)$$

$$\Delta displacement_1 = 350\ (t)$$

$$P_1(x) = y_0 + \frac{y_1 - y_0}{x_1 - x_0}(x - x_0) \ \rightarrow \frac{(x - x_0)}{x_1 - x_0}\ y_1 - y_0 \rightarrow$$

$$\Delta displacement_2 = \frac{(x-x_0)}{x_1-x_0}\ y_1 - y_0 = \frac{\Delta draft\ _2}{\Delta draft_1}\Delta displacement_1 = \frac{draft_2 - draft_1}{draft - draft_1}(displacement_2 - displacement_1)$$

$$= \frac{10.34 - 10.30}{10.4 - 10.30}(33190 - 32840) = \frac{0.04}{0.1}(350) = 140\ (t)\ (14)$$

5. Calculation of the required value (e.g. displacement) is given by adding or subtracting the difference between required and lower value to either higher or lower value, depending if in the second step we were chose upper or lower value, that is, whether the value increases or decreases. Since the value of displacement increases with the increasing mean draft, we will add the difference between required and lower value to the lower value, that is subtract it from the higher value

$$displacement = displacement_1 + \Delta displacement_2 = displacement_2 - \Delta displacement_2 \ \ (15)$$

$$displacement = 32840 + 140 = 33190 - 140 = 32980\ (t)$$

$$P_1(x) = y_0 + \frac{(x - x_0)}{x_1 - x_0}\ y_1 - y_0 \ \ (9)$$

$$displacement = displacement_1 + \frac{\Delta draft_2}{\Delta draft_1} \Delta displacement_1 \quad (16)$$

$$= displacement_1 + \frac{draft_2 - draft_1}{draft - draft_1}(displacement_2 - displacement_1)$$

$$= 32840 + \frac{10.34-10.3}{10.4-10.3}(33190 - 32840) = 32840 + \frac{0.04}{0.1}(350) = 32980\ (t) \quad (17)$$

Draft	Displ.	KB	MCTC
10.30	32840	5.33	413
10.34	**32980**	**5.35**	**413.8**
10.40	33190	5.38	415
0.04			
0.1	350	0.05	2
0.04 ÷ 0.1 = **0.4**	350 x **0.4** = **140**	0.05 x **0.4** = **0.02**	2 x **0.4** = **0.8**

Table 6. – table with interpolated values (prepared by the authors)

Graphical approximation method

As it had already been explained, some of the hydrostatic parameters can be given in the form of curves composed on a diagram. However, as it can be clearly seen from the diagram below (see figure 1.) none of the parameters portrayed follows a straight line but rather a curve, which means that the tabulated values are not linear. So, if we were to interpolate nonlinear values accurately, one should consider the effect that this curvature poses on the calculation requirements. However, in most diagrams, the points of the curve selected for calculation are usually close enough so that the portion between the tabulated values shown graphically as a curve can be considered a straight line without introducing a significant enough error as such (Bowditch, 2017, p. 197).

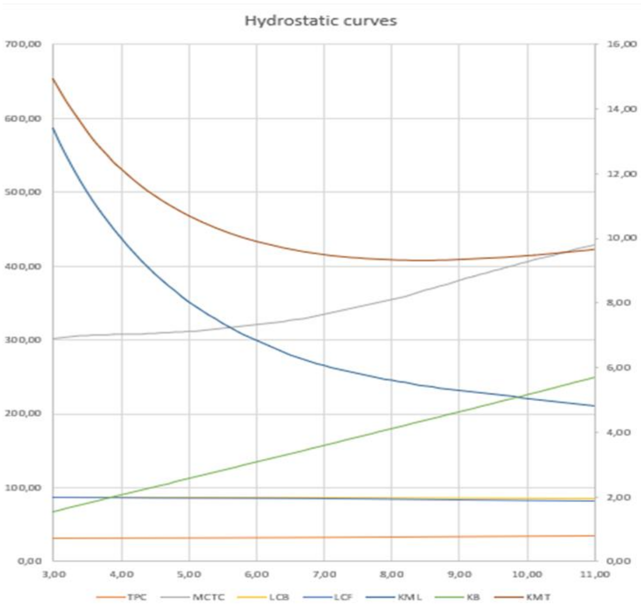

Figure 1. – Hydrostatic curves (example vessel - M/V Almar) (prepared by the authors)

Let us extract the curve representing KB with some imaginary values and suppose that the vessel in question has a displacement of 21300 tones and that one is looking for the corresponding KB value. Looking at Figure 2 the given displacement value fits in the interval between two selected displacement values with their respective KB values.

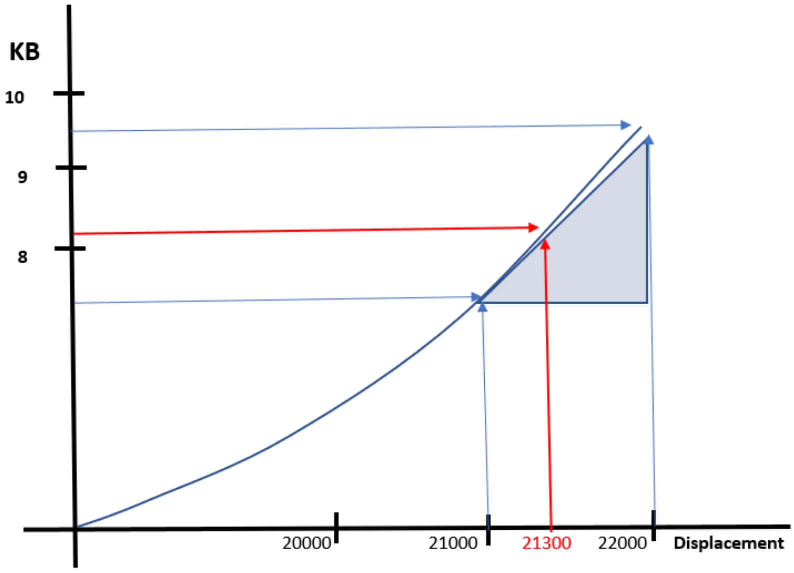

Figure 2. – Example of curve approximation method (prepared by the authors)

Because of the sufficiently small difference in the values of given parameters the KB curve can easily be approximated to the hypotenuse of a right-angled triangle. Considering the given displacement value, and the previous/subsequent displacement values, similar right-angled triangles are formed (Figure 3).

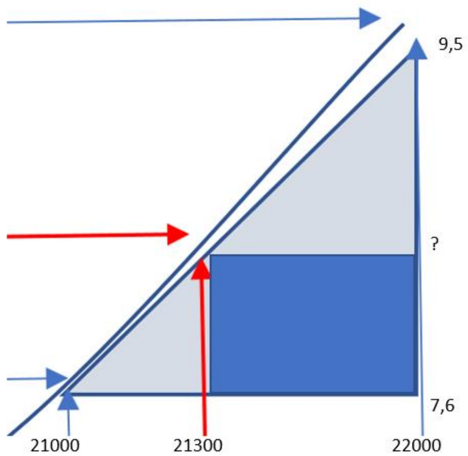

Figure 3. - Example of curve approximation method (prepared by the authors)

Singled out and marked with the according lengths of their sides, the proportion equation can be formulated (Figure 4), out of which the required value is calculated by adding the difference between the required and lower value to the lower value.

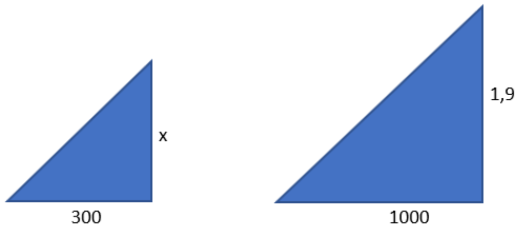

Figure 4. - Example of curve approximation method (prepared by the authors)

Proportion equation:

$$x{:}\, 1.9 = 300{:}\, 1000 \quad \rightarrow \quad \frac{x}{9} = \frac{300}{1000} \quad \rightarrow \quad x \times 1000 = 9 \times 300 \quad \rightarrow \quad x = \frac{9 \times 300}{1000} \approx 0.57 \quad (18)$$

$$KB = 7.6 + 0.57 = 8.17\ (m)$$

OTHER APPLICATIONS OF INTERPOLATION IN THE MARITIME INDUSTRY

There is an approach of presenting real industrial problems and their mathematical modeling as a motivation for developing mathematical methods that are needed for solving the problems (Heilio, 2004). And on that basis some research has shown that interpolation is very applicable in reconstructing lost AIS data, thus producing useful information for VTS stations or other ships. The number of time-series available for ship traffic and maneuvering analysis has increased from tens, or hundreds, to several thousands. Sifting through these data manually, either to find the salient features of traffic, or to provide statistical distributions of decision variables is an extremely time-consuming procedure (Karl and Moan, 2009). The research shows that in this application, the interpolation in use is cubic Hermit that enables the researchers to provide possible AIS data regarding ship position, COG, SOG and HDG when divided into separate time series (Nguyen, Im and Lee, 2015, p. 377). Nevertheless, other research has shown that this way of conveying lost data, in the end, shows an unacceptably large margin of error. However, as a future developmental field, it has great potential in search and rescue operations as a means of showing a plausible ship's route. Also improved Lagrange interpolation is used in other researches to fill the navigational sequence gap in the AIS data. The essence of Lagrange interpolation is the use of polynomials to fit the relevant point positions (Liu and Ma, 2022).

Another practical field in which more and more interpolation is used in software algorithms is in collision avoidance and maneuvering. The main focus in that field of research is the prediction of the vessels vector with its position coordinates, speed, heading, and other movement parameters given at fixed time intervals for different steering scenarios. Research shows that one of the possible ways of resolutions to problems which might arise is using the interpolation of the ship's state vector based on the data from measurements conducted during the sea trials of the ship (Borkowski, Pietrzykowski and Magaj, 2021, p. 1). Certainly, something that is going to contribute to the faster development of autonomous vessels and to enable higher levels of safety and predictions about the best possible actions in the maneuvering, that is, in the sense of remote control of the vessel. For instance, Akakpo and Marios (2015) claimed and developed a mathematical model for the determination of collision distance and collision zone between two ensuing ships on collision course and how it could be avoided (Akakpo, 2016).

But also, when talking about autonomous vessels, the development of S-100 electronic nautical charts group of standards, as well as hydrographic and meteorological information and forecasts from the same group of standards, which are well suited for the navigation of autonomous ships, have shown that selecting from the full range of interpolation algorithms listed by the standard for each individual map, interpolation allows a very accurate representation of the seafloor and river bed (Brozovic, Kezić and Bošnjak, 2021, p. 1).

Even more complex than that is the "E∗ algorithm" developed as a path planning method capable of considering the dynamical changes to ensure better passage planning and adjustable path cost interpolation. It calculates a set of different navigational parameters for as safe as possible track planning whilst taking the possible marked dangers set in coastal navigation (Philippsen and Siegwart, 2005, p. 1).

CONCLUSION

Interpolation is a widely applicable mathematical tool in the maritime industry. It can be used in various fields, such as reconstructing lost AIS data, collision avoidance and maneuvering, autonomous vessel navigation, and even path planning methods. While there are limitations and challenges associated with interpolation, ongoing research and development in this area offer a promising potential for improving safety and efficiency in the maritime industry. The coastal, astronomical or electronic navigation fields and vessel stability rely heavily on mathematical calculations and interpolation methods to ensure safe and accurate operations. Using tables and data interpolation is essential for determining the height of water, the height of tide levels, and vessel stability, among other parameters, which are critical for maritime safety. Interpolation methods, such as Newton's, play an important role in making these calculations possible. As such, simple interpolation methods play a crucial role in various branches of navigation and ship handling and are necessary for officers in their everyday work. Overall, the increasing use of interpolation in various applications within the industry highlights its importance in ensuring accurate and reliable maritime operations. The precision and attention to detail required in these calculations highlight the importance of education and training in the maritime industry.

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Enhancing Students' Engagement in Learning Mathematics Using GeoGebra in Maritime Education

Anita Gudelj

This study presents the effectiveness of resources developed by mathematics teachers during the MareMathics project. The focus is on the effects of the dynamic mathematics software GeoGebra on student achievement in learning mathematics at maritime higher education institutions from Croatia, Latvia, Poland and Estonia. Geogebra is an open-source computer program to support teaching and learning mathematics contents, especially in algebra, geometry and statistics. During this project, various Geogebra models were developed, which are expected to greatly assist students in visualizing abstract mathematical content and maritime applications quickly, accurately and efficiently. The research was conducted on 45 students who participated in the MareMathics Summer School. Data were obtained from students' pre-test and post-test. The analysis of the collected data determined the students' satisfaction with the presented contents and that GeoGebra is an effective tool for enhancing students learning and understanding of mathematical contents and their application in solving different maritime issues. GeoGebra software can effectively encourage teachers at maritime higher educational institutions to employ information technology as a supporting tool to improve students' attitudes towards mathematics learning. Learning models with Geogebra give students more chances to explore their minds and more ideas on how to connect mathematical knowledge with solving various issues in maritime affairs.

KEY WORDS
Higher maritime education, Mathematics, Visualization and simulation, GeoGebra, Student's attitude

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INTRODUCTION

Many Maritime Higher Education Institutes (MHEI) students have deficient knowledge and poor mathematical abilities and drop out of their studies in their first year. In response to this problem, the University of Split, Faculty of Maritime Studies (FoMS) carried out the project MareMathics - *An innovative approach to mathematics education for maritime students* [5]. Three more MHEI participated in the project: Latvian Maritime Academy (LMA), Polish Naval Academy (PNA) and Tallinn University of Technology, Estonian Maritime Academy (TalTech). This research is one of project outcomes.

During this project, teachers – project members complemented existing teaching resources with online visual elements, videos, animated simulations, quizzes, and exercises presenting classical mathematics in a dynamic and more attractive way, relating topics with real-life maritime situations (https://marematics.pfst.hr). It has been proven that technology is an important medium in creating a good teaching and learning environment; it plays an important role in overcoming learning difficulties and helps students visualize and understand mathematical concepts (Bwalya, 2019; Jatiariska et al., 2019; Wang, 2019). Thus, the project objective was to incorporate advances in information technology into conventional mathematics courses to promote more effective and attractive teaching and help students to improve their success on exams. Developed MareMathics applications in GeoGebra, especially those related to real-life problems, can motivate students to learn mathematics, overcome gaps in mathematical knowledge and better understand its importance for maritime.

Therefore, the aim of this study is to investigate

- the effect of GeoGebra in teaching mathematical concepts to maritime students
- students' attitudes and interest towards learning mathematics using GeoGebra software.

This research was conducted during MareMathics Summer School in Split, 2021/2022 academic year (1 week). Dynamic applications were initially developed for the fundamentals of maritime nautical courses, in which trigonometry and vectors are powerful instruments for describing and determining shipping courses and bearing. Three interactive GeoGebra simulations, developed by the author who is also academic leader of MareMathics project, served as the main examples in this study. By analogy, the concepts are applicable to other courses such as maritime electrical engineering.

The results of a questionnaire-based evaluation with respect to students' perception and satisfaction with the received teaching environment, and students' achievement in pre and post-testing are presented. This research shows the benefits of integrating GeoGebra visualization and simulations with traditional teaching mathematical concepts.

MOTIVATION

A preliminary survey of student preferences, satisfaction and perception of teaching and learning mathematics subjects conducted at universities in Croatia, Latvia, Poland and Estonia (Gudelj et al., 2021) showed that students are not interested and motivated in learning mathematics. The reasons are different. For example, most students do not realize the importance of mathematics for their future profession and work. Another reason is that teachers mostly use traditional methods and tools such as whiteboards, felt-tip pens, and PowerPoint presentations. These methods are still acceptable but are not attractive and motivating for students.

Integrating information technologies into traditional mathematics courses offers new opportunities for teaching strategies, motivating students to explore, and building positive attitudes and technical skills necessary for successful problem-solving. Simulations allow teachers to focus attention on interesting concepts. By running the simulation, students can check how the outputs change by modifying the inputs (Hennig et al., 2013).

GeoGebra is a dynamic and freely available mathematical software. Hundreds of posted applets can be run online or downloaded for offline use. GeoGebra offers a friendly interface and multilingual tool, and it facilitates making dynamic applets to make activities.

In the MareMathics project, the use of GeoGebra applets was used as an attractive and interactive learning strategy. The set of applets for complex numbers, vectors, trigonometry, functions, and calculus was developed. In addition, some of these applications simulate real problems from navigation and electro-technique. Also, other educational activities (tests, quizzes, games, and videos) have been developed and posted on the web page https://www.geogebra.org/u/maremathics.

RESEARCH METHODOLOGY

This research work was carried out on 45 students from project partner institutions who participated MareMathich Summer School. It was a homogenous student group since our previous research has shown that these institutions have similar problems with student failure in mathematics exams, similar mathematical teaching and learning environments, students have a common educational background, and studied mathematics as a subject in their studies in the first year (Gudelj et al., 2021). Table 1 presents the student sample. The average age of students was 21.

MHEI	Number of students	
	Male	Female
FoMS	12	3
LMA	8	2
PNA	9	1
TalTech	6	4

Table 1. Sample of participants

Students were randomly divided into two groups A and B. While 23 students in group A received traditional teaching using presentations and whiteboards, group B included 22 students who were presented with solving mathematical content and applications using GeoGebra. Also, the research was conducted to examine students' satisfaction with teaching and their perception of using GeoGebra in teaching mathematical concepts.

Research procedures

This research was conducted in the following phases. In the first phase, pre-testing was conducted for both student groups at the begging of summer school. In the second phase, the students received mathematics lessons with classical (group A) and new technologies (group B) for one week. The third phase included post-testing for both groups at the end of the week.

In the last phase, students answered the questionnaire to reveal their attitudes and satisfaction with received teaching.

Tools

The tools used in this research consist of a pre-test and a post-test. These tests consisted of eight questions on trigonometric functions and vectors. The purpose of the test was to compare what the students learnt and remember from regular mathematics courses and what they received during summer school as the effect of using GeoGebra simulations and visual examples.

Also, the questionnaire was used to examine students' satisfaction with provided lessons and their perception of using GeoGebra in teaching mathematical concepts. Using the scale of “1-Poor, 2-Below Average, 3-Average, 4-Above Average, 5-Excellent” students answered the following five questions at the end of each lesson:

- Presenter Effectiveness
- Presented Content
- Usefulness
- Innovation of lecture
- Comment.

Teaching mathematics with traditional and new technologies

This research aimed to examine the effect of GeoGebra software on students' attitudes and understanding of the applications of trigonometry and vectors in maritime. Trigonometric functions and vectors link algebraic, geometric, and graphical thinking that can be manipulated using GeoGebra software. These mathematical concepts are an important precursor to understanding mathematical calculations used in navigation, such as calculating sailing courses. Also, it can be used for presenting AC phasors and power factors which based on the concept of complex numbers and sinusoidal waveforms. Since the students have a weak prior knowledge of mathematics, it is difficult for them to understand and apply these contents. Integrating GeoGebra applets into a course can be a fruitful approach to help students overcome these problems.

During this research, students received a lesson and exercised on three problems. The first one was on how to find the location of an object by using Cartesian coordinates or bearings. The second one related to the influence of wind on the movement of the drone. It was necessary to calculate the direction and magnitude of the velocity relative to the ground. The effect of wind on a drone is like the effect of a river current on a ship. So, the last problem was related to a ship sailing from point A to point B under the influence of wind or sea currents. It would not reach the shore directly at point B, therefor it was necessary to calculate how long it takes the ship to travel from shore to shore and determine the point at which it reaches the shore. The text problem and map were downloaded from https://www.teachengineering.org/. For students in group B, these examples were presented by using GeoGebra simulations (Figure 1-3). On their mobile phones, they were able to run these simulations and solve GeoGebra quiz https://www.geogebra.org/m/nykj3shg#material/agackn5r.

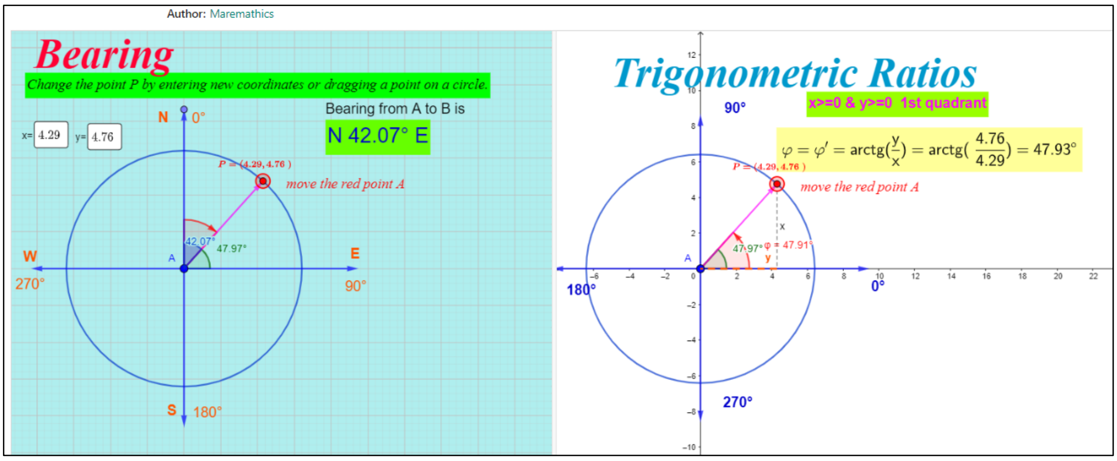

Figure 1. Bearing & Trigonometric Ratios of figure representing ship underway (Source: MareMathics https://www.geogebra.org).

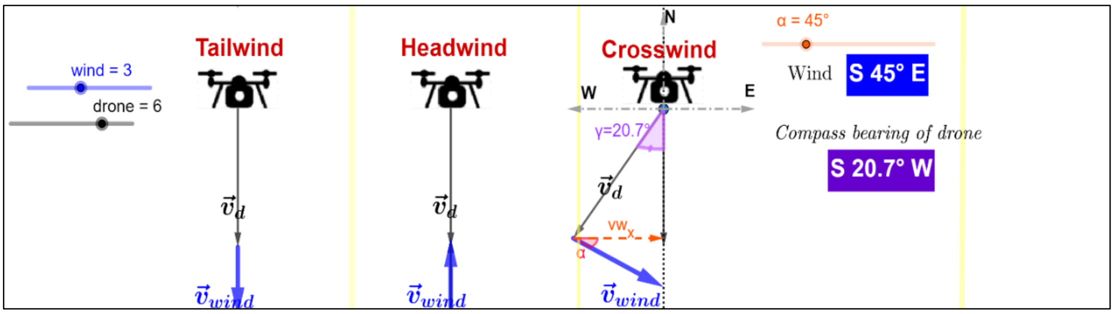

Figure 2. Motion of a drone with wind (Source: https://www.geogebra.org).

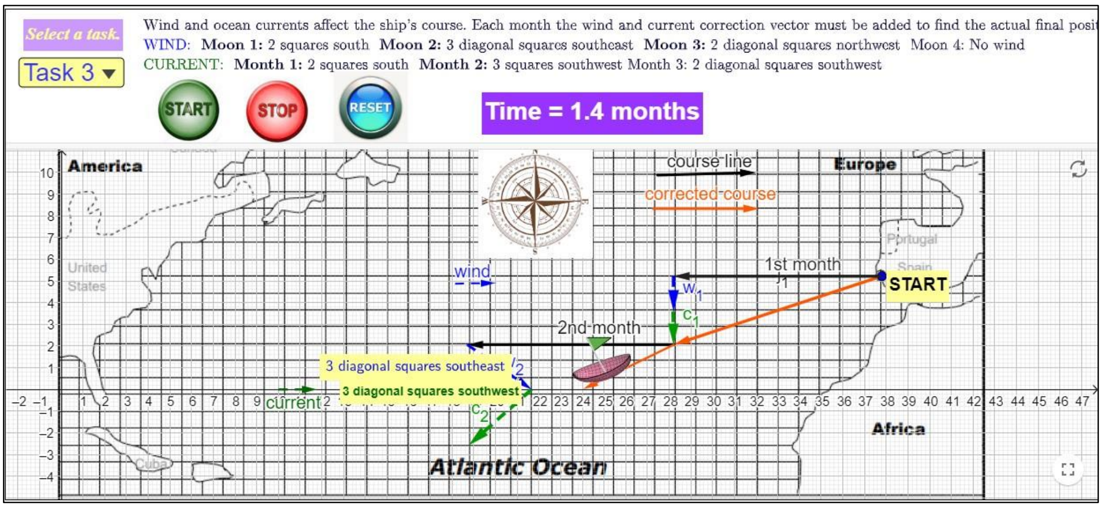

Figure 3. Vector application. Ship bearing under wind and current influences (Source: MareMathics https://www.geogebra.org).

RESULTS AND FINDINGS

The results of the student pre- and post-tests are analysed in MS Excel. It includes the results of 45 students: 23 students in Group A and 22 students in Group B.

Table 2 shows the average scores of each of the groups in pre and post-testing. Results show that students in both groups achieved similar results in pre-testing (before providing teaching). In post-testing average scores increased for both groups which indicate improved learning achievement. However, there is a difference in achieved scores between students who received traditional teaching (Mean Scores = 59.46) and those who received teaching using GeoGebra (Mean Scores = 75.30). It is obviously the effect of GeoGebra applications.

Group	Test	No Students	Mean Scores	SD	Min	Max
A - traditional teaching	Pre-Test	23	42.50	7.60	17	100
	Post-Test	23	59.46	8.50	25	100
B - teaching using GeoGebra	Pre-Test	22	41.8	9.8	10	100
	Post-Test	22	75.3	10.6	49	100

Table 2. Students' achievements in pre and post-testing

In the fourth phase of this study, students' attitudes were investigated according to the teaching strategy offered. Groups A and B are analyzed separately about attitudes such as exhibitors, content appropriations, the usefulness of the content and innovation of the lecture. The following figures show the percentage of students about their attitudes according to a particular factor. All factors show high positive attitudes for students who have learned using GeoGebra, unlike Group B who are averagely satisfied.

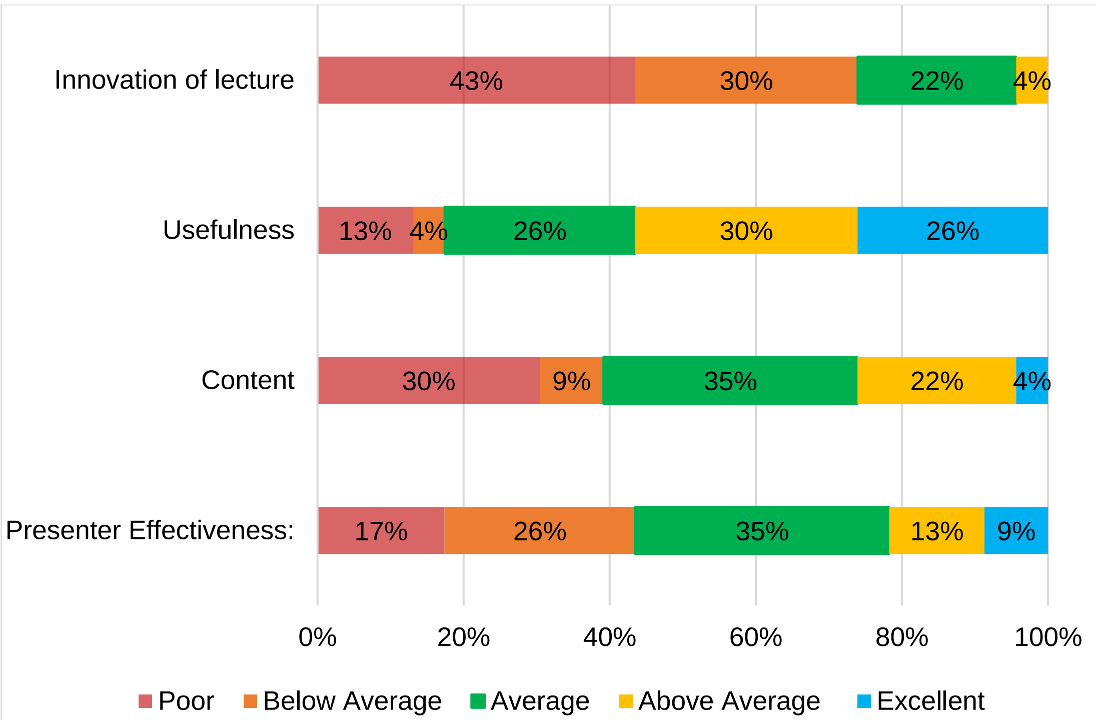

Figure 4. Percentage of group A students regarding the attitude factors (Source: Author).

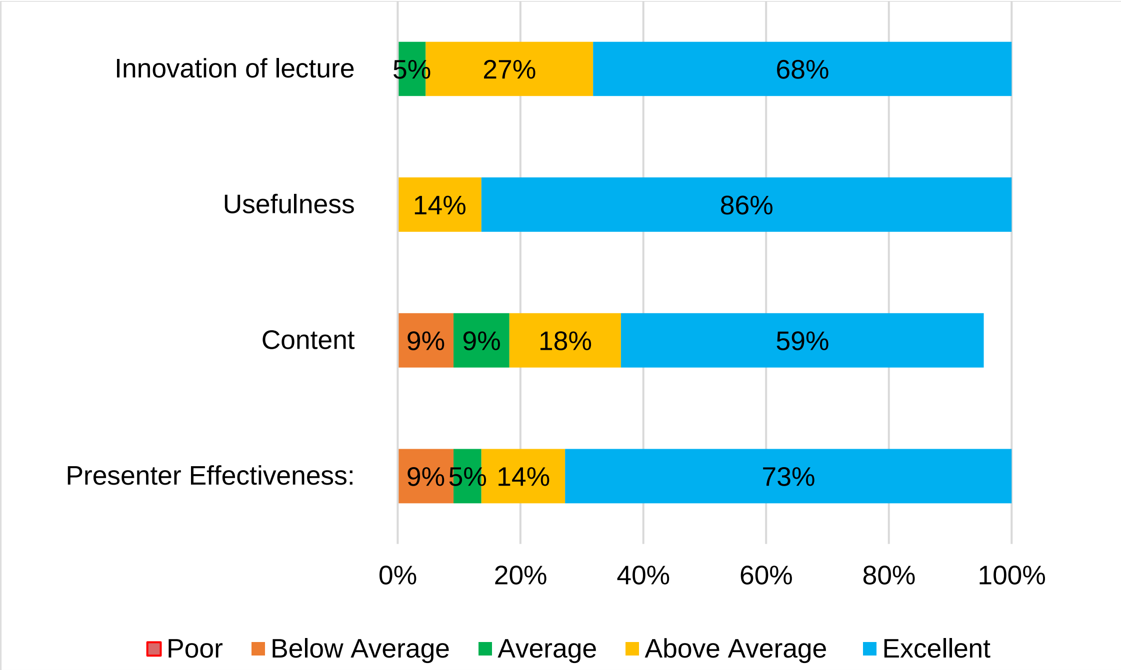

Figure 5. Percentage of group B students regarding the attitude factors (Source: Author).

To support the hypothesis that there are significant differences in attitude factors between these two groups of students, an independent samples t-Test was conducted. Results presented in Table 3 supported the null-hypothesis that difference in attitudes between students who received traditional teaching (group A) and students receiving teaching by using GeoGebra (group B) is significant ($t(150) = -11.956724$; $P = 7.258E-24 < 0.01$), in favour of group B.

	Group A	Group B
Mean	2.67	4.58
SD	1.30	0.78
Median	3.00	5.00
Variance	1.69	0.61
Observations	92	88
Hypothesized Mean Difference	0	
df	150	
t	-11.956724	

Table 3. t-Test Summary

CONCLUSIONS

The aim of this research was to investigate the effect of using GeoGebra visualization and simulations in teaching mathematics and their effects on student's achievements. The survey was conducted with a homogenous group of 45 international students (participants MareMathics Summer School) who were divided into two subgroups A and B. Traditional teaching was offered to group A while group B were learning using GeoGebra simulations.

Gained results support the hypothesis that there is a significant difference in students' achievements whether simulations are incorporated into traditional teaching or not. Students expressed positive attitudes towards offered simulations and positive attitudes toward similar GeoGebra applications in other mathematical concepts and courses. Also, findings suggest that using technologies, particularly GeoGebra applets can be an excellent way to raise students' motivation and awareness about the importance of mathematical knowledge for their study and for their profession, better understand mathematical concepts and encourage them to research. On the other hand, the simulation software allows teachers to make their own didactic design and do more effectively.

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Investigating Actual Use of SMCPs inVHF Communications: Assessment and Implications for MET

Matthew Rooks

Clear, comprehensible VHF communications are a vital part of ensuring safe navigation for vessels. The use of Standard Marine Communication Phrases (SMCPs), including Message Markers (MM) during radio communications are some of the methods IMO implemented in 2001 to ensure communications are conducted in a unified language that reduces the risk of miscommunications and subsequent dangerous situations. Through the implementation of surveys, this research investigates the actual use of such SMPCs by port radio operators in Japan as well as various techniques used by these professionals to deal with miscommunication and/or difficulties with VHF communications. Results indicate disparate usage of SMCPs and MMs in both seafarers and port operators, and some clear indicators of methods used to overcome instances of miscommunication. Both problematic areas connected to the utilization of SMCPs in VHF communication as well as effective techniques for dealing with miscommunication identified through this investigation offer insight into how to improve future MET to ensure increased compliance with SMCP usage rates in VHF communications between port radio operators and seafarers.

KEY WORDS

Maritime English, VHF Communication, SMCP, MET, VTS.

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INTRODUCTION

Clear, comprehensible VHF communications are a vital part of ensuring safe navigation for vessels. It is typical for parties involved in radio communications at sea to come from very different linguistic and cultural backgrounds, roles in the maritime industry, and possess varying levels of English proficiency (Dževerdanović-Pejović, 2013; Demydenko, 2010; Pritchard & Kalogjera, 2000). The use of Standard Marine Communication Phrases (SMCPs), including Message Markers (MMs) during radio communications are some of the methods IMO implemented in 2001 to ensure communications are conducted in a unified language that reduces the risk of miscommunications and subsequent dangerous situations (Bocanegra-Valle, 2012; John, Brooks, Shchriever, 2017; Johnson, 1999; Frolova, 2020; Trenker, 2000). Through the implementation of surveys, this research investigates the actual use of such SMPCs by port radio operators in Japan, as well as various techniques used by them to deal with miscommunication and/or difficulties with VHF communications. Results indicate disparate usage of SMCPs and MMs by both port operators and the seafarers they communicate with, but also similarities in methods used to overcome instances of miscommunication. Both problematic areas connected to the utilization of SMCPs in VHF communication as well as effective techniques for dealing with miscommunication identified through this investigation offer insight into how to improve future MET to ensure increased compliance with SMCP usage rates in future seafarers.

Study Objectives

One of the main objectives of this study was to gain insight into how SMCPs were being implemented by port operators in Japan for VHF communications, with a particular focus on message markers. Measures concerning the practical use of VHF communication, namely during communication difficulties and miscommunication, were also investigated. The main targets for this study were port radio operators (PROs). The scope and usage of the 4 main MM choices used by PROs (question, information, warning, advice) were researched. This survey aimed to gauge how effectively/frequently these key SMCPs were used, as well as problems/difficulties that accompanied their use, in order to identify problems and suggest improvements for VHF communication points that can possibly be implemented in future Maritime Education and Training (MET).

Message Markers

Message markers were designed to increase the probability of the purpose of the message being properly understood, and to reduce the chances of miscommunication (IMO, 2001). There are eight standard MMs:

Instruction:

A command that is required to be followed according to regulations or laws. Typically, only Coast Guard or military vessels can use this MM. Example: “Instruction: do not cross the fairway.”

Advice:

Used for suggesting an action to assist vessels to safely navigate or respond to various situations. Example: “Advice: take avoiding action.”

Warning:

Used to indicate dangerous situations. “Warning: collision imminent.”

Information:

Used for messages restricted to observed facts, situations, etc. "Information: one inbound vessel ahead of you."

Question:

Used at the beginning of messages that will use an interrogative. "Question: What is your ETA?"

Answer:

This MM is used to respond to Questions. "Answer: My ETA is 1430."

Request:

This MM indicates that the subsequent message will ask for action from others with respect to the vessel. "Request: I will pass astern of you, maintain your speed and course."

Intention

MM used to inform of a ship's subsequent actions/maneuvers other vessels. "Intention: I will return to anchorage to commence engine repairs."

Typically, Japanese Radio operators only use the following 4 MMs: Information, Advice, Question, and Warning. The questionnaire used in this survey focused on these MMs and how they were used by by PROs in their Vessel Traffic Service (VTS) operations.

METHODOLOGY

The surveys administered for this study were carried out in July 2021. These surveys were administered in paper form in Japanese, and the contents of the translated survey questions are found in section 2.1 below. The questionnaire was administered to 18 port radio operators with various job experience who work at the Toyo Shingo Tsushinsya Corporation (TST corporation) in the Kobe area. TST corporation carries out radio operators in all of the major ports in Japan, and port radio messaging covers harbor limit communications in these ports as part of VTS operations. Questions were separated mainly into the following categories: difficulties with VHF communications, failures in communication or miscommunication, countermeasures against miscommunication, consideration points when sending messages, and various communication techniques used when radioing in ship to shore situations. MMs were a focal point of the surveys, with emphasis placed on frequency and ease of use.

Survey Questions

- How long have you worked long work as a port radio operator?
- What message marker(s) do you most frequently use?
- Why do you use the MMs from Question 2 most frequently?
- What message marker(s) is/are difficult for you to use?
- Why does your answer for Question 4 cause difficulty?
- Which situation(s) cause communication difficulties? Why?
- When experiencing miscommunication, do you take special measures with your communications in regards to accent, speaking speed, phrasing, others?
- When you find it difficult to comprehend a message from a ship, what measures do you take?
- Do ships employ the usage of SMCPs and MMs in their ship to shore VHF communications? If not, what sort of language/phrasing do they use?

RESULTS AND DISCUSSION

The 18 PROs who participated in the survey had varying levels of work experience:

Figure 1. PRO job experience

Job experience may have an effect on MM usage, and measures implemented when experiencing communication difficulties, so this data could provide some insight into how PRO responses change as job experience accumulates.

Next, PROs were also asked to rank the 4 main MMs used in port radio VTS operations in order of frequency of use (see Fig. 2):

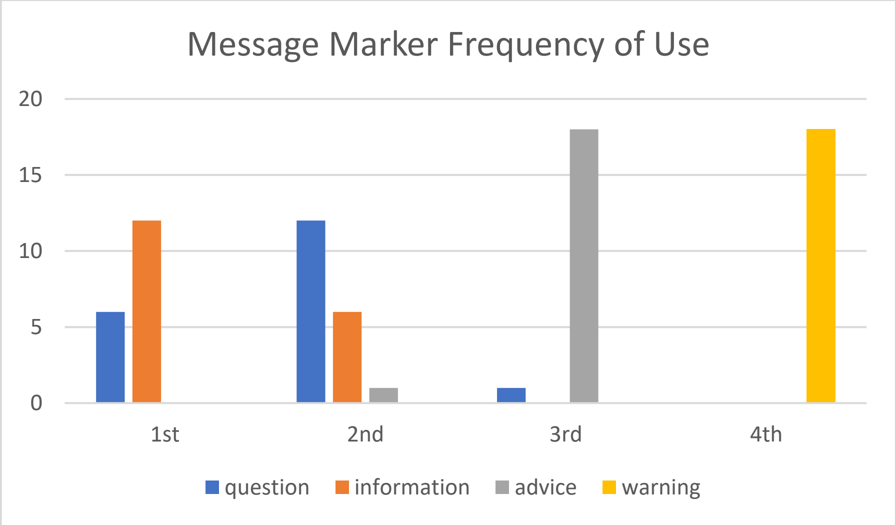

Figure 2. Message Marker Frequency of Use

Unsurprisingly, information, and question were the most commonly occurring MMs, with warning being the least frequent. As dangerous or emergency situations rarely happen, the frequency for this MM was the lowest according to the PRO respondents, while the other three were reported to be commonly used in daily communications. Advice is only given when necessary, while information and common questions were used in the highest volume of VHF communications, according to the PRO respondents.

PROs were next asked about which MMs were the most difficult to use. They ranked each of the 4 MMs from 1~4, with 1 being the most difficult, and 4 being the least difficult to use:

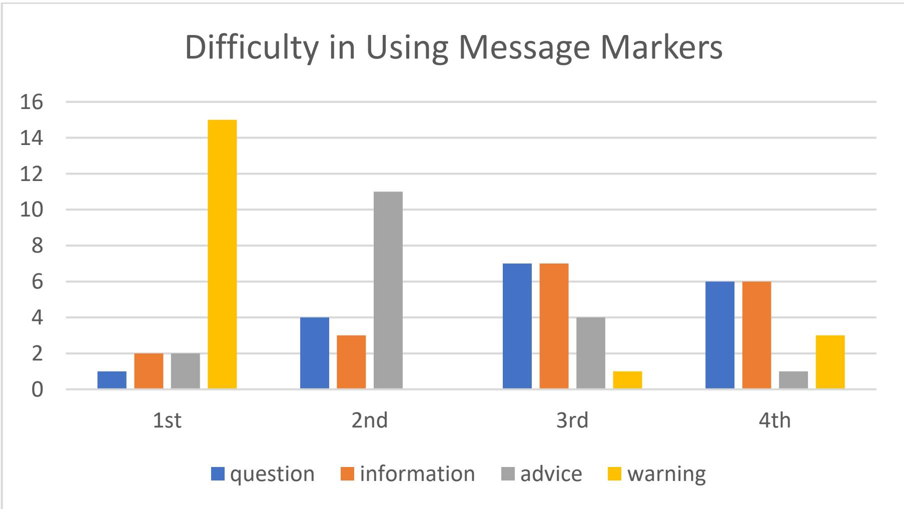

Figure 3. Difficulty in Using Message Markers

The overwhelming response of all 19 PROs was that the warning MM was the most difficult to use, with the reasoning being that all operators had used this in actual communications the least amount of times. PROs are highly trained, and undergo frequent simulation training for how to respond to various emergency situations, but the fact remains that real-life emergencies rarely happen, and thus their actual experience with using them in real situations is similarly rare. This is why they perceive this MM as the most difficult to use. Advice came in 2nd in the ranking for difficulty of use, and Port Radio Operator responses indicate that due to the wide variety of situations that require the usage of this MM, selecting the proper advice to give to vessels can often prove difficult. Situations that range from taking avoiding action in near miss situations, changing course to avoid shallow areas/grounding, and responding to other problems like engine trouble require PROs to be at the ready with a wide array of advice depending on the specific situation.

Next, PROs were asked about the various causes of communication difficulties. See Fig. 4 below for a detailed breakdown of the various causes:

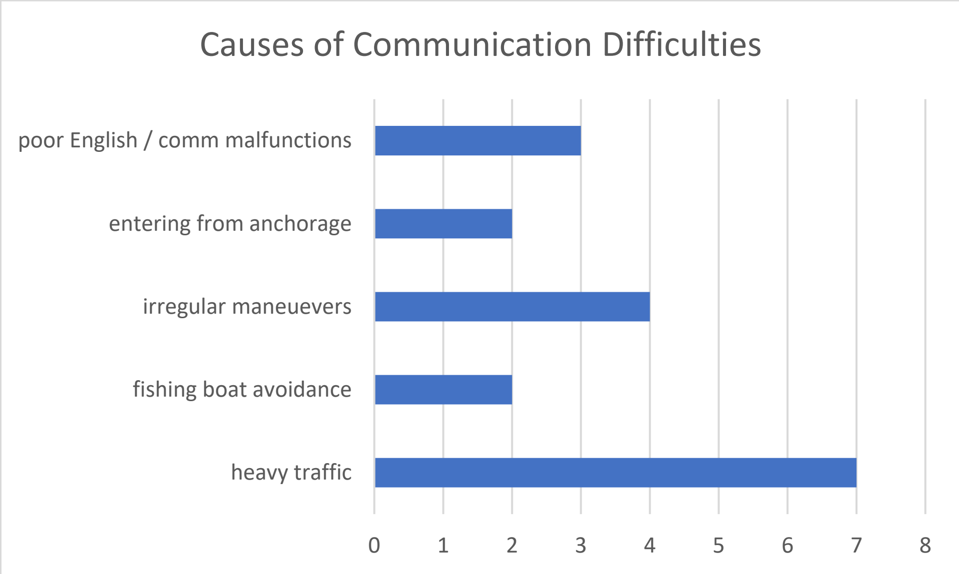

Figure 4. Causes of Communication Difficulties

Heavy traffic situations were the most common cause of communication difficulties, followed by irregular maneuvers and instances of poor English ability of crew members and/or communication equipment malfunctions (such as cut off transmissions, radio interference, etc.). Heavy traffic situations were reported to cause PROs difficulties, as morning and evening rush hours can see high levels of congestion that sometimes lead to vessels ignoring port regulations, set entry/departure orders, or close quarter situations when vessels fail to keep safe distances from each other.

PROs were also asked about specific measures taken when experiencing miscommunication, or other communication difficulties. See Fig. 5 below:

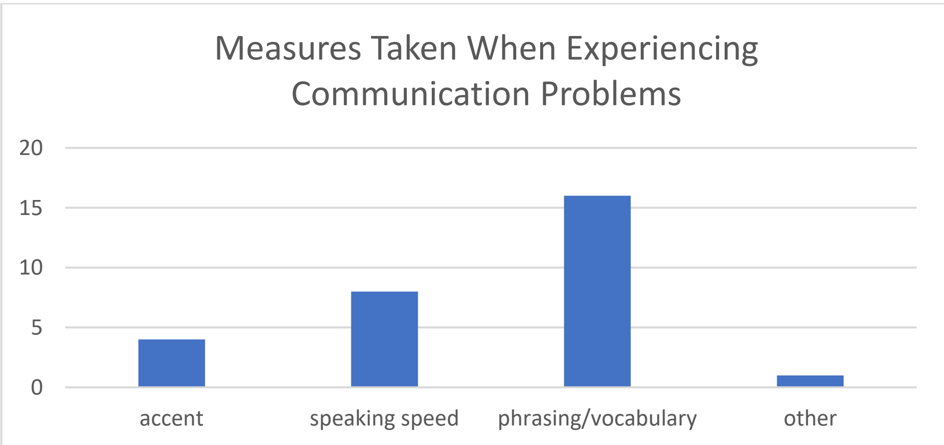

Figure 5. Measures Taken When Experiencing Communication Problems

PROs reported that they would first resort to changing the phrasing/vocabulary used when experiencing communication problems, and this cleared up most problems. The most common type of rephrasing was using simpler English if the first few messages were not understood (eg: "Advice: Keep clear of the fairway entrance" instead of "Advice: Do not hinder vessels approaching the fairway.") If that didn't work, speaking slower, or placing emphasis on key words to help facilitate communication was chosen.

PROs were also asked to report on actions they took after receiving an incomprehensible transmission from a vessel. See Fig. 6 below:

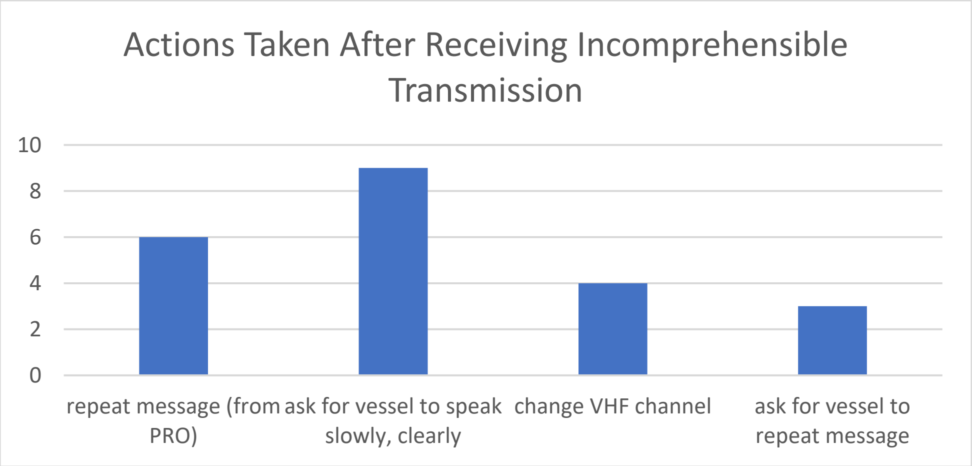

Figure 6. Responding to an Incomprehensible Transmission

Nine respondents answered that they would first ask the vessel to speak more slowly and/or more clearly, and usually this would clear up the garbled transmission. Six PROs reported that they would simply repeat their own message in hopes of getting a clearer response, while four respondents reported resorting to changing the VHF channel in hopes of getting a clearer signal. Three of the PRO respondents reported specifically asking the vessel to repeat the message (without asking for a slower or more clear transmission).

Finally, PROs were asked to estimate what percentage of vessels actually used proper SMCPs and MMs when communicating in ship to shore VHF communications. See Fig. 5 below:

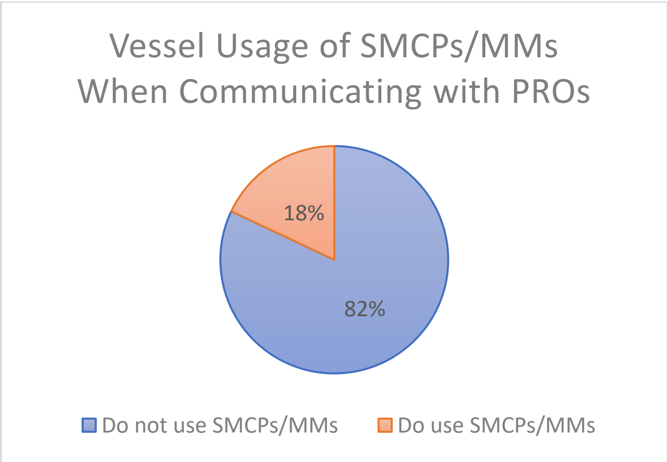

Figure 7. Vessel Usage of SMCPs/MMs When in Ship to Shore VHF Communications

The Port Radio Operators surveyed in this study estimated that 82% of vessels did *not* utilize SMCPS and/or MMs during ship to shore VHF communications. This indicates that even when faced with frequent use of MMs from the port radio side, vessels did not respond with the proper standard marine communication phrases as outlined by IMO.

CONCLUSIONS

From the data gleaned from the port radio operator surveys, results indicate that a variety of deficiencies exist in terms of the proper use of SMCPs and MMs in ship to shore VHF communications, at least in Japanese port of Kobe. While TST PROs undergo constant simulation training and in-house examining to ensure the highest levels of clear communication, seafarers themselves appear to largely ignore the usage of set SMCPs in their VHF communications. This would indicate that a stronger emphasis needs to be placed on MET institutions and shipping companies themselves to improve the adoption of the standardized phrasing that is outlined by IMO. Further research in this area must be carried out in various regions throughout the globe to see if this is a local problem, or more endemic in the maritime industry at large.

ACKNOWLEDGEMENTS

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Prejudice Against Seafarers' Wives

Andrea Russo[1], Slavka Kraljević[1], Roko Glavinović[1], Katarina Matić[1], Rosanda Mulić[1,2], Srđan Gjurković[3]

Prejudices are unfounded judgments and ideas about someone or something, and the connotations lean more toward the negative. The maritime industry represents a set of activities, skills, and social relations at sea or related to the sea. Thus, it is clear that there are several aspects of employment in the maritime industry: at sea and on land. This paper investigates and shows the potential existence of prejudices against the wives (partners) of seafarers who are aboard in the academic community intending to see if any exist and what are the differences in opinions between teaching and non-teaching academic staff. Since very little research has generally been conducted on the partners of seafarers as a demographic group, this paper tries to encourage further research on this topic. For that, a survey was conducted on 124 employees of the University of Split, of which 30 were teaching staff and 94 were non-teaching staff, and the results showed that 36.67% of the teaching staff believe that there are still prejudices against seafarers' wives, and of that number, 27.27% think or were undecided that the happiest women are those married to seafarers, and 18.18% believe or have remained undecided how there is no unity in the seafarer's family. On the other hand, of the 46.07% of non-teaching staff who believe that there are prejudices against seafarers' wives, 34.15% believe or are undecided that the happiest women are those married to a seafarer, and 12.20% believe that there is no unity in a seafarer's family with a large number of those who could not decide (43.90%). The results of the research showed that there are still significant prejudices against seafarers' wives. Separation from her husband and constant change of routine along with the existence of prejudice about the ease of life of a seafarer's wife further complicates the daily life of a seafarer's wife and can contribute to additional unrealistic expectations and evaluations in the relationship between the seafarer-husband and the seafarer's wife.

KEY WORDS

Prejudice, Seafarers, Seafarer's wives, Maritime industry.

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INTRODUCTION

Given the complexity of the seafaring industry, it is important to recognize that being involved in seafaring is regarded as a profession both at sea and on land distinguished by distinct mental, emotional, and physical pressures that cannot be matched to other land-based vocations (Juranko, 2017). To understand the problem of prejudice against the partners (in this case, wives) of seafarers, it is necessary to first differentiate between stereotypes and prejudice. Stereotypes are a collection of ideas about an individual's or a group's usual features and ways of behaving that may problematize nearly anything: age, gender, ethnicity, religion, country, occupation, sexual orientation, appearance, class affiliation, and so on. They range from culture to culture and are widely held beliefs about a certain group that is frequently attributed to all of its members (Bedlek, 2020). Prejudices are unjustified judgments and notions about someone or something, with negative implications usually based on preconceived beliefs, clichés, and unwarranted judgments that might cause a negative attitude toward a person, group, institution, or an entire social environment. Prejudice is also an erroneous and rigid generalization (ENSEMBLE, 2023).

Secondly, to fully grasp the researched problem of prejudice against the seafarer's wives, it is vital to note the seafarer's absence due to work is a requirement for economic survival (in many cases, it is the only source of income). Once seafarers board a vessel, they begin to live in a closed community with particular behavioural standards and social values that may differ from those found in the outside world. Seafarers' wives suffer extended periods of intermittent separation from their spouses or the partner with whom they are in a relationship due to the nature of the partner's employment. They frequently endure emotions of loneliness and isolation during separation. They may also tend to believe that they just live a different lifestyle than other women whose partners work in a different industry (no separation of longer duration) as a result of the intermittent and long-term separation (Juranko, 2017).

ABSENT SEAFARER – THE DICHOTOMY OF SEAFARING LIFE

International seafaring is distinguished by sailors' absence from home for extended periods ranging from months to years. Such a way of life can be difficult for both the seafarer and his family. In theory, shorter work rotations (4-6 weeks on/off) should have a lower impact on the stress of both partners (Ulven, et al., 2007). Morrice and Taylor are the first to incorporate the term "intermittent husband" in 1978. Home and away occupations are distinguished by a separation and reunion cycle that provides a repeating crisis and a consistent pattern of emotions which comprises emotions of despair, sadness, anger, and recrimination against a spouse during the cycle and upon his return, followed by feelings of depression, grief, anger, and recrimination towards a husband during the cycle and upon his return (Hubinger, et al., 2002).

The majority of women believe how long periods of separation can induce significant problems, such as loneliness during the partner's absence or emotional distance, obstructing the interpersonal relationship when the partner returns home and having positive and meaningful interpersonal relationships are considered a basic human necessity (Juranko, 2017). Hagmark, 2003, incorporates the previously mentioned in a study published in 2003, describing the dichotomy of the life of the seafarer's wife. The study shows how, while the seafarer is absent, all the responsibilities (for example, housework) are entirely on the wife, where she has learned a certain way of life during his absence and has to fully re-adapt to his presence once he returns claiming to have two different lives. Even though most of the participants in the study appeared to deal well with seafaring life despite occasional tensions and a never-ending succession of departures and returns, they seemed to be content with their lives and to adapt well to shifting between their two worlds, some women in the study were frustrated and exhausted with seafaring life and the never-ending changeover from single to marital life. The frequent adjustment between their partner's presence and absence made those women weary and confused about which lifestyle is reality (Hagmark, 2003).

Furthermore, it should be noted that this way of living may also have good effects on a romantic relationship. Many seafarers and their partners express their deep delight and happiness when the seafarer comes home. They claim that it is precisely these brief absences that keep the relationship from stagnating and encourage the pair to respect one other and the time they spend together more. Some women stress the benefits of their spouse's absence, such as the increased possibilities and freedom they enjoy while their partner is around. Women utilize this time to pursue their interests, hobbies, and friendships, and to see alone time positively (Juranko, 2017). Separation, loneliness, money, and promiscuous partners are all elements that may pique people's interest and inquiry when prejudice against a seafarer's wife is discussed. Others may not inquire about or debate her habits in front of her. They can, however, do so in an indirect manner. Some covet the wife's wealth, while others sympathize and feel sorry for her plight, and others question her reason for pursuing relationships with a seafarer (Tang, 2007).

Life of a seafarer’s wife during his absence

During the search and review of available literature, there was limited research found on prejudices against seafarers’ wives in the sense of beliefs, attitudes, and opinions of others; however, the most relevant research found was of interviewed seafarers' wives and how they contend with absence. The studies included spouses from Norway (Hagmark, 2003; Ulven, et al., 2007), the Philippines (Galam, 2012), China (Tang, 2007) and Greece (Katsounis, et al., 2020).

The majority of a wife's issues and disputes during her husband's absence revolve around house upkeep - physically, emotionally, and socially (Rosenfeld, et al., 1973). Because of their spouses' lengthy absences, the women must deal with and live with their yearning for them (Galam, 2012) The seamen's wives work hard to maintain a sense of home for themselves and their children, understanding that in the absence of their husbands and fathers, this is primarily dependent on their efforts (Rosenfeld, et al., 1973). Aside from household duties, the seafarer's wife also has societal obligations and must cope with the societal ramifications and consequences of her husband's absence (Katsounis, et al., 2020). When researching the positive and negative aspects of having a partner who is an absent seafarer by surveying seafarers’ wives or girlfriends, Slišković and Juranko, 2018, describe the commentaries the participants gave – loneliness, emptiness, constant fear if the partner will return safe and sound, handling all problems while the surroundings believe the hard-earned money solves everything usually mentioning easiness because she has a seafaring partner. The majority have stated that the only positive is financial safety (Slišković & Juranko, 2018).

According to Yur and Nas, 2012, communication with the seafarers is the most difficult issue for the spouses of seafarers. Because seafarers are sometimes unable to contact or notify their spouses while moving through risky areas given the rise in piracy, seafarer spouses have expressed concern for their husbands (Yur & Nas, 2012). The loneliness that most seafarers’ wives experience causes a quandary in terms of social connections. Because associations with other seafarers’ spouses, while providing some respite, also serve to remind them of the abnormal circumstances in their lives, many of them prefer to avoid them. Relationships with intact families, on the other hand, may make them painfully conscious of their unique way of life. As a result, many seafarers’ wives drastically restrict all social contact (Rosenfeld, et al., 1973). Communication can be extremely upsetting for some partners: rather than alleviating loneliness, it can sometimes make couples miss each other even more. Sailing with husbands appears to be the best method for seafarers' wives to escape emotional loneliness. However, not all spouses are afforded this luxury. Furthermore, most women have jobs or professions, or they must stay at home to care for their children (Tang, 2007).

Considering Croatian nature towards seafarer's wives, all possible aspects of the seafarer's wife (unemployed, employed, has children, doesn't have children and so on) are highly judged (Kovač, 2017). If she is unemployed, then she is usually considered to only spend her husband's hard-earned money, is free from obligations and can do whatever she likes (considering the couple is still childless). In case the wife is unemployed but has a child/children, she is most likely judged the same way the previous is, disregarding her caring for her child/children. Most of the time, it is widely considered she does nothing at all and has no concerns. In case she is employed, most judgement she receives comes from the idea of why she is working, she has a seafarer husband who earns enough for both (considering the couple is childless). In case the couple has a child/children, and the wife is working (irrelevant of full-time or part-time employment), most of the judging comes as her inability to care for her child/children properly simply for her being employed. Her employment is only medium valued if the child/children are of age where constant care is no longer needed or necessary (Kovač, 2017).

Coping with the absent seafarer

Seeing as partners may be their attachment figures, it is plausible to presume that when their partners are missing, wives will experience the loneliness of emotional isolation. When their partners are absent, women stay at home and participate in their regular social networks (Tang, 2007). Some research indicates that intermittent spouse absence has a detrimental effect on wives' social activities rather than personal characteristics or personalities. Intermittent partners (seafarer and seafaring spouse) demonstrated that lone partners used three types of coping strategies in their daily lives: reflection and acceptance, which emphasizes solitary thought and acceptance of loneliness, self-development and understanding, which emphasizes belief in and knowledge of oneself, and religion and faith. The second coping strategies category may be susceptible to harmful behaviours such as the use of illicit substances. The third coping strategies category is made of increased activity and social support networks (such as increased social involvement and interactions with others or devoting oneself to work or other activities) (Tang, 2007).

Adaptation to life after seafarer's arrival

The only challenging aspect of this type of life is the time of separation, and the couple's reunion is viewed as a happy occasion. However, for the pair, the transfer time (home-aboard, aboard-home) can be stressful, inconvenient, tense, and burdensome. A certain period of adaptation to life on land is needed after the seafarer's arrival, typically a week, and during this time they prefer to remain at home rather than go out into large crowds and engage in different gatherings. This can be exhausting for seafarers' spouses given that they have to allow for the adaptation period to pass, which often makes them anxious due to having been waiting a long time for their partners to come back home and wanting to spend as much time as possible with them. On the other hand, despite their desires, they demonstrate empathy because they recognize that their partners require serenity and leisure after difficult and exhausting work (Juranko, 2017). In their study, Yur and Nas concluded that all interviewed seafarer wives stated wanting their husbands to leave the industry after a certain period but have left this choice completely up to them. The reason for this has been stated to be that the seafarers would be uncomfortable receiving commands on land after the management roles they served in while at sea duty, and the spouses of seafarers have also stated that they do not want to take on such a burden (Yur & Nas, 2012).

During the periods when the partners are at home, their adaptation can follow a routine. Usually, there is an initial period of elation at the reconnection, followed by irritability, which gives way to a "normal phase" of transition around the middle of the partner's days off, followed later by a period of stress built up in the days before the partner departs again. The irritation that appears in the first few days after the partner's return reflects both partners' potential difficulties in managing the various transitions; the seafarer must mentally switch from the ship's environment to the home environment, while the partner must adjust to the fact that the partner is no longer away. When the partners return home, they need time to relax and adjust to their new surroundings, which takes away valuable time the couple could spend together. As soon as they adapt and regain awareness of their environment, they begin to consider returning aboard ship, and the tension and anxiety between the couple resurface (Juranko, 2017).

RESEARCH AND RESULTS

Seafarers' wives must deal with the societal repercussions of their partner's absenteeism in addition to dealing with increased time demands (e.g., partner's and/or shared duties taken on when the partner is on board). To ensure the survival of a seafarer's relationship with his wife, she must be not only independent and capable of managing household and family responsibilities but also have the necessary strength to cope with the emotional and other demands brought on by the partner's absence. On the contrary, the partner's freedom, ability, and flexibility in handling all aspects of life and responsibilities can make the partner feel superfluous in almost all areas, except the one in which he manages the financial structure. Furthermore, many of them, to cope with loneliness, tend to isolate themselves seeking understanding and sympathy from others often finding dismissals to their problems mainly because the general idea is that financial safety solves all issues one may have. As it has been analysed, explored, researched, and reviewed by many authors, these prejudices (usually: "It is easy for you, your husband is a seafarer") others have of seafarers' wives believing her life is easy-going, tranquil, free of worries while it is exactly opposite. By reviewing the literature, however, none have researched the views and opinions of others in society, in general, asking about having or observing prejudices in others towards wives, which is what this paper and research want to advance. The main hypothesis proposes that participants higher in age are more susceptible to prejudice than those who are younger.

Data collection and research methods

Observing a lack of research on the attitudes, beliefs and opinions of others about the existence of prejudices against seafarers' wives while considering the struggles they face daily as well as the lack of understanding and sympathy from others, which have been briefly explored in the preceding paragraphs, the purpose of the research was to showcase the perceptions and beliefs towards the presence of prejudices against seafarers' wives to see if there were any prejudices against the wives (partners) of seafarers which are often onboard/offshore among the academic community, and if so, what the variations in views were between teaching and non-teaching academic employees considering such to be implementers of change in society. To present research results, a study-specific questionnaire was developed and conducted *in-vivo*, targeting female teaching and non-teaching staff of the University of Split as participants. The questionnaire consisted of a sociodemographic set of questions (age, education level) and questions targeting opinions and beliefs of prejudices of seafarers' wives. The latter consisted of five questions, all of which have been answered using a Likert scale from 1 – 5 (1 – I fully disagree; 2 – I disagree; 3 – Neutral; 4 – I agree; 5 – I fully agree). None of the questions were mandatory to be answered therefore some questions have a No answer section. The results are explained through a comparison of two participating groups where teaching staff is abbreviated as TS and non-teaching staff as NTS. The main idea was to notice if there are any differences in opinions between two groups divided into their ages and education levels. The number of total participants was 124, of which 30 are teaching staff and 94 are non-teaching staff. Descriptive statistics were computed for participants' sociodemographic characteristics. Exploratory factor analysis was used to examine structure of items measuring prejudices. The results of EFA suggested that one item was not satisfactory saturated. Therefore, it was decided to compute a composite result formed from remaining four items. However, the composite measure of prejudices was not reliable (Cronbach Alpha=0.56). Taking this into account, examined are the differences between TS and NTS in prejudices for each separate question using t-test for independent samples. The data in Tables 1. and 2. were calculated using Jamovi statistical software (jamovi, 2022), and the rest was done manually.

Results

Most participants were between 40-49 years of age, the least being over 60 (shown in Table 1.). Education level was divided into non-qualified, high school graduate, undergraduate level (Bachelor's degree or similar) and graduate/PhD level and showed most of TS (63,33%) having a graduate/PhD level, whereas NTS is predominately undergraduate level (56,99%). Table 1. describes age data between TS and NTS where 4 participants of NTS have not answered the question about age. The table shows the mean ages between the groups, median, maximum and minimum age of participants as well as standard deviation, and displays similarities of the research participants.

	N	Missing	M	Median	SD	Minimum	Maximum
Teaching staff	90	4	39.9	40	9.02	21	66
Non-teaching staff	30	0	42.4	41	10.8	29	65

Table 1. Age data between TS and NTS subsamples (Source: authors)

Figure 1. shows how TS and NTS view the existence of prejudices among wives of seafarers. 63,33% of TS and 53,93% of NTS disagree or are unsure of any prejudices seafarers' wives face which gives a slightly below half of both groups which perceive the existence of prejudices against seafarers' wives (36,67% of TS and 46,07% of NTS).

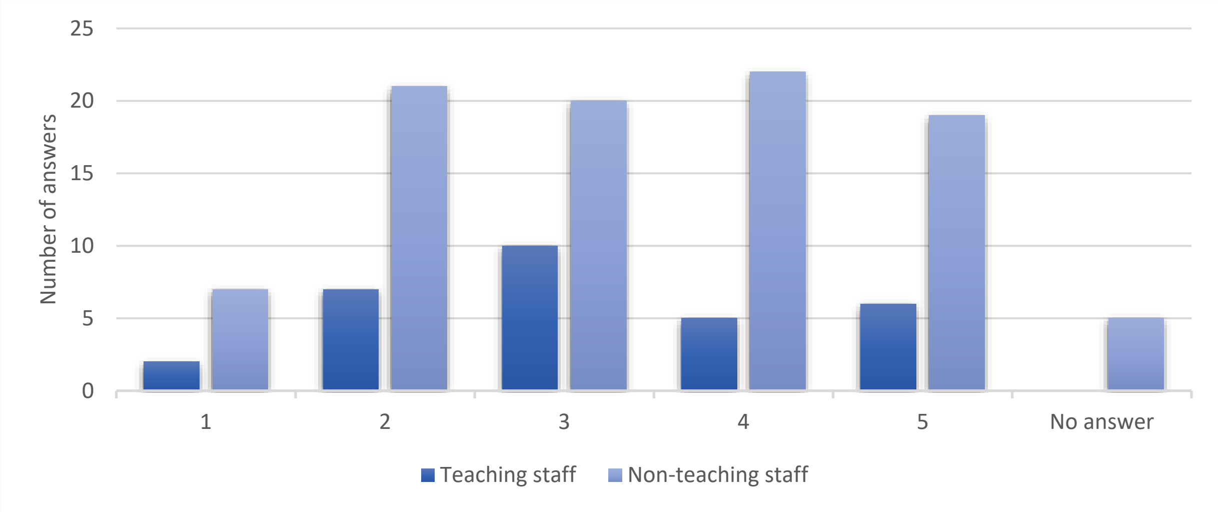

Figure 1. Responses of the participants on the question *"There are prejudices against seafarers' wives"* (Source: authors)

The rest of the results were calculated shown using the number of participants of both groups who agree on the prejudices against seafarers' wives still being actual through the rest of the questions in search of differences in opinions. Out of 36,67% of TS which agree there are prejudices against seafarers' wives, 45,45% agree money is more important than education, 72,73% disagree that the happiest are those women married to a seafarer, 81,82% believe that there is enough union in the family where the husband is a seafarer, and 72,73% oppose how the wife handles all life's issues in a family where the husband is a seafarer.

46,07% of NTS who stated seafarers' wives encounter prejudices, 56,10% believe money is more important than education, 64,84% oppose that the happiest are those women married to a seafarer, 13,90% think that there is enough union in the family where the husband is a seafarer, and 34,14% disagree how the wife handles all life's issues in a family where the husband is a seafarer.

The above data shows significant similarities in the opinions of the two participating groups in all questions except "*The happiest are those women married to a seafarer*" and "*There is not enough union in the family where the husband is a seafarer*" where they were differently agreeing or disagreeing with the questions.

Table 2. describes t-testing of 4 particles used to investigate variations in prejudice measures between teaching and non-teaching staff (TS is marked as 1, and NTS as 0).

ITEMS	Group	N	M	SD	t	df	p
MONEY IS MORE IMPORTANT THAN EDUCATION	0	92	2.72	1.31	1.46	120	0.146
	1	30	2.33	1.028			
THE HAPPIEST ARE THOSE WOMEN MARRIED TO A SEAFARER	0	90	2.10	1.35	1.75	118	0.083
	1	30	1.63	0.964			
THERE IS NOT ENOUGH UNION IN THE FAMILY WHERE THE HUSBAND IS A SEAFARER	0	90	2.49	1.11	3.36	118	0.001
	1	30	1.73	0.907			
THE WIFE HANDLES ALL LIFE'S ISSUES IN A FAMILY WHERE THE HUSBAND IS A SEAFARER	0	90	2.93	1.23	1.20	118	0.231
	1	30	2.63	1.033			

Table 2. T-Test for examining differences between teaching and non-teaching staff in items measuring prejudice (N=124) (Source: authors)

When viewing answers to these questions through age, most participants agreeing to the prejudices against seafarers' wives still being actual were 45,45% of TS aged between 40-49, whereas 39,02% of NTS were aged between 30-39. 66,67% of TS participants aged between 40-49 think money is more important than education, as opposed to 60,87% of NTS participants aged between 20-29 and 30-39 (30,43% respectively for both age ranges). 100% of TS participants aged between 30-39 and 40-49 consider the happiest woman married to a seafarer. The same range follows the NTS participants, however, the total is 55,55% (27,78% respectively for each age range). Only one TS participant aged between 40-49 believes there is not enough union in the family of an absent seafarer, whereas 38,46% of NTS participants were between 30-39 years of age. 50,00% of TS participants agree the wife handles all life's issues which is the same range for 70,59% of NTS participants.

Discussion

This research's main idea was to present if there still are prejudices against seafarers' wives, knowing how difficult her life is capable of being through determining what women in the academic circle assumed about seafarers' wives. Thus, we created a questionnaire and distributed it throughout the University of Split. We received 124 responses from teaching and non-teaching staff and wanted to compare the opinions to see if there are any differences regarding age and/or education level.

Observing the ages of two participating groups, in TS most of the agreements on the existence of prejudices were present in participants aged between 40-49, as opposed to slightly younger participants in the NTS group, mostly aged between 30-39. Seeing that the age range is not that distant, not much difference can be presented, and observing Table 1., data on education level have significant differences between the two groups. None of the NTS (aged between 30-39) have a Graduate level degree and/or PhD, which 5 of the TS participants of the same ages have, and in the age range of 40-49, TS participants have a low count of Undergraduate education level opposed to higher NTS participants in both observed age ranges. The answers the participants submitted could then be significant in determining if higher education lowers the possibility of having and/or perceiving prejudices against seafarers' wives. Although the majority of participants were between the ages of 30-49, younger or older participants of this age range expressed fewer unfavourable views on the lifestyles of seafarers. This research showed prejudices towards seafarers' wives are present, however, younger participants of the research showed more understanding of the problems the wives encounter and the uneasiness of their life situation. Further research might give more insight into the researched topic to describe if the general opinions have been shifted more positively. The hypothesis was, therefore, just marginally supported meaning, if the sample of respondents had been larger and demographically more diverse, it might be possible that the hypothesis would have been realized differently.

It is not possible to compare the research presented in this paper that talks about the prejudices of others concerning seafarers’ wives, given that no such was found, however, the research found that touches the mental health of seafarers' spouses and/or their daily life during the seafarer's absence suggest how in certain different instances, the spouses of seafarers received less social assistance than the control groups, however, the majority of them were pleased with their families' way of life (Ulven, et al., 2007), including the findings displaying that personal resources (resilience, stress coping strategy, relationship satisfaction, and perceived social support) played a vital role in explaining the mental health of seafarers’ partners, but did not corroborate a link between separation time and mental health (Slišković & Juranko, 2018.).

The results obtained are based on a convenience sample of academic staff (teaching and non-teaching) who voluntarily participated in this study, including the fact that the sample has limitations in terms of demographic characteristics (all females). Despite the research’s limitations, the findings represent a significant theoretical addition since they are based on an unresearched topic on the prejudices conveyed by others about the spouses of seafarers. Given the paucity of research on the wives of seafarers as a demographic group, this paper, in a way pioneering research, aims to encourage more studies in this area by collecting data from the wives themselves and how they cope with absence, as well as collecting more information on society's attitudes and opinions on the wives and their position in society through existing prejudices, all with the aim of removing prejudices by demonstrating how seafarer's wives cope, how they feel and how they live.

CONCLUSIONS

Understanding the absence of one’s partner can create vast difficulties and obstacles, manifest through fear of the staying partner if the absent one (such as it is in this case) is involved in a substantially dangerous vocation. It is known personal opinions, beliefs, assumptions, and attitudes start to develop from a young age, usually observing the surroundings – friends, family, neighbours, figures of authority, and in modern times, the media. As people develop through age, the belief system oftentimes changes and the more one knows about certain situations, the more one can have positive or negative opinions and attitudes.

To conclude, many seafarers’ wives isolate themselves in pursuit of compassionate and understanding support from others, often finding refusals of their problems. Empathy and kindness towards them need to be available irregardless of gender, age, education level, vocation, and so on.

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Genre Features of a Seaman Resume

Kristina Radnjić, Milena Dževerdanović Pejović

A seaman resume, as a genre, has become a novelty in recent scientific studies. Most of these studies are focused on analyzing the content of this formal document. However, there are certain aspects in which a seaman's resume differs from others. In particular, although the layout of the resume has been standardized in the maritime industry, there have been many differences in the structure and quality of language. With this in mind, the aim of this paper is to point out which features are commonly used in a seaman resume. To achieve that, the authors have used a corpus-based analysis of 25 seaman resumes in the English language. Relying on the genre analysis approach, we first discern the specific structure of a resume and then proceed with the analysis of peculiar syntactic and semantic levels. Finally, we propose a sample model of a high-quality seaman's resume that will draw the attention of future employers, in particular the manning agents. The research findings of this paper have educational implications as they can be used as guidelines for creating a well-structured seaman resume.

KEY WORDS
Seaman's resume, Genre analysis, Maritime education.

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Open-source-based Approach to Delineate the Shoreline from Space: A Case Study in Failaka Island, the State of Kuwait

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Researchers need to delineate the shoreline for different applications with no access to costly resources such as topographic maps and high-resolution satellite images. With the increase of open source data, this study aims to present a methodology to use open source data in the best possible way to map the shoreline. Several methods have been tested using open source remote sensing data (Landsat and Aster), such as supervised classification, unsupervised classification, manual digitizing, and by applying some spectral indices, among others. The accuracy of the extracted shoreline data was verified using high-resolution open database images such as Google Earth Pro basemap. The results showed that the manually digitized shoreline through applying NDWI (green- near infrared/green+ near infrared) is the most accurate, although it remains important to validate and modify it using high-resolution images of open databases. Open source data showed acceptable accuracy in mapping the shoreline.

KEY WORDS

Remote sensing (RS), Geographic Information system (GIS), Geography, Coastal geomorphology, Arabian Gulf.

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INTRODUCTION

The words "shore" and "coast" are mostly used synonymously, but previous literature indicates that they are two different concepts. Hill (2013) used two simple definitions to differentiate between them. He defined the shore as the land bordering the sea, and the coast as the side of the land next to the sea (Fig. 1). The coastal zone is an important place in the lives of humankind, and this importance cannot be seen more clearly than in night-light satellite images. These space-images show how humans tend to live next to the sea, or in places where the sea is easily accessible (Albanai, 2021a, 2021d). Nowadays, more than half of the earth's population lives in what can be classed as coastal areas (McGranahan et al., 2007; Hill, 2013). Just a short look back in time, looking at the history of humankind compared to the earth's age, we can notice that the beginnings of human stability and settlement were near the banks of rivers and coasts. All the features of coastal areas have made it crucial for humanity.

Geographers and cartographers have long since been involved in coastal studies; many have been active in trying to delineate the shoreline. This process is not as easy as it seems. The sea level varies every day according to the tidal forces. Therefore, it is necessary first to define the shoreline for mapping. Scientists differ in their methods for determining the shoreline, but geographers tend to rely on the high tide line (Lipakis et al., 2008). In some countries, there is a law that states that the shoreline is the line of the highest water level (Gens, 2010). There is also the term coastline, which refers to the line where the water and land touch (Gens, 2010). However, the term shoreline is often used to determine the borderline of water separating from land. Additionally, according to the recommendation of the International Hydrographic Organization (IHO), most maritime countries define coastline as the intersection of the mean high water with the land. In practice, it is calculated as the mean high water from the 18.6-year series of hourly values of long-period sea level oscillations obtained from tidal measurements.

Methods used to map the shoreline have evolved with the development of geography. Ancient studies relied on the mapping of the shoreline by field surveys, which are often limited in scope. As approaches have developed, topographic maps and aerial photographs have emerged (Al-Mutari, 2017). Aerial photography can contain large areas, and cover much of what the topographic maps contain. The satellite data was the latest source used in the mapping of the shoreline; the spatial data provided by satellite imagery has facilitated a great leap in shoreline mapping, especially in studies related to shoreline change and coastal erosion. These satellites provide constant coverage of the earth's surface, which makes them a reliable source for this type of study(Albanai, 2021a). Satellite images have also increased the accuracy of topographic maps. The accuracy of satellite images for shoreline mapping varies according to their spectral and spatial resolution. The spectral resolution is the ability of a sensor to define fine wavelength intervals, or the ability of a sensor to resolve the energy received in a spectral bandwidth to characterize different constituents of Earth's surface (Gibson, 2000). The spatial resolution is a measure of the area or size of the smallest dimension on the Earth's surface over which an independent measurement can be made by the sensor (Gibson, 2000). In more simple words, it is the size of the image pixels. Nowadays, all these methods are still used in mapping the shoreline because of its effectiveness and importance; most studies rely on the integration of information from these sources.

Many methods have been applied to delineate the shoreline using satellite images. Two main techniques can be used, one of them is to delineate the shoreline automatically using quantitative methods. This depends on the spectral behaviour of water and land. For example, Near Infrared Radiation is extremely useful for separating land from water, because it is reflected strongly by land,

and absorbed strongly by water. Thus, it is effective as a tool to delineate the shoreline (Frazier et al., 2000; Lohani & Mason, 1999). Studies came later, proving that using more than one band increases the accuracy of shoreline mapping (Ryu et al., 2002); this is a technique known as band ratios, which can enhance the spectral differences between bands. Dividing one spectral band by another produces an image that provides relative band intensities. The image thus enhances the spectral differences between bands (Harris Geospatial product, 2018). Several studies have used this method, and one of the most important indicators used in mapping the shoreline is the Normalized Difference Water Index, or NDWI (McFeeters, 2013; Rokni et al., 2014; Al-Mutari, 2017). Another method is digitizing the shoreline manually using qualitative methods. This technique depends on visual analysis of the sources, whether they be satellite image, aerial photography or topographic map. It also shows great results in delineating the shoreline (Ford, 2013; Meyer et al., 2016). Studies have later proven that using both quantitative and qualitative methods can increase the accuracy of shoreline delineation (Aedla et al., 2015; Cenci et al., 2017). Overall, the choice of shoreline mapping method depends on the type of the shoreline, the available sources and the purpose of the study.

Supervised or unsupervised classification can be used based on the spectral differences of the relevant bands to classify the land cover in the study area and determine the shoreline (Albanai, 2019). On one hand, the basis of supervised classification is the notion that an image's sample pixels can be chosen by the user to be representative of particular classes. The user can then instruct the image processing software to use these training data as references when classifying the image's remaining pixels. The Spectral Angle Mapper Algorithm is one of the deserving classification techniques that produced positive results in separating land from water (Albanai, 2020). By calculating the angle between the spectra and treating them as vectors in a space with a dimensionality equivalent to the number of bands, the algorithm finds the degree of spectral similarity between two spectra (Harris Geospatial product, 2018). Unsupervised classification, on the other hand, aims to autonomously classify pixels in a remote sensing image into groups with comparable spectral characteristics. A statistical procedure known as "clustering" is used for classification, which divides pixels into groups based on the spectral characteristics they share. Colour slicing is one of the unsupervised techniques that showed promising results in mapping the shoreline automatically. Specific objects can be distinguished from their surroundings using the colour image processing slicing method (Harris Geospatial product, 2018). Additionally, it operates by effectively erasing all hues outside of a specific band of the colour spectrum by filtering through only that band. When the user bases the classification on the proper spectral bands for the study's objectives, the finest results are obtained.

This study aims to map the shoreline of Failaka Island in Kuwait using open source data. Data from Landsat 8 and Aster satellites were used. Nine shorelines were extracted using different methods including unsupervised classification, colour slicing, manual editing (digitizing), spectral indices, manual editing, and manual editing after applying different spectral indices. All these quantitative and qualitative methods have been applied to delineate most accurately the shoreline. The study also aims to verify the mapped shorelines using open source high-resolution images.

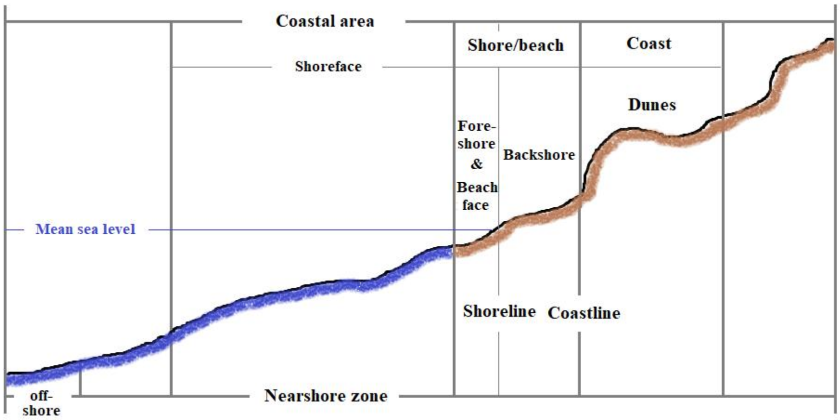


Figure 1. The coastal terms.

STUDY AREA

Failaka Island (Fig. 2) is located in the state of Kuwait, a country located in the north-western reaches of the Arabian/Persian Gulf (Albanai, 2021e; Hassan et al., 2021), and north-eastern side of the Arabian Pennunsela (Albanai, 2021; Albanai et al., 2022; Albanai, Karam, et al., 2022). The island is located on the entrance of Kuwait Bay, about 20 km from the mainland of Kuwait (Albanai, 2020). The depth range around the island does not exceed 12 meters below sea level (Albanai, 2021c, 2021b; Albanai et al., 2022). Failaka has a total area of around 46 km^2, and a shoreline of approximately 38 km in length (Albanai, 2019). The Kuwaiti Government is planning to develop the island, as it is mostly free of people now. The island was habitable before the Gulf War in 1990 (it accommodated around 3,500 civilians). The people left behind them a small destroyed urban area on the western side of the island (Al-Sarawi et al., 1996). The island is considered a flat land with some sabkha and few small spread hills. The highest areas on Failaka may reach 9 meters above sea level. Tides and waves are the most physical forces that effect Failaka coastal zone. Fig. 3. shows the tidal condition of the island. Additionally, anthropogenic forces can be seen clearly in the urban area and beaches (Al-Sarawi et al., 1996). Based on Al-Sarawi et al.'s (1996) study, many different geomorphologic features can be seen on the island such as sabkha, wetland, sandy beach and hard rocks among others.

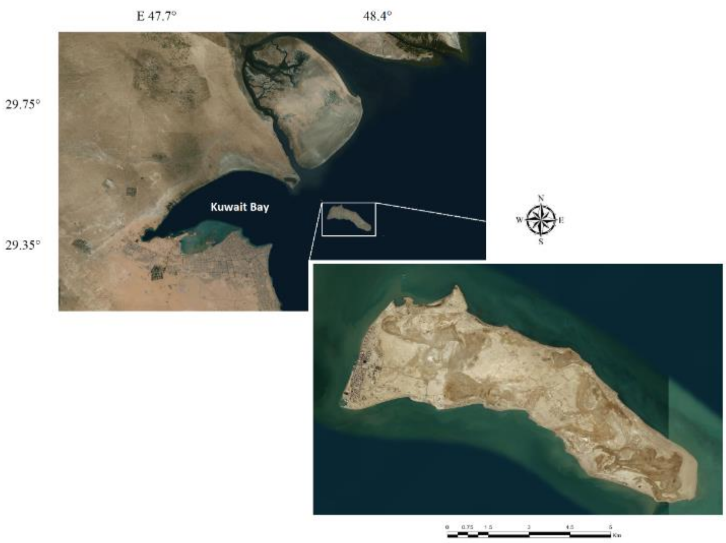
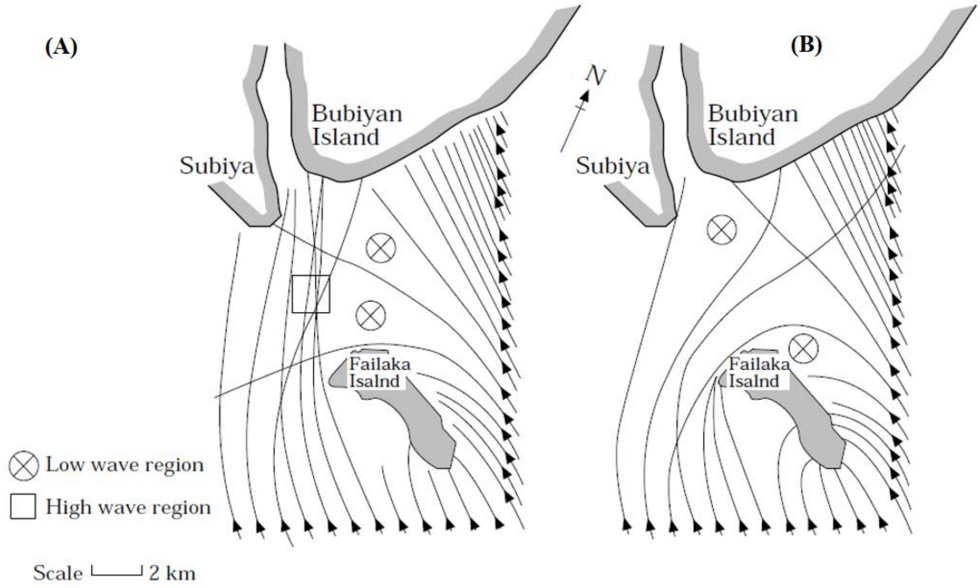
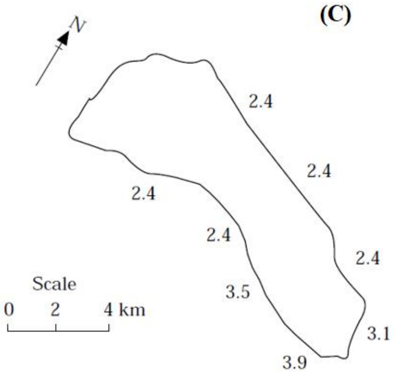


Figure 2. Failaka Island (the study area)





(D)

Wave direction	Wave height (m)	Wave period (s)
SE	4·53	7·62
ESE	5·18	8·39
E	3·77	7·24
ENE	3·60	7·09
WNW	1·14	4·26
W	2·03	5·27

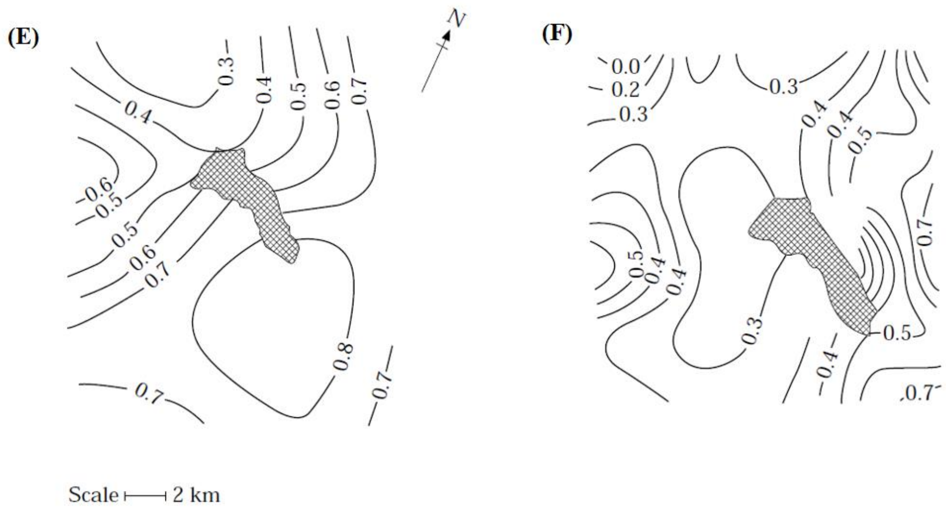


Figure 3. Wave refraction patterns around Failaka Island on high water level (a), and low water level (b), (c) is the maximum breaking wave heights around Failaka Island in meters, (d) shows in numbers the offshore wave conditions, the maximum tidal currents (m/s) around Failka, where (e) shows the spring tidal cycle, and (f) the neap tidal cycle (Al-Sarawi et al., 1996 with modification).

MATERIAL & METHODS

Fig. 4 shows a summary of the overall methodology. Multiple sources have been used and techniques applied to find the most accurate estimation of the shoreline of Failaka Island. The study depended on the satellite images as the main source for mapping the shoreline. Landsat 8 image, taken at 10 AM on 25 August 2014 at around high tide time (9 AM) was used (Table 1). An Advanced Spaceborne Thermal Emission and Reflection Radiometer (Aster) Image taken at high tide on 17 July 2012 was also used (Table. 2). Both images were freely downloaded from the United States Geological Survey site (USGS, 2018a).

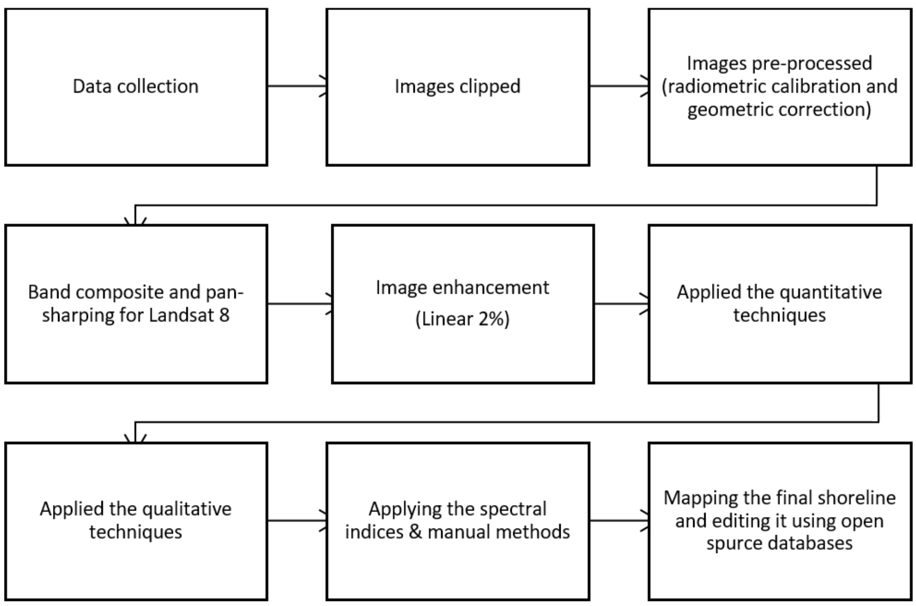


Figure 4. Summary of shoreline delineation process. The methodology included data collection, preprocessing, applying different quantitative and qualitative methods, choosing the most accurate shoreline, editing and validating it using open source databases.

Spectral Band	Wavelength (μm)	Resolution (m)
Band 1 – Coastal / Aerosol	0.433 – 0.453	30
Band 2 – Blue	0.540 – 0.515	30
Band 3 – Green	0.525 – 0.600	30
Band 4 – Red	0.630 – 0.680	30
Band 5 – Near Infrared (NIR)	0.845 – 0.885	30
Band 6 – Short Wavelength Infrared (SWIR)	1.560 – 1.660	30
Band 7 – Short Wavelength Infrared (SWIR)	2.100 – 2.300	30
Band 8 - Panchromatic	0.500 – 0.680	15
Band 9 – Cirrus	1.360 – 1.390	30
Band 10 – Long Wavelength Infrared	10.30 – 11.30	100
Band 11 – Long Wavelength Infrared	11.50 – 12.50	100

Table 1. Properties of Landsat 8 satellite. Bands 1 – 9 are OLI Sensor, while 10 – 11 are TIRS Sensor (USGS, 2018b).

Spectral Band	Wavelength (μm)	Resolution (m)
Band 1 – Blue	0.52 – 0.60	15
Band 2 - Green	0.63 – 0.69	15
Band 3N – Near Infrared (NIR)	0.76 – 0.86	15
Band 10 - TIR	8.125 – 8.475	30
Band 11 - TIR	8.475 – 8.825	30
Band 12 - TIR	8.925 – 9.275	30
Band 13 - TIR	10.25 – 10.95	30
Band 14 - TIR	10.95 – 11.65	30

Table 2. Properties of Aster Sensor. 1 – 3 are VNIR bands, while 10 – 14 are TIR bands (California Institute of Technology: NASA, 2012).

For pre-processing, the required spectral bands of both images have extracted. Then, the images were calibrated radiometrically using ENVI 5.2, a software for processing and analyzing remote sensing data. The radiometric calibration process changes the pixels values from a digital number to the radiance. This process helps us to detect the spectral signature of the land cover, and is necessary to class and analyse the earth's features (Albanai, 2019). Both Aster and Landsat 8 images were projected on the local coordinate system UTM_Zone_39N.

For the Landsat 8 Image, the bands have been composited using ArcGIS 10.4.1, a software for managing and analyzing GIS data. Then, the pan sharping technique was applied using. Pan sharpening combines a lower spatial resolution multispectral bands (raster dataset) with a higher-resolution panchromatic band. The outcome creates multispectral bands with the panchromatic band's spatial resolution, where the multi-spectral bands and the panchromatic band completely overlay (Albanai, 2019). The multispectral bands of Landsat 8 cover 7 bands and have a spatial resolution of 30 meters for all of them, while the panchromatic band is a single spectral band with a spatial resolution of 15 meters. This technique is used to overlay the multispectral bands with the panchromatic for Landsat 7 raster dataset. Figure 5 shows an example of pan sharping. Additionally, the images have been enhanced using the linear properties on ENVI 5.2 for visual purposes. The satellite images need to be enhanced to avoid the weather conditions and the differences in the image colours and lights that may affect the analysis process (Albanai, 2019).

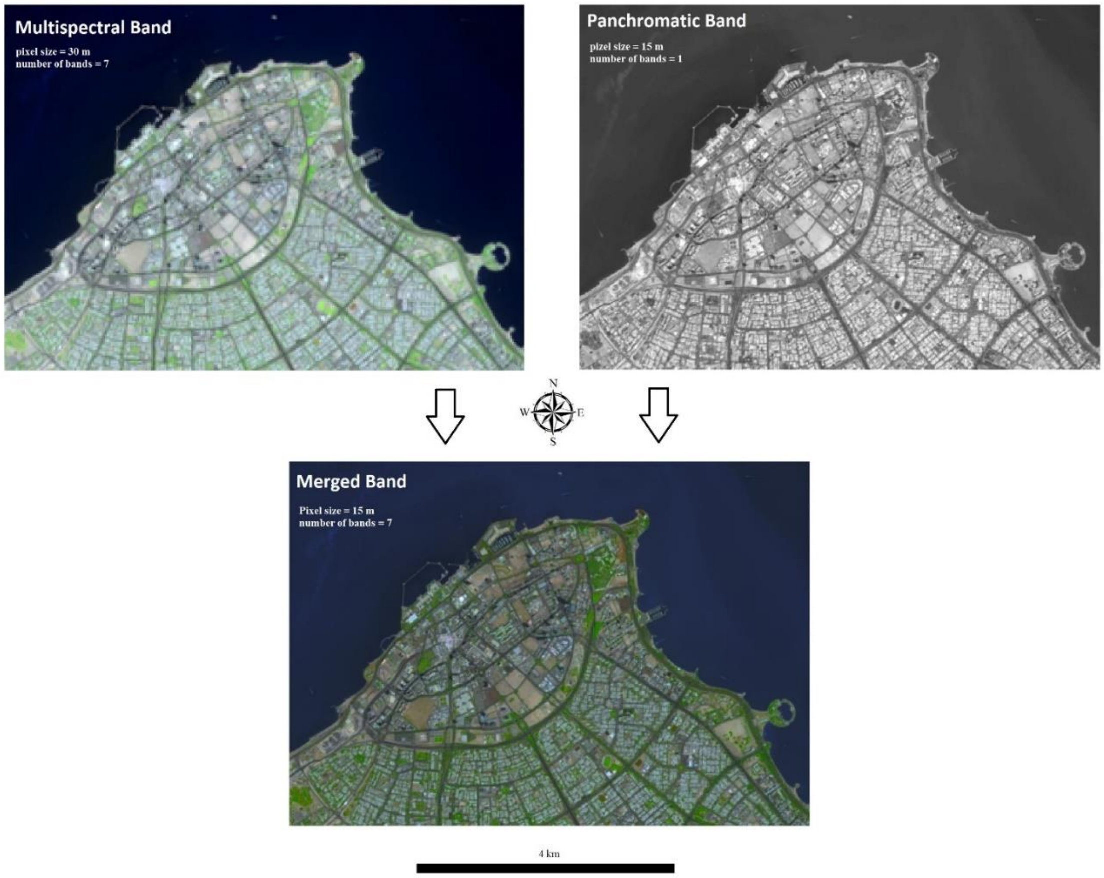


Figure 5. An example of the pan sharping techniques on Landsat 8 image on Kuwait City.

Different methods have been applied to extract the most accurate shoreline. Overall, they can be divided into qualitative, quantitative and integrated methods.

Shoreline 1: Landsat 8 OLI image, after applying pan sharping, has been classified using the supervised classification wizard appears technique (Spectral Angle Mapper Algorithm) with training data by visual analysis on ENVI 5.2 software. Then, the shoreline has been extracted depending in the different classes of the algorithm.

Shoreline 2: the same technique has been applied for Aster image (VNIR sensor) to extract the shoreline (Fig. 6).

Shoreline 3: Landsat 8 NIR band, after applying pan sharping, was classified using the colour slicing technique (unsupervised classification on ENVI 5.2). Then the shoreline has been extracted depending on the different classes of slicing.

Shoreline 4: the same technique has been applied for Aster image to extract the shoreline.

Shoreline 5: the enhanced image of Landsat 8 was used to map the shoreline manually depending on different bands by visual analysis.

Shoreline 6: Aster VNIR was used to map the shoreline manually depending on different bands by visual analysis.

Shoreline 7: NDWI (a), presented by McFeeters (2023) was applied for the enhanced Landsat 8 using band math tool on ENVI 5.2, a tool that can be used to develop custom bands processing function, where it is possible to define the bands used as input, to delineate the shoreline of Failaka Island by manual digitizing after applying the following algorithm:

$$x^1 = \frac{Green - NIR}{Green + NIR} \qquad (1)$$

Shoreline 8: NDWI (b), presented by McFeeters (2013) was applied for the Landsat 8 to delineate the shoreline of Failaka Island by manual digitizing after applying the following algorithm:

$$x^2 = \frac{NIR - SWIR}{NIR + SWIR} \qquad (2)$$

Shoreline 9: NDWI (c), presented by McFeeters (2013) was applied for the Landsat 8 to delineate the shoreline of Failaka Island by manual digitizing after applying the following algorithm:

$$x^3 = \frac{NIR - SWIR\ 2}{NIR + SWIR\ 2} \qquad (3)$$

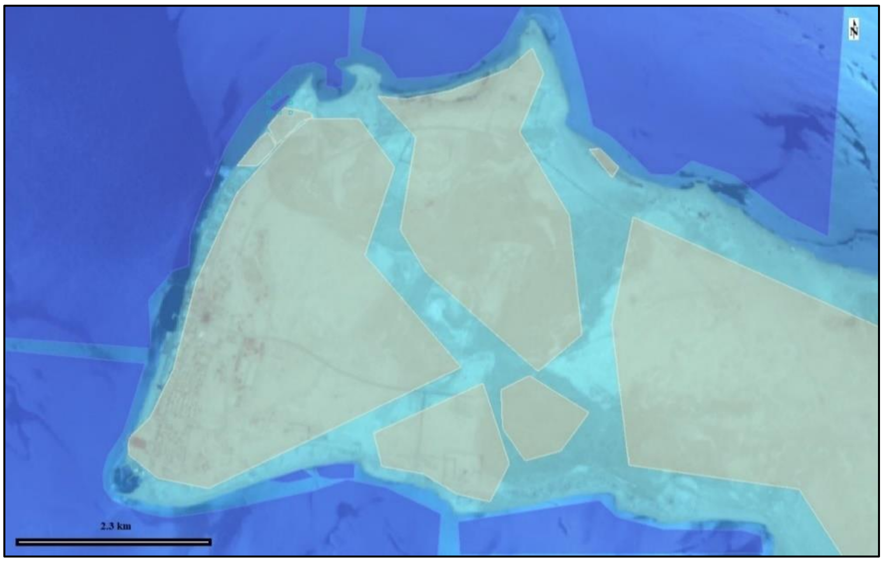


Figure 6. An example of the supervised classification wizard appears technique using training data for Aster image.

For validation and final editing purposes, high-resolution basemap images from both ArcGIS 10.4.1 (ArcGIS Online, 2018), and Google Earth Pro in June 2018 (Google Earth, 2018) have been used. Both were used as a reference shoreline for validating and editing the mapped shorelines. Even though they are not taken at high tide, they are an important free resource to use. Their spatial resolution reaches a few centimetres. It should be mentioned that the images used in the Google Earth Pro and ArcGIS basemaps belong to different satellites, but the information of these satellites, such as the name, is not mentioned. Fig. 7 shows the images used in this study. The final shorelines were projected on the local coordinate system UTM_Zone_39N.

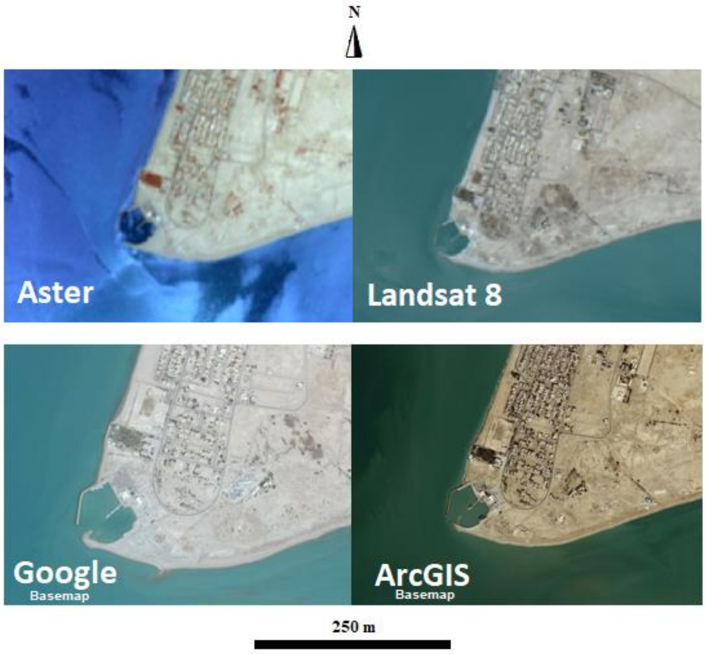


Figure 7. The images used in this study for mapping, editing and validating the shoreline.

RESULTS AND DISCUSSION

The results show that shoreline 7 is is the most accurate among the others (Figs. 8 & 9). This shoreline was verified using the high-resolution images of the basemaps. Even though the shoreline 7 gave the best result, there were some simple displacements on the shoreline according to the spatial resolution of the band (Fig. 10). The high-resolution basemaps showed some generalization in the mapping. Although the high-resolution images were taken at different times, the high tide line can be determined, especially with field knowledge of the study area, and the background of analyzing satellite images based on coastal geomorphology concepts, in particular experience in distinguishing some phenomena such as wave-cut platforms and swash line, among others. Additionally, the spatial resolution of these data reaches a few centimetres in some places. The maximum tidal currents and waves around Failaka Island were less than 5 meters (Al-Sarawi et al., 1996); this is less than the spatial resolution of the merged image used to map the shoreline. According to that, it was better to use these high-resolution images to edit the extracted shoreline 7, which was extracted from the spectral index of Landsat 8 merged image using visual analysis. The band rationing technique could not be applied to Aster image due to the band's range and number.

The use of multiple spectral bands increases the resolution of the image, especially on the intertidal areas and sabkhas or wetland zones, where it is hard to separate the land from the water using natural colours (Ryu et al., 2002). In addition, the band rationing method separates the land from the water into two clear colours, unlike the natural colours, which often shows a gradual shift between the two. In contrast to the automatic methods, the band rationing technique make the use of more than one band, and this has many advantages in identification of shorelines (Albanai, 2019).

Near infrared band is extremely useful for separating land from water because it is reflected strongly by land, and absorbed strongly by water (Albanai, 2022). This technique depends on the value of each pixel on the image. The program classifies the pixels depending on the number of classes that the analyst chooses.

For the quantitative methods, both the Aster VNIR and the merged image of Landsat 8 showed good results compared with the satellite basemap data. In the supervised classification methods, the technique depends on the user visual analysis of separating the land covers using samples of polygon annotation. Then, the program identifies the classes depending on the similarities of pixel values chosen by the user, and the number of classes sought by the analyst. Overall, this technique depends on which band is seen, and the spatial resolution of this band. On the other hand, unsupervised techniques are similar to the supervised classification, except it groups the pixels automatically, in contrast to the supervised classification, where the land cover pixels are classified based on ground truthing points, which gives better accuracy (Fig. 11). This method also depends on the spectral band that the user chooses, and the spatial resolution of the image. The results are good for studies which do not require a high resolution on mapping the shoreline. The required accuracy depends on the study's purpose. When the two are compared, manual mapping remains more accurate and efficient.

Moving to the manual methods, the two satellites show good accuracy compared to the basemap data depending on the visual analysis. The variation between Aster and the merged band of Landsat 8 on mapping the shorelines was too close, and less than the spatial resolution of the images. Although this result is acceptable, it was difficult to separate the land from the water in some areas. This difficulty is due to the natural colour applied in the image. There were some difficulties in mapping the shoreline using natural colours. These difficulties highlight the importance of using another spectral composite to help with the mapping process. Figure 11 shows a comparison among the 9 extracted shorelines.

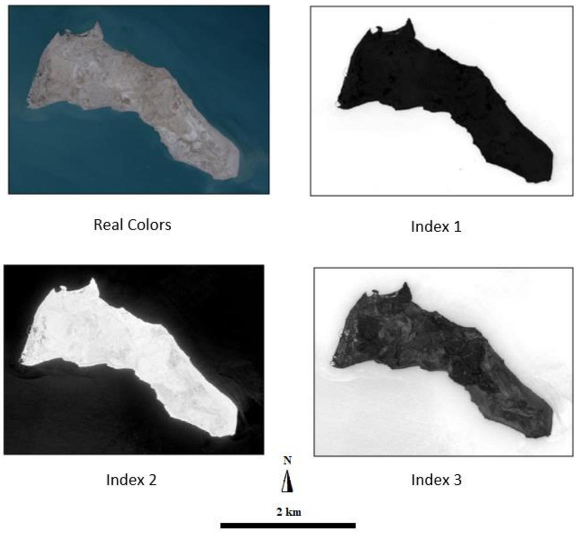


Figure 8. Application of the three NDWI indices on Landsat 8 Image. Index 1 = shoreline 7, index 2 = shoreline 8, and index 3 = shoreline 9.

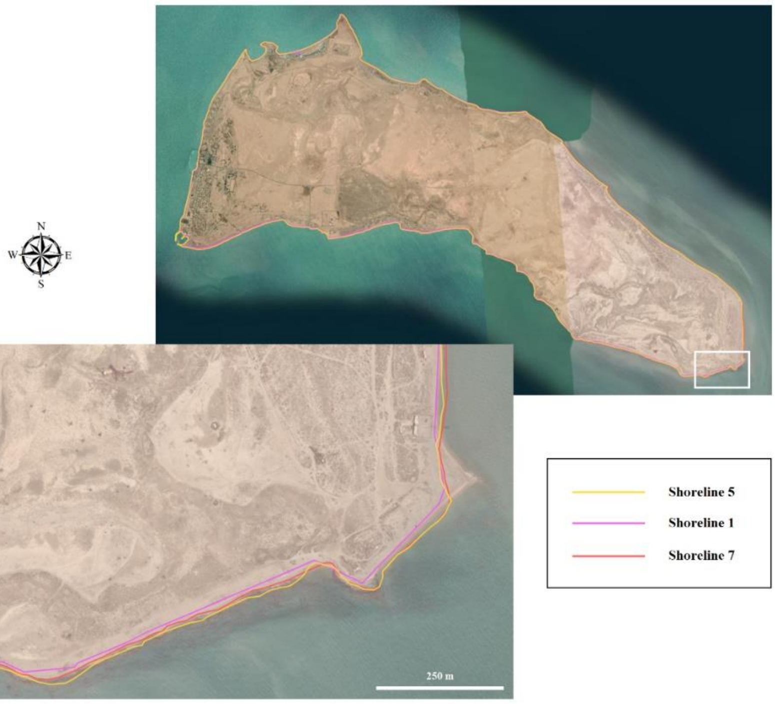


Figure 9. Comparison of three representative extracted shorelines. (1) the most accurate shoreline based on classification, (2) manually digitized shoreline using natural colours, (3) manually digitized shoreline after applying the best index of NDWI. It can be seen that shoreline 7 still needs some adjustment.

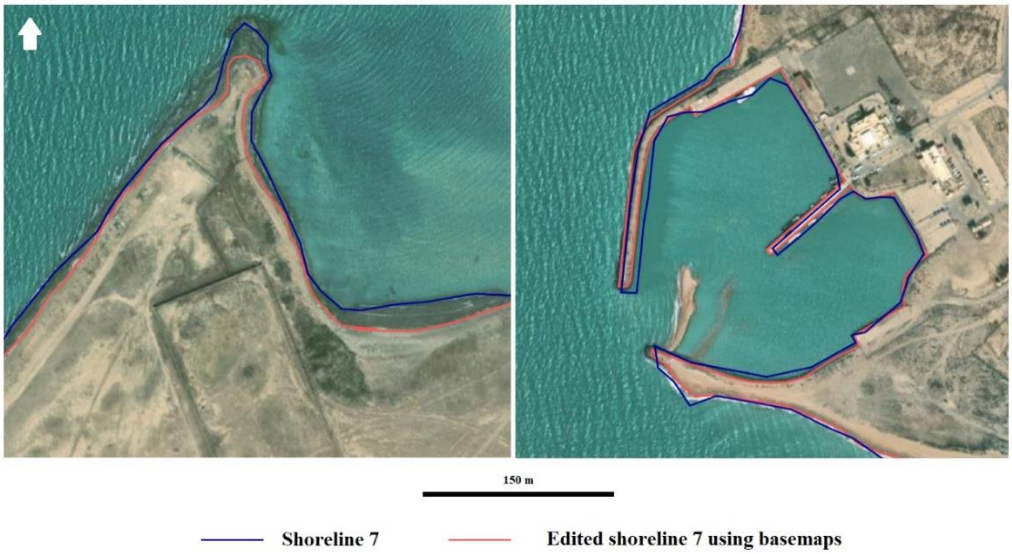


Figure 10. Shoreline 7, which showed the best result, has been modified and verified using high-repulsion basemaps of Google Earth Pro and

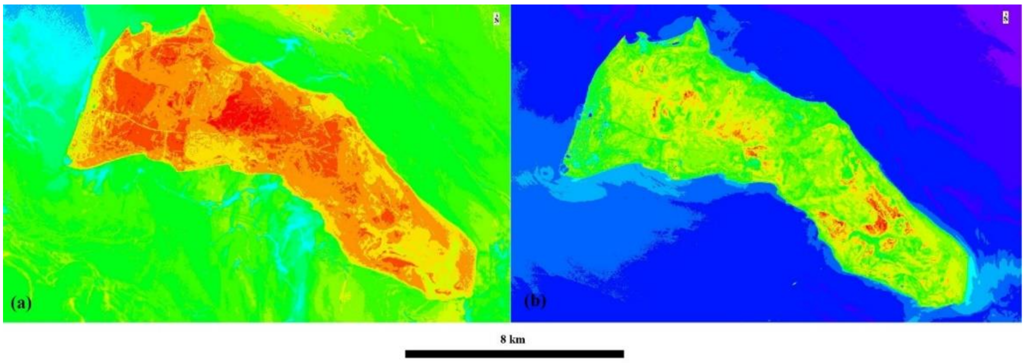


Figure 11. The application of unsupervised classification (colour slicing technique) on (a) Aster and (b) Landsat 8 NIR band.

CONCLUSION

This study presents a methodology to use open source data in the best possible way to map the shoreline. Several methods have been tested using open source remote sensing data (Landsat and Aster) such as supervised classification, unsupervised classification, manual mapping, and by applying some spectral indicators, among others. The accuracy of the extracted shorelines was verified using high-resolution open database images (such as Google Earth basemap). The results showed that the manually mapped (digitaized or editied) shoreline through applying spectral index (green- near infrared/green+ near infrared) is the most accurate, although it is important to modify it using high-resolution open database images. This study recommends relying on the latest available open source data, and this methodology can be applied to the latest satellite data such as Landsat – as well as to the Sentinel satellites, for example – in addition to any other open access satellites that may be launched in the future with better spatial resolution.

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Standardization in Maritime Education and Training - Case Study of the Faculty of Maritime Studies Kotor

Vera Kapetanović[1], Maja Krčum[2], Igor Petrović[1], Igor Stanovčić[1], Tatijana Dlabač[1]

Standardization of seafarers' competencies is regulated by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). This Convention defines minimum quality standards in the education and training of seafarers. Therefore, it is crucial to understand the concept of standardization and distinguish the terms competence, knowledge and skill. The level of competence depends on the quality of education and training of seafarers, which are carried out at the corresponding institutions.

Maritime Education and Training (MET) institutions worldwide aim to create a high quality seafarer with adequate competencies. The quality of these institutions' work is the responsibility of a their countries. In order to create a competent seafarer, MET institutions should follow the development of new technologies, and innovate their curricula accordance with STCW and other relevant Conventions. It is also necessary to develop a model that assesses the actual competence of candidates who received their education and/or training at the aforementioned institutions.

This paper will present research on the importance of standardization in the education and training of seafarers at the Faculty of Maritime Studies Kotor. The aim of the work is to determine to what extent a student or a seafarer recognizes the importance of standardization within the educational process as well as the application of acquired knowledge on board. For this purpose, a survey will be conducted among a representative number of students and seafarers.

KEY WORDS

Standardization, Maritime Education and Training (MET), Seafarers, Educational process

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INTRODUCTION

Standardization improves the protection of life and health, the quality of products, processes and services through the development of international harmonization of standards and related documents (*Institute for Standardization of Montenegro*, 2023). The understanding of standardization is extremely important in all the segments of life and work. It represents a framework of an agreement that all interested parties must adhere to in order to ensure that all processes related to the creation of a product or the quality of a service are carried out in accordance with the set guidelines. The introduction of standardization raises the quality of products and is a reflection of the technical, technological and economic development of a country. It is a prerequisite for eliminating all forms of barriers and limitations in the development of services and products. When it comes to standardization and its application in institutions, it is important to understand that it is not just a set of documents, but a "living process" that is constantly supplemented, changed, adjusted and which serves to ensure that planned processes take place smoothly within the framework of an institution. It must be used in practice, and only in this way will the effectiveness and benefit of its implementation be demonstrated.

The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), which stipulates seafarers' competencies on a global scale, was adopted by the International Maritime Organization (IMO) in order to better and more efficiently define the content and level of educational programs that will ensure the quality of teaching in MET institutions. (Marušić, 2010; Dlabač *et al.*, 2022)

The second section of the paper presents the importance of standards in maritime industry and MET. An overview of the implementation of standards in maritime education and training at the Faculty of Maritime Studies Kotor, University of Montenegro, is given in the third section. In the fourth section of the paper, the results of the surveys prepared for students and seafarers are presented, with corresponding questions related to standardization and its application its practical application.

THE IMPORTANCE OF STANDARDS IN MARITIME INDUSTRY AND MET

A proper, safe and trouble-free operation of the vessel is fully based on standardization. First of all, there are ISO standards. Three particular standards, i.e. 9001, 14001 and 45001 (ISO 9001- Quality management system, ISO 14001 – Environmental management system and ISO 45001 - Occupational health and safety management systems) are essential for any organization to be run safely and smoothly and achieve relevant aims and objectives, including customer satisfaction, environmental protection and safety of all personnel involved in the organizational structure (Karakasnaki *et al.*, 2018).

In addition to the mentioned standards, the maritime industry, recognized for its diversity, has adopted a special Code dealing with safety management – International Safety Management (ISM) Code. The Code has been adopted in 1993, and entered into force in 1998. The implementation of this Code was also assisted by the introduction of Chapter IX into the SOLAS Convention. The purpose of the Code is to enable shipping companies to achieve high standards of safety and environmental protection. Despite their different sources (ISO and IMO), these standards and Codes have a common goal: safe and environmental friendly shipping operations that meets customer's demands.

Lately, many companies have been establishing Integrated Management System (IMS) as a system unifying all relevant standards, requirements, regulations and rules. Its primary purpose is to set company quality policy including aims, objectives and procedures that will produce and maintain this declared quality. Moreover, it presents evidence that the company takes safety and environment protection seriously.

Safety Management System (SMS) is a part of ISM system that sets safe working principles, guidelines and procedures that must be followed on board the ship. The purpose is to establish and maintain safe working condition and environment, ensuring safety of the vessel and crew at all times without causing any risk to the environment or involved properties. An example of the implementation of SMS in marine industry and its connection to other requirements (from various standards and ISM Code) is shown in Figure 1 (Knight, no date).

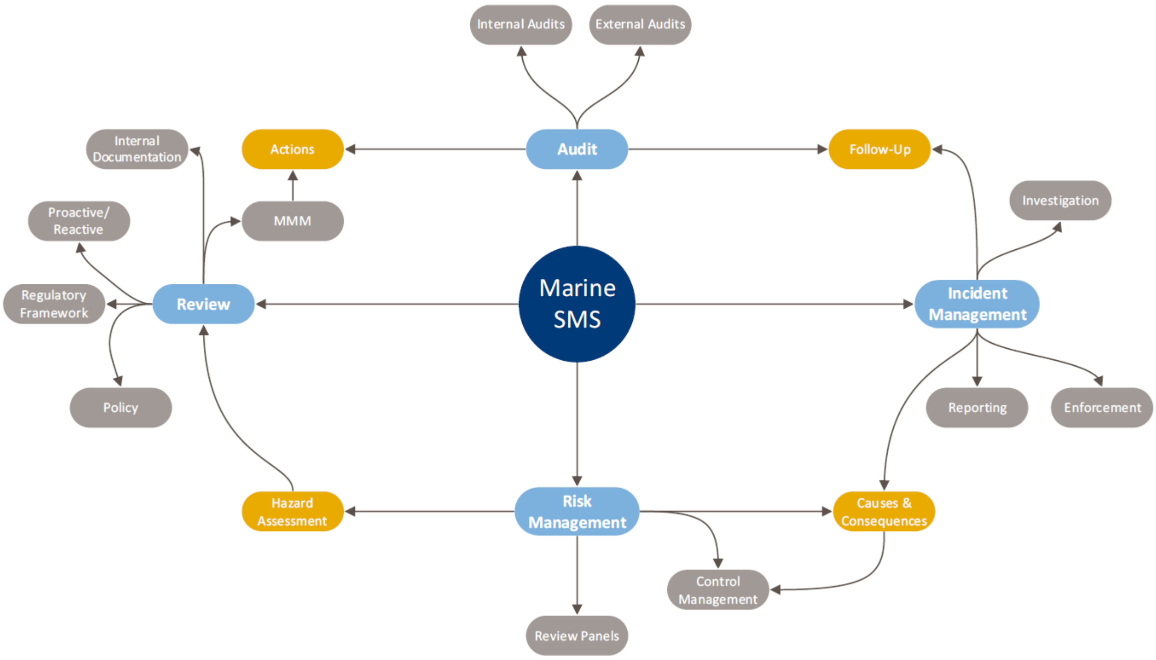

Figure 1. Example of the practical implementation of SMS in marine industry (Knight, no date)

Standardization has achieved its wide application even in maritime education and training (Čampara, Frančić and Bupić, 2017; Bao *et al.*, 2021; Dlabač *et al.*, 2021; Kapetanović *et al.*, 2022). Taking into account complex and demanding shipboard procedures, it is essential that ship's crew is trained up to the highest standards. This has been recognized by the International Maritime Organization (IMO), which laid down the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). The Convention gives a detailed explanation of competencies that are required for each rank on board. However, the Convention itself does not provide a guideline on how to achieve these requirements.

In order to assist the Administrations (especially of developing maritime counties) in the implementation of the STCW Convention, IMO has developed a set of model training courses (IMO Model Courses, 2023). The purpose of these model courses is to assist training institutes and instructors in the organization and introduction of new training courses, as well as in improving the quality of the existing courses by enhancing, updating and supplementing existing training material. It must be highlighted that these model courses do not present teaching material that must be strictly followed, as many Administrations accepted. It is just a tool that can be of assistance to training centers and instructors to transfer the required knowledge, skill and competence to the participants to the level that is required by the STCW Convention.

AN OVERVIEW OF THE IMPLEMENTATION OF STANDARDS IN MARITIME EDUCATION AND TRAINING AT THE FACULTY OF MARITIME STUDIES KOTOR

Montenegrin institutions that deal with the education and training of seafarers apply the ISO 9001:2015 standard. A good and expedient application of this standard not only represents the foundation for the Quality Management System (QMS), but is also a sound basis for the development of other standards. On the other hand, its application, in addition to the Quality Management System, is also reflected in the fact that its proper implementation enhances the performance of all the processes in each segment of work, both within the MET institution itself and other participants involved in the institution's work (Dlabač *et al.*, 2022)

Quality Regulations, which are the basis for the implementation of the ISO 9001:2015 standard, and relevant procedures define all the proceedings within the institution. The Quality Regulations define, among other things, the quality policy, organizational units, goals, mission and vision of the institution, as well as the responsibilities and capacities necessary for the proper functioning of the quality system.

It is very important to point out that the adequate application of the Rulebook on Quality Procedure is a prerequisite for quality, and this will reflect on good operations and improvement of work in all segments of the institution. Each institution has the right to change and adjust procedures through work in order to facilitate and simplify work processes. This will certainly enable continuous improvement of work in all segments. Therefore, the entire documentation of the Quality Management System represents a "living process" that can be changed, adapted, and innovated, but all this, of course, in accordance with the prescribed procedures and in accordance with the regulations of the mentioned standard ISO 9001:2015.(Kapetanović *et al.*, 2022)

Following modern development trends, the Faculty of Maritime Studies Kotor introduced the Quality Management System in 2001, and the first implemented standard was ISO 9001/1994. After this one, and the standards ISO 9001:2008 and ISO 9001:2009, the Faculty of Maritime Studies Kotor received valid certificates in 2004. Since 2016, the necessary actions for the introduction of the ISO 9001:2015 standard have been started, and since 2017 it has been successfully applied. Figure 2 schematically shows how the quality management system is organized at the Faculty of Maritime Studies Kotor. In addition to the Quality Regulations, there are fourteen procedures followed by appropriate records. Each procedure has its own code from PF P01 to PF P14, where PF is the code that refers to the Faculty of Maritime Studies (Pomorski fakultet), P is the code for Procedures and, finally, the number of the procedure. In the example of the Teaching Process Procedure, the records that go with this procedure, as well as with every other procedure, are shown. Records are marked FO, which stands for "Faculty Form" (Fakultetski obrazac). The numbers for each FO are listed in order, with the first number always being the number of the procedure to which the forms belong.

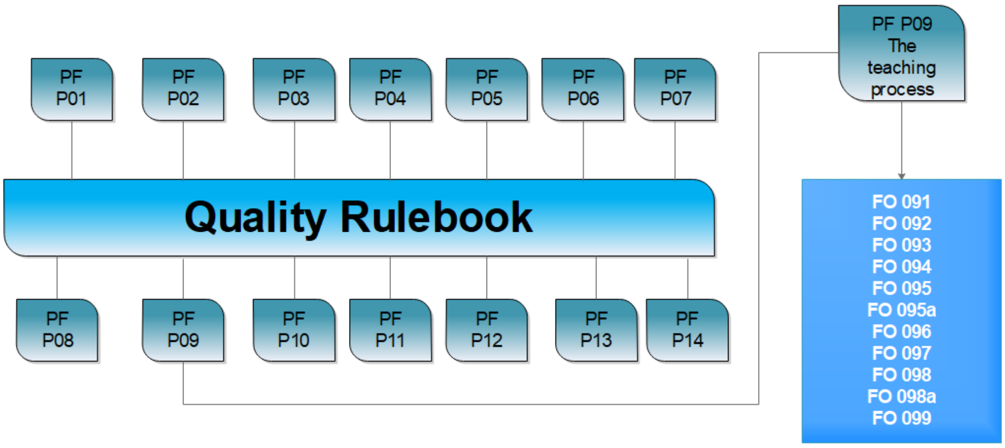

Figure 2. The schematic representation of the QMS organization at the Faculty of Maritime Studies Kotor

Each work process is covered by rules prescribed by a certain procedure. Thus, the activities related to the education and training of seafarers are defined by the procedures Teaching Process (PF P09) and Training of Seafarers (PF P10) and the corresponding documents accompanying these procedures. Internal audits of the entire work of the Faculty are very important activities, both for improving the work and for external controls. For this reason, a correct implementation of the procedure for internal audit (PF P11) is required. What is important to point out is that the internal audits that are carried out at least once a year, in addition to checking all activities at the Faculty, primarily check the compliance of the quality management system of the Faculty of Maritime Studies Kotor with the requirements of the ISO 9001-2015 standard. External audits that are carried out at least once a year by recognized organizations always include an examination of the internal audit documentation. In addition, external auditors verify the compliance of both education and training, as well as the quality management system with the ISO 9001-2015 standard.

Figure 3 shows a schematic representation of the alignment of the study programs of the Faculty of Maritime Studies Kotor with the related IMO Model Courses.

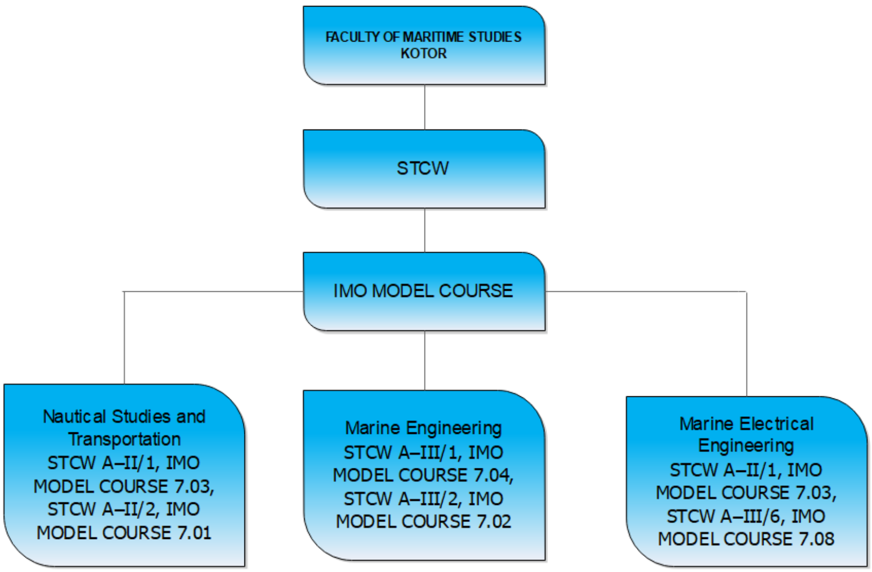

Figure 3. Schematic representation of IMO Model Courses by study programs

CASE STUDY: THE FEEDBACK FROM STUDENTS AND SEAFARERS

Having in mind the importance of standards governing the education and training of seafarers, a question is raised on how much maritime students and active seafarers are actually familiar with aforementioned.

Two different questionnaires have been developed to obtain the relevant data. The first one was designated for students with the focus on general knowledge about ISO standards and STCW Convention requirements. The other one, designed for seafarers, is focused on their attitude towards the importance of standards before joining the vessel for the first time and after gaining certain sea service.

This section presents the results of the mentioned questionnaires that have been filled out by the students of the Faculty of Maritime Studies Kotor and active seafarers from Montenegro.

Students' feedback

The number of students from all study levels that were surveyed is N=58. Out of the total number of the respondents, 86.2% were between the age of 18 and 27 (Figure 4). Figure 5 shows the responses to the question: "During your education, have you heard about the term standardization or ISO standards?". Fifty-two (52) students, or 89.7% gave an affirmative answer to this question, and six (6) students or 10.3% of the respondents, answered *No*.

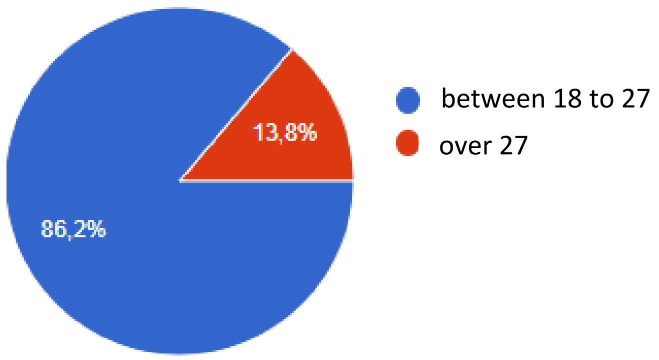

Figure 4. The age structure of surveyed students

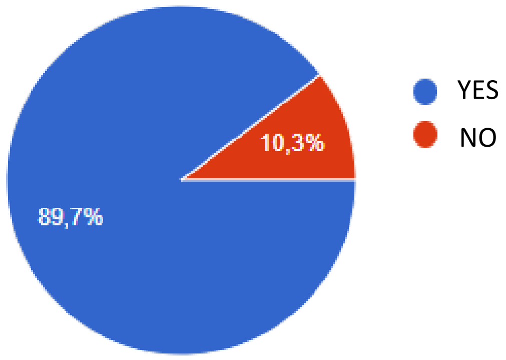

Figure 5. Students' awareness of standardization or the ISO standard

The aim was to acquire information from students on whether they had been familiarized with the concept of the Quality Management System (QMS) through some of the subjects taught during their studies. Out of 58 surveyed students, 28 or 48.3%, answered *Yes*, while 30 or 51.7%, answered *No* (Figure 6).

Answering the question "Are you familiar with the STCW Convention and its importance for the education and training of seafarers?" 77.6% or 45 respondents gave an affirmative answer. The answer *No* was given by 22.4% or 13 respondents (Figure 7)

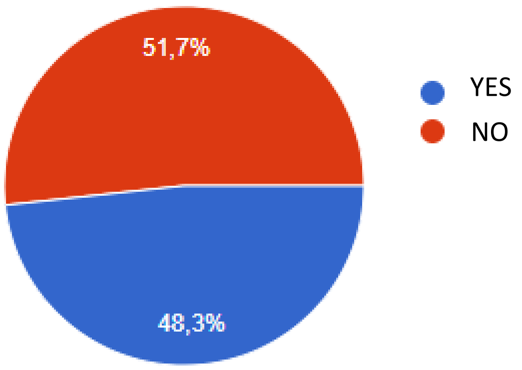

Figure 6. Students' awareness of Quality Management System-QMS

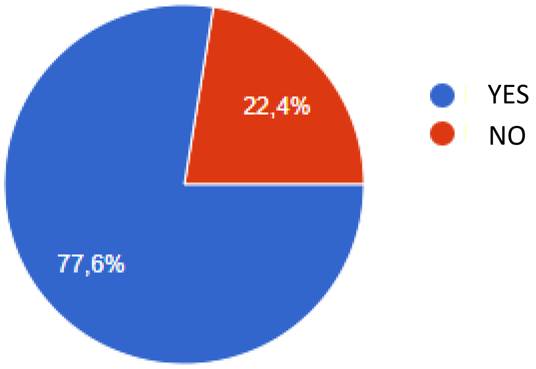

Figure 7. Students' awareness of the importance STCW Convention

When asked how familiar they were with some of the IMO Model Courses through the education process, the students answered as follows: 60.3% or 35 students answered *Yes*, while 39.7% or 23 students answered *No* (Figure 8).

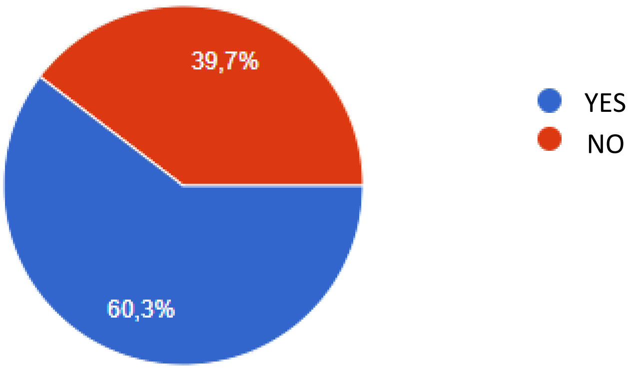

Figure 8. Students' awareness of the IMO Model Courses

What is noticeable in the previous graphs is that the percentage of students who answered affirmatively to the questions about being informed, both about the Quality Management System and ISO standard, as well as the STCW Convention and the IMO Model courses, is over 50% of the total number of respondents. On the other hand, one should not ignore the figure of 48.3% of the surveyed students not being informed about the Quality Management System, as well as 39.7% of students not being informed about the IMO Model Courses. The students' lack of information about the STCW Convention amounts to 22.4%. Based on these data, it is necessary to make a systematic analysis in order to see what is the cause of the student's unawareness about the important things on which their education is based, namely the STCW Convention, IMO Model Courses, and the Quality Management System as an indispensable part of all that. This phenomenon is even more interesting if it is known that all study programs deal with this topic through various subjects. Figure 9 presents the summary results of some of the answers given by the students regarding the importance of standardization.

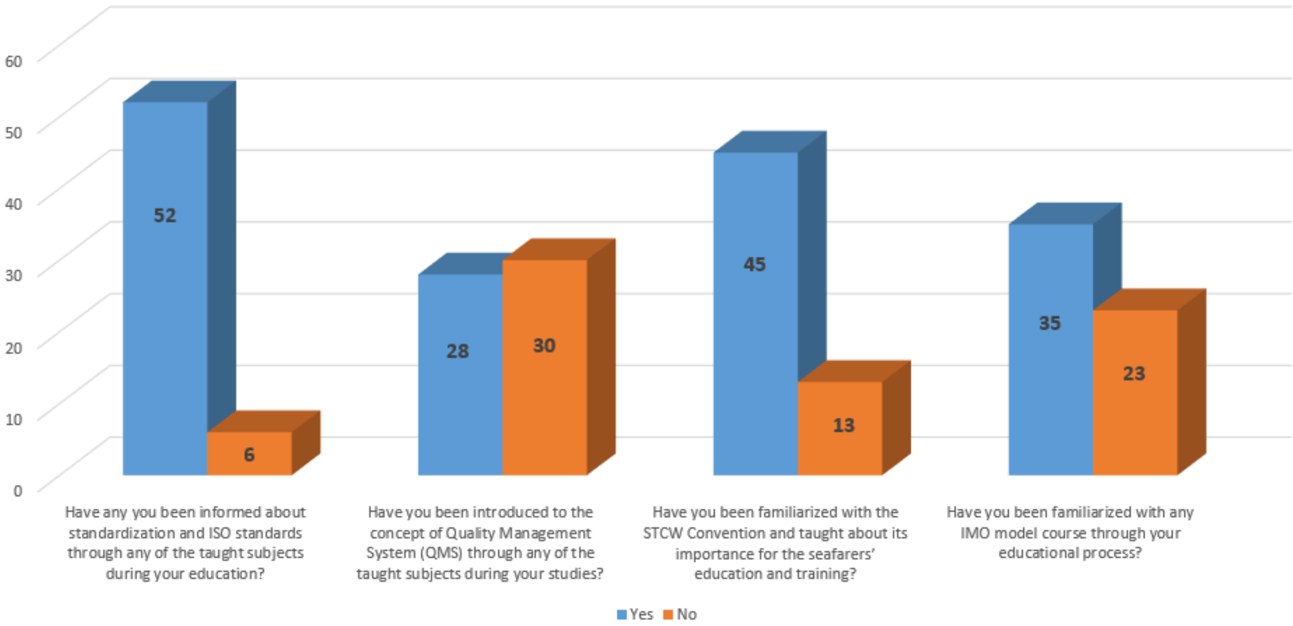

Figure 9. The overview of students' answers about the importance of standardization

Seafarers' feedback

The number of seafarers from Montenegro that were surveyed is N=63. Figure 10 shows the age structure of the surveyed seafarers.

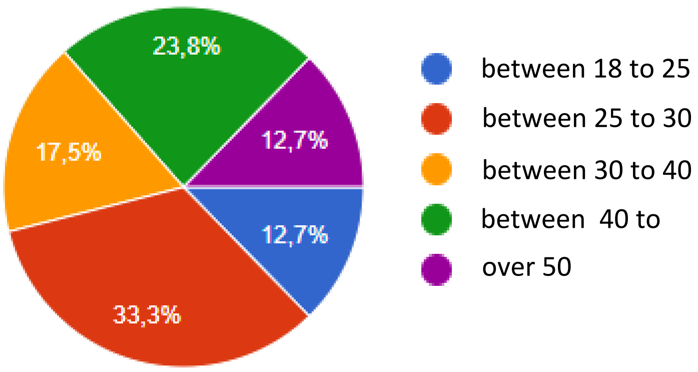

Figure 10. The age structure of surveyed seafarers

One of the questions for the seafarers was the following: "On a scale of 1 to 5, it is necessary to rate how much you knew about the importance of standardization/quality management system/international regulations/national regulations before joining the ship for the first time?" (1 - I had no knowledge, 2 - I had very little knowledge, 3 - I had partial knowledge, 4 - I had solid knowledge, 5 - I had full knowledge). The responses are shown in Figure 11.

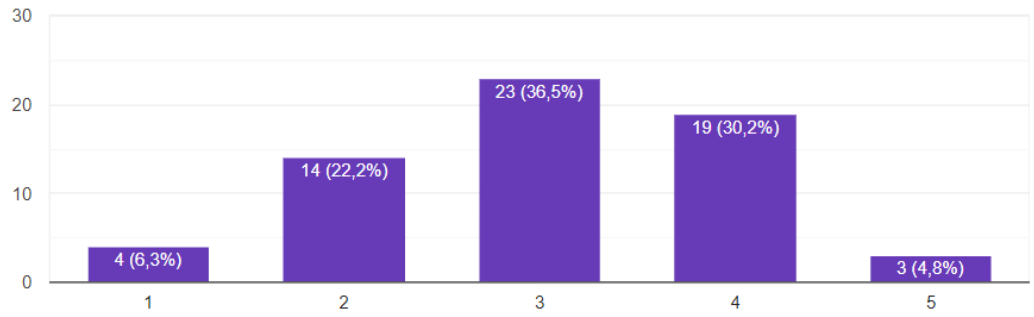

Figure 11. The knowledge of the importance of standardization before joining the ship for the first time

This paper also investigated how much knowledge seafarers had about the importance of standardization/quality management system/international regulations/national regulations after a certain time spent on board. On a scale from 1 to 5, it was necessary to evaluate as follows: 1- I do not have the necessary knowledge even now; 2 - I have very little knowledge; 3 - I have partial knowledge; 4 - I have solid knowledge and 5 - I have full knowledge. The answers are shown in Figure 12.

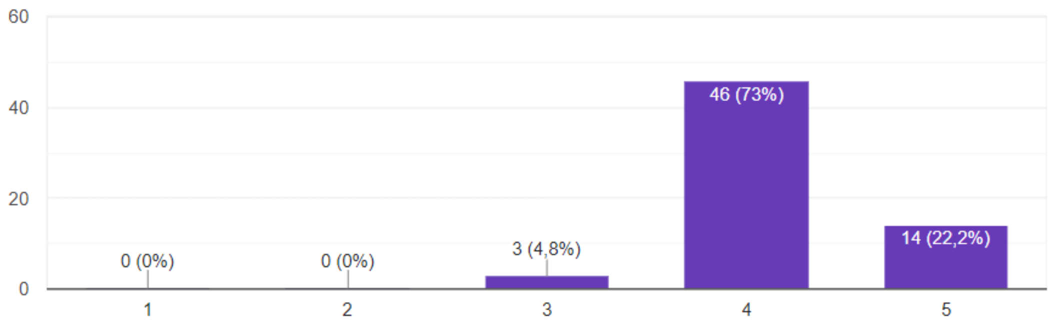

Figure 12. Knowledge about the importance of standardization after a certain time spent on board

Comparing the answers given by the seafarers regarding their knowledge about the importance of standardization/quality management system/international regulations/national regulations, before joining the ship for the first time and after a certain time spent on board, it is evident that it is greater only after a few years of sea service (Charts 11 and 12). Therefore, out of 63 respondents with no sea service, four had no knowledge, fourteen had very little knowledge, while twenty-three had partial knowledge. Only five seafarers answered that they were fully informed about the importance of standardization and its application. The results obtained from seafarers after they gained some experience are obviously. Out of 63 surveyed seafarers, 46 declared that they had solid knowledge, and 5 had full knowledge. Three mariners had partial knowledge, and none declared that they had very little or no knowledge". Figure 13 shows the summary results of some answers given by the seafarers about the importance of standardization.

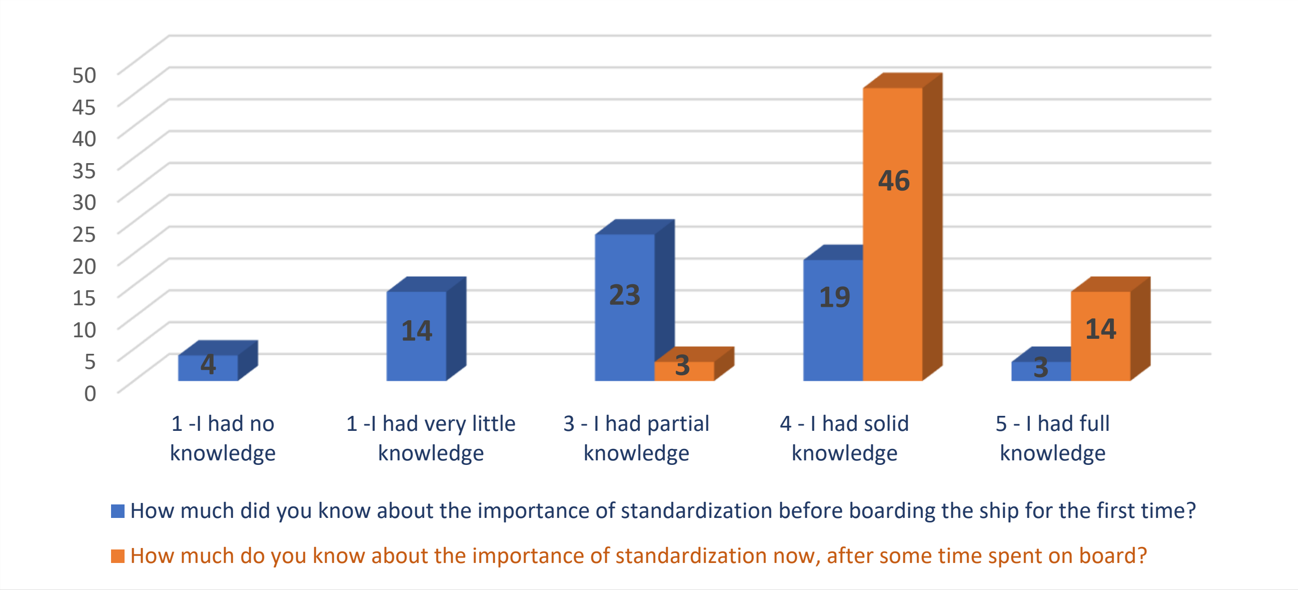

Figure 13. The overview of the seafarers' responses about the importance of standardization

CONCLUSION

External audits over education and training in Montenegrin educational institutions and training centers are conducted by recognized organizations hired by the competent Ministry. Thus, an audit is made once a year verifying that the standards and provisions of the STCW Convention are properly implemented, as well as that the curricula are aligned with the recommended IMO Model courses. In the case of the Faculty of Maritime Studies Kotor, these are the Croatian Register of Shipping and Bureau Veritas. In addition to the mentioned external audits, there are also external audits of the quality of education and training, which are occasionally conducted by the European Maritime Safety Agency (EMSA).

The fact is that the Faculty of Maritime Studies Kotor has been following all the prescribed standards properly for more than two decades has been confirmed by regular certification or recertification.

However, this paper aimed to explore how familiar our present students and seafarers (former students) are with the standards, the STCW Convention, the IMO Model Courses and the Quality Management System in general. A part of the negative results will undoubtedly be the basis for further analysis because of the fact is that, through the teaching process based on these standards, most of the students had to be better acquainted with these topics. This doesn't refer to the professional courses which are mainly made according to the appropriate IMO Model Courses, but to the courses that represent quality management in maritime affairs and various subjects where students should get acquainted with numerous Conventions, etc. That is why this negative score, regardless of the percentages shown, leaves room for additional research and activities aimed at pointing out the importance of standards in the education and training of seafarers. In addition to the awareness of STCW and IMO Model Courses, special attention should be paid to other Conventions and onboard safety procedures during the education process in order to get competent seafarers that will undoubtedly contribute to the improvement of the safety and environmental protection while onboard ships.

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Change in Perception About Stress Causing Factors of Maritime Students on Becoming a Seafarer

Mihir Chandra, R S P Singh

This qualitative and longitudinal study focuses on the change of perception of erstwhile maritime students once they start sailing. In earlier research we found multiple factors causing stress to Indian maritime students. These factors can be broadly classified either as Personal Factor, Academic Factor, Family Factor and Fear Factor. After they started sailing, they find that now their families are satisfied that he/she was right in choosing this career and they now have more realistic expectations. They are surprisingly now feeling less homesick compared to when they were maritime students. They find it easier to adjust to the food available on the ships. But they miss the social intimacy even more when onboard. They now face language barrier on ships, may be because the staff on a ship come from different cultural, ethnic national backgrounds. The workload is much more than what they had anticipated as maritime students. They also find that the competition with colleagues is much more intense than what they faced with the classmates as maritime students, as also the pressure to perform. But they get enough resources on the ship to achieve their optimum performance. However, they are not sure whether their concern about job continuity as a seafarer is higher than the job prospect anxiety as a maritime student. As regards health factors, surprisingly they are satisfied with the quantity of sleep they get. Another surprise was that they feel less threatened by pandemic on ships as compared to campuses. Two obvious findings are the fear of sailing has gone and they now feel more financially secure. We conclude that the perceptions about stress causing factors change with after becoming a seafarer. However, most of them have expressed the opinion that a full-fledged course at the campus about the factors mentioned above would have prepared them better in facing the changes which they encounter now.

KEY WORDS

Change in perception, Indian, Seafarer, Stress causing factors, Full-fledged course, Better prepared

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INTRODUCTION

For better health-related quality of life [HRQOL] 80% nutrition, 20% workout and 100% attitude is a prerequisite and it should be ameliorated with community support. However, any factor which causes stress is an impediment to the HRQOL. Stress is a natural phenomenon of emotional or physical tension due to a demand or challenge, which can come from a variety of different events or thoughts often leading to sadness, frustrations, and nervousness. Each and every person faces some or the other stress in almost every phase of their life. There are numerous factors which cause such stress. While some of the factors are omnipresent, others are unique depending upon multiple factors like age, gender, profession. Also, our perception about the factors which may cause stress in the forthcoming stages may or may not be the same. As students, our perception about stress causing factors after joining a job may be same or different from the reality. In an extensive literature review, some of which have been cited below, it is evident that a lot of research has been conducted about the academic stress of maritime students as also the stress factors of seafarers. But apparently, no study has ever been undertaken to find the change in perception about stress causing factors of maritime students on becoming a seafarer. This research is an attempt to fill that gap.

Through a structured questionnaire, consisting of 6 demographic and 16 ordinal variables, responses were collected online from Indian seafarers. A total of 235 responses were received out of which 219 were found to be valid. This data was analyzed using Microsoft Excel. Analysis of the data indicates that the perception about factors causing stress to seafarers as a maritime student change dramatically once they become seafarer themselves.

LITERATURE REVIEW

Academic self-efficacy is important both in moderating the effect of stressors on perceived stress for college students and in predicting academic success (Zajacova, Lynch and Espenshade, 2005). The traditional approach used by MET institutes to admit students who are trained to become seafarers is increasingly becoming deficient in the face of the growing labour crisis within the global shipping industry. When the expectations of students are not understood, it may consequently lead to the poor management of their career aspirations which may result in attrition from ships to landside jobs when they become seafarers (Caesar and Cahoon, 2015). Parental expectation is one of the factors responsible for students' underachievement and low performance, but it can be managed by appropriate training of students in dealing with factors causing academic stress (Haider, 2022).

In the traditional maritime countries, there is an apparent reluctance on the part of young people to choose seafaring as a profession. And even for those young people who do make that choice, their careers at sea are often short as they are either unwilling or unable to take on higher duties or, even more importantly, they actively chose not to remain at sea (Sasirekha and Ramani, 2013). The nationality of seafarers is changing from traditional maritime states to developing countries in the Asian region and they are not accorded the same respect and value previously bestowed on their predecessors, then the shipping industry may face shortage of qualified, competent, and dedicated (Sena et al., 2003).

There is excessive consumption of highly processed food, sugar, salt, alcohol, and saturated fats whereas consumption of fish, vegetables, and fruit is insufficient. Overeating and an unbalanced diet are often accompanied by stress and a lack of physical activity. These are also true about the seafarers (Jezewska et al., 2009). There is an overall supply of meat, fat and eggs, whereas the proportions of fruits, vegetables, dairy products and cereals are much lower than recommended.

Thus, for future health intervention programs, it is a necessity to include the quality of the food supply as well as information about a healthy diet and adequate food selection. And in case of mixed crews, culture-specific differences should also be considered (Zyriax et al., 2018).

New seafarers face many psychophysical stressors in daily life on a ship which may be because of the lack of respective education, it is thus recommended that stress management and diversity training in intercultural communication be included in the higher education of future superiors on board (Jensen et al., 2020). Seafaring is associated with mental, psychosocial, and physical stressors. The most important factors were separation from family, loneliness on board, fatigue, multi-nationality, limited recreation activity, and sleep deprivation. Also, the stressors affecting seafarers working in the engine room are different from those involving the deck crew (Carotenuto et al., 2012). Increased levels of illness on board ships, poor performance/productivity and unsafe working practices have all been linked to stress among seafarers (Yuen et al., 2020)

Managing the work–life balance of seafarers requires much tact and ingenuity as not all the generic flexible workplace arrangements used in the traditional human resource settings could be applied in the shipping industry. Discrimination and wage issues not only upset seafarers but may also lead to stressful and traumatic episodes for them with work-family conflicts being a common outcome of the chains of reactions that ensue (Livingstone Divine Caesar, 2018).

Job satisfaction is correlated with job performance of seafarers. In addition, the amount of stress associated with working onboard a ship, attractiveness of rewards, dispositions of seafarers and appeal of the job design are the key determinants of job satisfaction (Yuen et al., 2018).

From the above literature review, it is evident that much research has been conducted about the academic stress of maritime students as also the stress factors of seafarers. But apparently, no study has ever been undertaken to find the change in perception about stress causing factors of maritime students on becoming a seafarer. This research is an attempt to fill that gap.

SIGNIFICANCE OF THE STUDY

The purpose of conducting this research is to understand the change in perception about the stress causing factors of the Indian seafarers when maritime students start seafaring. It will help the maritime institutes to take actions which apprise the students about the stress causing factors more realistically. It will also help the seafarers to handle stress in a better way, if they find that the reality is closer to what they have thought about it as maritime student.

OBJECTIVES OF THE STUDY

The main objective of this study is to study change in perception of maritime students about the stress causing factors of the Indian seafarers once they themselves become one of them.

RESEARCH METHODOLGY

Change in perception is best studied using Q methodology which provides a foundation for thesystematic study of subjectivity, a person's viewpoint, opinion, beliefs, attitude, and the like. There are two different methods followed by researchers:

Method I: This approach is appropriate for assessing the changes in perceptions between two different conditions of instruction applied to the same subjects. The changes are assessed using a factor analysis on the differences between the Q-sorts from the two conditions of instruction.

Method II: This method examines the changes in perception from a baseline Q-analysis. This is usually appropriate when data are collected at two time-points, e.g., before-after situations, where the first assessment is considered as the baseline. In this approach, a by-person factor analysis is conducted on the baseline Q-sorts (condition 1) and factors are identified. Then, the changes in perceptions are assessed for the subjects loaded on any factor from baseline using the Q-sorts from condition 2.

For our research, we use Method I. There are five basic steps in setting up this methodology:

- Definition of the domain of discourse on the issue.
- Development of the set of statements (Q-sort).
- Selection of the participants representing different perspectives.
- Q sort by participants.
- Analysis and interpretation.

To achieve the objectives of this research, which is exploratory research based on primary data, data was collected online through questionnaire-based survey using Google forms. The data so collected was analyzed for change in perception about various factors which cause stress to Indian seafarers.

DATA COLLECTION AND ANALYSIS

The questionnaire consisted of two parts- the first part asked participants to record their demographic details, viz., Gender, Current rank, Course, Batch, and the Campus they attended as maritime student. The second part included a list of 16 questions which causes stress to them. The questionnaire was based on a five-point Likert scale, and respondents were asked to indicate the importance of 17 listed variables on this five-point Likert scale. On this scale, 1 corresponds to ‘strongly disagree’ and 5 to ‘strongly agree’, with 2,3 and 4 corresponding to disagree, neutral and agree respectively.

A total of 235 responses were received, some of which were duplicate. After removing the duplicates, 219 responses were found to be valid. Out of the total valid responses, only 3 were female and 216 males. Of them, 206 are Deck cadets, 11 are Engine cadets, 1 third officer and 1 junior officer. Otherwise, there is not much difference in terms of other demographic factors and hence the entire group has been analyzed as a single homogeneous group.

Results

Analysis of the valid responses resulted in the following outcome:

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	5	2.28%	2.28%
Unsatisfied	1	0.46%	2.74%
Not sure	5	2.28%	5.02%
Satisfied	28	12.79%	17.81%
Highly satisfied	180	82.19%	100.00%
Total	219	100.00%	

Table 1. How satisfied are your Parents/Guardian on your joining this job? (Source: Researchers' analysis)

Inference: From Table 1, we can conclude that most of the parents of the newly joined seafarers are satisfied with the decision of their ward to join the job.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	1	0.46%	0.46%
Unsatisfied	1	0.46%	0.91%
Not sure	5	2.28%	3.20%
Satisfied	33	15.07%	18.26%
Highly satisfied	179	81.74%	100.00%
Total	219	100.00%	

Table 2. Your parents'/Guardian's expectation from you are now more realistic? (Source: Researchers' analysis)

Inference: From Table 2, we can infer that most of the expectations of the parents from their ward are now more realistic.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	9	4.11%	4.11%
Unsatisfied	174	79.45%	83.56%
Not sure	4	1.83%	85.39%
Satisfied	26	11.87%	97.26%
Highly satisfied	6	2.74%	100.00%
Total	219	100.00%	

Table 3. You are feeling more homesick compared to when you were a maritime student. (Source: Researchers' analysis)

Inference: Table 3 indicates that most of them are feeling less homesick compared to their campus life. It is surprising and the reason may be the adaptation to live separately from their families.

Response	**Frequency**	**Percent**	**Cumulative Percent**
Highly unsatisfied	9	4.11%	4.11%
Unsatisfied	174	79.45%	83.56%
Not sure	4	1.83%	85.39%
Satisfied	26	11.87%	97.26%
Highly satisfied	6	2.74%	100.00%
Total	219	100.00%	

Table 4. I am finding it more difficult to adjust to the food available on ship compared to the Indian Maritime University's campus. (Source: Researchers' analysis)

Inference: From Table 4, it appears that the new seafarers don't find it difficult to adjust to the food available on ship.

Response	**Frequency**	**Percent**	**Cumulative Percent**
Highly unsatisfied	8	3.65%	3.65%
Unsatisfied	12	5.48%	9.13%
Not sure	2	0.91%	10.05%
Satisfied	187	85.39%	95.43%
Highly satisfied	10	4.57%	100.00%
Total	219	100.00%	

Table 5. I miss the social intimacy more than that on the campus. (Source: Researchers' analysis)

Inference: As one can expect, Table 5 indicates that the newly joined seafarers miss the social intimacy more than that in the campus.

Response	**Frequency**	**Percent**	**Cumulative Percent**
Highly unsatisfied	16	7.31%	7.31%
Unsatisfied	21	9.59%	16.89%
Not sure	4	1.83%	18.72%
Satisfied	173	79.00%	97.72%
Highly satisfied	5	2.28%	100.00%
Total	219	100.00%	

Table 6. I face more language barriers than on the campus. (Source: Researchers' analysis)

Inference: From Table 6, it is evident that the newly joined seafarers face more language barrier than those in the campus. It is not surprising as the staff on the ships come of different nationalities.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	5	2.28%	2.28%
Unsatisfied	42	19.18%	21.46%
Not sure	3	1.37%	22.83%
Satisfied	63	28.77%	51.60%
Highly satisfied	106	48.40%	100.00%
Total	219	100.00%	

Table 7. The workload is more than what I had anticipated. (Source: Researchers' analysis)

Inference: From Table 7, it is evident that most of the newly joined seafarers find the workload on ships higher that what they had anticipated. In fact, it happens in most jobs.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	11	5.02%	5.02%
Unsatisfied	51	23.29%	28.31%
Not sure	5	2.28%	30.59%
Satisfied	40	18.26%	48.86%
Highly satisfied	112	51.14%	100.00%
Total	219	100.00%	

Table 8. Competition with colleagues is more intense than the competition with classmates at the campus. (Source: Researchers' analysis)

Inference: From Table 8, we find that competition for new seafarers with colleagues is more intense than the competition with classmates at the campus may be because in jobs better performance may lead to promotions before others whereas for students it is just a matter of ranking unless they fail.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	3	1.37%	1.37%
Unsatisfied	42	19.18%	20.55%
Not sure	4	1.83%	22.37%
Satisfied	60	27.40%	49.77%
Highly satisfied	110	50.23%	100.00%
Total	219	100.00%	

Table 9. Pressure to perform is more intense than the academic pressure at the campus. (Source: Researchers' analysis)

Inference: From Table 9, it is evident that the new seafarers feel that the pressure to perform in job is much more intense than the academic pressure in student life.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	9	4.11%	4.11%
Unsatisfied	187	85.39%	89.50%
Not sure	5	2.28%	91.78%
Satisfied	12	5.48%	97.26%
Highly satisfied	6	2.74%	100.00%
Total	219	100.00%	

Table 10. The resources are inadequate for my optimum performance. (Source: Researchers' analysis)

Inference: From Table 10, it is evident that the new seafarers feel that the resources available on ships are adequate for their optimum performance. It is a very positive factor which contributes to their increased productivity.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	1	0.46%	0.46%
Unsatisfied	19	8.68%	9.13%
Not sure	176	80.37%	89.50%
Satisfied	19	8.68%	98.17%
Highly satisfied	4	1.83%	100.00%
Total	219	100.00%	

Table 11. Job continuity concern as a seafarer is higher than the job prospect anxiety as a maritime student. (Source: Researchers' analysis)

Inference: Table 11 indicates that the new seafarers are still not sure whether job continuity is more stressful than the job prospect anxiety as a maritime student. It may be because they are too new to make real comparisons. It may or may not change with time.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	2	0.91%	0.91%
Unsatisfied	170	77.63%	78.54%
Not sure	2	0.91%	79.45%
Satisfied	29	13.24%	92.69%
Highly satisfied	16	7.31%	100.00%
Total	219	100.00%	

Table 12. I get less sleep as a seafarer than as a maritime student. (Source: Researchers' analysis)

Inference: From Table 12 it appears that the newly joined seafarers are comfortable with the sleeping time available to them. It is against the general perception and maybe they spent more time studying as maritime students.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	4	1.83%	1.83%
Unsatisfied	165	75.34%	77.17%
Not sure	7	3.20%	80.37%
Satisfied	32	14.61%	94.98%
Highly satisfied	11	5.02%	100.00%
Total	219	100.00%	

Table 13. Fear of pandemic in ships is more than on the campus. (Source: Researchers' analysis)

Inference: Table 13 shows that the newly joined seafarers feel safer on ships compared to campus, as regards the fear of pandemic. The reason for this perception may have roots in the high number of inhabitants in campus. Secondly, they have experienced the real threat while residing in the campus which has not been a major concern after they moved to ships.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	2	0.91%	0.91%
Unsatisfied	0	0.00%	0.91%
Not sure	6	2.74%	3.65%
Satisfied	34	15.53%	19.18%
Highly satisfied	177	80.82%	100.00%
Total	219	100.00%	

Table 14. Fear of sailing has now gone. (Source: Researchers' analysis)

Inference: Table 14 indicates that the fear of sailing, which might have been there in their student life, has almost fully disappeared. It is natural when they are sailing in the sea round the clock.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	0	0.00%	0.00%
Unsatisfied	2	0.91%	0.91%
Not sure	2	0.91%	1.83%
Satisfied	25	11.42%	13.24%
Highly satisfied	190	86.76%	100.00%
Total	219	100.00%	

Table 15. You now feel more financially secure. (Source: Researchers' analysis)

Inference: From Table 15, it is evident that more than 98% of the new seafarers feel financially secure. It is logical too that when someone starts earning, he/she feels financially more secure.

Response	Frequency	Percent	Cumulative Percent
Highly unsatisfied	1	0.46%	0.46%
Unsatisfied	2	0.91%	1.37%
Not sure	12	5.48%	6.85%
Satisfied	30	13.70%	20.55%
Highly satisfied	190	86.76%	100.00%
Total	219	100.00%	

Table 16. Feel that a full-fledged course at the campus about the factors mentioned above would have prepared more in facing the stress-causing factors. (Source: Researchers' analysis)

Inference: From Table 16, it is emerging that there is a strong case for starting a full-fledged course at the campuses which prepares the maritime students for facing the stress causing factors to be faced by them when they start sailing.

FINDINGS AND DISUSSION

Though a lot of research has been conducted on stress causing factors to students, as also the seafarers. However, we fail in finding any study analysis of the change in perception about factors causing stress among maritime students and the factors which cause stress to them once they become a seafarer. This research has provided an insight into how the perception about the stress causing factors among seafarers change once maritime students themselves join a ship as seafarers. Some changes which emerge from this study are:

- They are feeling less homesick compared to their campus life. It is surprising and the reason may be the adaptation to live separately from their families.
- They could easily adjust to the food available on ships as compared to adjusting for it when they shifted to campus from their home. This may be because of gradual acclimatization.
- Newly joined seafarers miss the social intimacy more than that in the campus. This may be because of fewer colleagues available on ships as compared to students on a campus.
- New seafarers face more language barrier than that in the campus. It is not surprising as the staff on ships come from different nationalities.
- Most of the newly joined seafarers find the workload on ships higher than what they had anticipated. This happens in most jobs, offshore or onshore.
- Competition for new seafarers with colleagues is more intense than the competition with classmates at the campus. Also, they feel that the pressure to perform in a job is much more intense than the academic pressure in student life. This may be because in jobs better performance may lead to promotions before others whereas for students it is just a matter of ranking unless they fail.
- New seafarers feel that the resources available on ships are adequate for their optimum performance. It is a very positive factor which contributes to their increased productivity.
- New seafarers are still not sure whether job continuity is more stressful than the job prospect anxiety as a maritime student. It may be because they are too new to make real comparisons. It may change with time.

- New seafarers are comfortable with the sleeping time available to them. It is against the general perception and maybe they spent more time studying as maritime students.
- New seafarers feel safer on ships compared to campus, as regards the fear of pandemic. The reason for this perception may have roots in the high number of inhabitants on campus. Secondly, they have experienced the real threat while residing on the campus which has not been a major concern after they moved to ships.
- The fear of sailing, which might have been there in their student life, has almost fully disappeared. It is natural when they are sailing in the sea round the clock.
- Now that they have started earning, they now find themselves more secure.
- Most of new seafarers believe that a full-fledged course at the campuses preparing them for the factors which cause stress to seafarers would have prepared them well to face them.

The results of this study may help Maritime Institutes to prepare students closer to the reality of seafaring life. It will also help maritime students to have a feel of what is going to change when they start sailing. This may help in mitigating the stress during the transition from maritime student to seafarer.

LIMITATIONS OF THE STUDY

This study was conducted on the online data collected from Indian seafarers only who have been students of Navi Mumbai and Chennai campuses of Indian maritime University. The findings may differ if the data is collected offline as also if seafarers from other campuses and countries are also included.

SCOPE FOR FUTURE RESEARCH

This research has conclusively proved that the perception about stress causing factors indeed change once students start their career. Future research may be conducted on differences in perception by different genders, different universities, different qualifications, and even different professions.

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Computer Vision for Autonomous Vehicles

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The aim of the study is to show how students can participate in experiments that are related to cutting-edge technologies. Edge detection method was explored in order to detect lines at road. Hence, the possible application is in the lane keeping in road transport or in autonomous vehicles. The work includes recording of real situations, which are analyzed later, but at real-time speed. The results section presents operation at real situations when there are no problems and when there are problems, which are discussed. Autonomous vehicles, AI, and machine learning are present in ever day life. In this paper, initial stage is presented for a part of autonomous vehicles – computer vision in lane detection. Further research should include situation awareness at real-world scenes. Used algorithm does not provide sufficient results in curved roads, but with additional experiments and development, it has a potential of improvements. Efficiency of the algorithm is a product of many factors, which should be considered during programming. Detection problems are caused by too much illumination, sudden change of the illumination (i.e. entrance/exit from the tunnel), running to the shadowed part of the road (binary margin filter does not operate with the same quality), etc. Adaptive thresholding could solve some of the problems. In such case, illumination should be measured, which should be an input to the definition of filter margins.

KEY WORDS

Lane keeping assistance, Computer vision, Traffic, Autonomous vehicles.

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INTRODUCTION

Knowledge and technology transfer should play important role in education of highly educated engineers able to success in Industry 4.0. Due to rapid advancement in vision systems, such knowledge should be incorporated in Faculty curriculum. Vision systems, as powerful tool, are useful in automated vehicles. Hence, this paper deals with usage of video analysis and application in automated cars. At 5-year study level, we cannot expect (and this is not necessary) from students to obtain the best results in the world, but to learn about problem, choose approach that fits to their abilities and their problem, and to repeat results from others. In that manner, the work obtained here is exactly that. However, since we were not interested in obtaining better results, but to transfer knowledge how to approach to some problem, we defined our goal in showing situations with problems in real-world video sequences. The final goal is that such results help scientists to generate referral databases with such problems. The addressed problem deals with systems for lane detection as a part of larger system for driving assistance. It alerts a driver about leaving the lane. Goal of such systems is to reduce number of traffic incidents caused by human error. Error can be result of tiredness, change in focus, loss of attention, etc. Such systems can be divided into three groups (Liu et al, 2019):

- lane departure warning (LDW),
- lane keeping assist (LKA/LKS), and
- lane centering assist (LCA).

This work will be used in exercises of new subjects at 5th year of Study for Marine Electrical Engineering and IT (MEEIT). There are: Maritime robotic systems (5th year, the last semester) and Visualization in autonomous maritime systems (5th year, the winter semester). Overall idea and algorithms for lane detection as a part of bigger system will be cover in the Maritime robotic systems. Video processing part of algorithms for lane detection will be included in the Visualization in autonomous maritime systems, such as edge detection, transformations in images, pre-processing, etc. Therefore this “experiment” with student preparing his master thesis (5 years Bologna, not MSc) plays vital role in understanding difficulties of students and professors for such task (Šimunović, 2019). The aim of the paper is to link research and ability to copy existing technologies (or algorithms) to educational process. Such aim does not imply novelty, but implementation of state-of-the-art technologies or algorithms.

The paper is organized as follows. The second section is literature overview. Methodology and used algorithm is addressed in the third section. Results are presented in the fourth section. The last section presents conclusions.

LITERATURE OVERVIEW

Line detection is the most important step in lane detection/following algorithms. Yim and Oh (2003) used Hough transform and vectors with three characteristics to detect lines and prediction of the current vector. It was tested on roads under rainy weather and with multiple shadows. The advantage is that it is not necessary to have a priori information about the road. Sehestedt et al. (2007) used detection based on weak model. Tracking was performed by clusterisation filter. Estimation is robust. This algorithm is suitable for strait roads. Aly (2008) used Hough transform and random sample consensus (RANSAC) to detect lines. This algorithm is not suitable for urban areas with a lot of vehicles and pedestrial crossing. Borkar et al. (2009) also used Hough transform in combination with iterating filters. Tracking was used by Kalman filters. This algorithm is robust to disturbances. The main disadvantage is in absence of line in the scene, which results in low performance of the algorithm. As it can be seen, the Hough transform is standard tool for line detection.

Guo et al. (2010) used Catmull Rom spline to detect lines in the scenes. This algorithm is robust to various weather and illumination conditions. Gopalan et al. (2012) detected lines by learning using particle filters. However, the algorithm is based on static movement model. Yoo et al. (2013) used adaptable Canny edge detector to preprocess the input frame. Advanced model with Hough transform was used to detect lines. This algorithm is robust to changes in illumination. It is suitable for all roads. Ozgunalp and Dahnoun (2014) used Hough transform to detect lines, and Kalman filter to track lines. This algorithm is robust to shadows, and can be used under night. It is suitable for all roads. Cutting edge algorithms in this field use ANNs (i.e. in (Ye et al., 2018; Patel et al., 2017; Guan et. al., 2016)), fuzzy logic (i.e. in (Arce et al., 2017)), PCA (i.e. in (Quach et al., 2018; Gupta and Choudhary, 2017), feature extraction (i.e. in (Xing et al., 2018; Wang and Wang, 2018; Li et al., 2018; Zeisler et al., 2017)), or SVM (i.e. in (Nguyen et al., 2017; Woo et al., 2017)). CNN is used in (Ye et al., 2018). It uses fitting tracking, Kalman filter, and particle filter. This results in high accuracy and results in better detection of curved lanes. Accuracy on the tested frames is 98%. Ellipsoidal Neural Networks with Dendrite Processing (ENNDPs) (Patel et al., 2017) was used to automatically detect lanes in urban highways. Another approach was to use Canny operator in combination with Hough transform as preprocessing for CNN (Guan et al., 2016). The advantage of this algorithm is in higher recall and accuracy. Presented accuracy of around 90.7%.

Interesting combination was presented in (Arce, 2017), when fuzzy c-means was used for segmentation, and hybridization of the additive Hough transform with artificial bee colony edge detection for detecting curve lanes. The result is better straight and curve lane detection. PCA was used to obtain low computational hardware platform in (Quach et al., 2018). Another PCA approach was presented in (Gupta and Choudhary, 2017). This algorithm used spatio-temporal incremental clustering. Accuracy is around 95% on tested images. Histograms of oriented gradients, SVM Classifier, and Kalman filter was combined in (Nguyen et al., 2017). This algorithm detects straight as well as curved lanes with accuracy of 96.3%. Similar combination, but Kalman filtering and SVM Classifier was used in (Woo et al., 2017). Obtained accuracy was about 98.1%. Next group of approaches to the problem are approaches with feature extraction. Feature extraction, model fitting, and Random Sample Consensus (RANSAC) technique (Xing et al., 2018) is the approach that is reported to have better computation efficiency, and high accuracy. An approach that incorporates Hough transform and Kirsch operator along with feature extraction (Wang and Wang, 2018) results in enhanced robustness and adaptability of the detection. The computational complexity of the algorithm is reduced by the matrix operation. Kalman filter, Hough transform, feature extraction, color extraction is the approach used in (Li et al., 2018). This approach results in better accuracy and faster processing speed. Accuracy of this approach is 95%. Approach with feature extraction presented in (Zeisler et al., 2017) detects lanes in different environment conditions successfully.

Median strip detection approach, along with lane change detection approach, and smart use of spatio-temporal information provided by the embedded sensors technology is proposed in (Lioris et al., 2018). Lane departure warning system (LDWS) algorithm, Canny's algorithm, and Hough transform technique are combined in (Cario et al., 2017). High accuracy and robustness against noise and model imperfection are the advantages of such approach. Canny edge detection algorithm and Hough transform was combined in (Dang et al., 2017) to obtain faster processing speed. Gabor filter, Hough transform method, Sobel operator, and least squares algorithm (Gao et al., 2017) is the approach for systems that operates in real-time efficiently. This also enhance the adaptability for the changing environment of road scene. Accuracy on the tested videos in 93%. Hough transform and morphological operations is relatively simple approach (Kodeeswari and Philemon, 2018) for detection of straight as well as curved roads of hilly areas using vision-based techniques. However, that simplicity results in only 81.67% accuracy in detection. Hough transform with Sobel operator results in better accuracy (96%) (Yelwande and Jahagirdar, 2019).

Interesting novel approach is to use image processing algorithms, such as morphological operations (i.e. bwareaopen in Matlab) to enhance the input signal to the driver assistance systems (Taher et al., 2018). This procedure removes all connected components (objects) that have fewer than P pixels from the binary image BW. Several techniques for lane detection are explained and compared in details in (Ramarao et al., 2019). A method using several Euclidean-distance-related parameters to calculate vehicle's position and its deviating status is proposed in (Liu et al., 2019). Intelligent vehicles algorithm for lane detection is presented in (Cao et al., 2019). Lack of ground truth data and uniform metrics make difficult the evaluation of the lane detection system, which poses the challenge (Xing et al., 2018).

A complete pipeline is proposed in (Cudrano et al., 2020), which includes single image retrieve of data required by a vehicle lateral control system: road line equation, centreline, vehicle heading and lateral displacement. The algorithm in (Riera et al., 2019) permits detection of driver lane departures into left or right lanes from continuous lane detections. A lane tracking method based on progressive probabilistic Hough transform is proposed in (Marzougui et al., 2020). The algorithm operates with 21.54 ms/frame. It also uses Adaptive region of Interest (AROI) and prediction of next frame. Deep residual network is used in proposed machine learning-based mechanism to identify drivers' unintended lane-departure behaviours, and simultaneously predict the possibility of driver proactive correction after slight departure (Gao et al., 2020).

An image processing-based method for lane detection has been proposed in (Shashidhar et al., 2022). The method includes Gaussian filtering, Canny edge detection, and Hough transform. A novel LLDNet (Lightweight Lane Detection) is presented in (Khan et al., 2022). It is based on an encoder–decoder architecture that is lightweight and has been tested in adverse weather as well as road conditions

METHODOLOGY AND EXPERIMENTAL SETTINGS

Since processing of huge video material in real time requires high processing power, the most often used hardware are graphical processors like Nvidia. Figure 1 shows a flow chart for the algorithm for line tracking. Firstly, color space is transformed to gray. Then image is blurred. Canny edge detection is performed.

Canny edge detection algorithm can be broken down to five different steps: Gaussian filtering, gradients calculation, lower bound cut-off suppression, double threshold to determine potential edges, and track edge by hysteresis. The equation for a Gaussian filter kernel of size (2k+1)×(2k+1) is given by:

$$H_{ij} = \frac{1}{2\pi\sigma^2} e^{\left(-\frac{(i-(k+1)^2+(j-(k+1)^2))}{2\sigma^2}\right)} \qquad (1)$$

After Canny edge detection, ROI (Region of Interest) is defined. Hence, Hough transform to obtain lines is executed to obtain the output. Hough transform is designed for feature extraction and, especially, for line/curve detection (Marzougui et al., 2020).

Camera is attached to the middle of the car's windshield. Therefore, a vehicle has the same point of view range as the alternate car's driver. Consequent problem is the illusion that road is narrowing, which can result in an-precise results of the video processing. Hence, different point of view is necessary. The solution is in transformation from driver's to birdseye view (Palazzi et al.,2017; Lee et al., 2019). Birdseye view is the prior requirement for better lane detection, and, consequently, for better car driving.

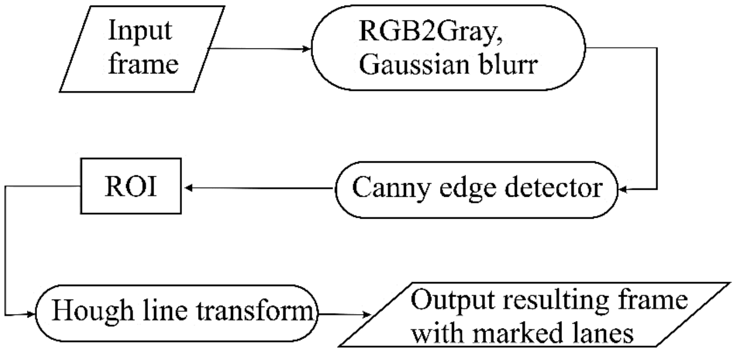


Figure 1. Algorithm for detection of lane margins.

In order to execute transformation of the view point, fix points should be defined. Computer vision packages (i.e. OpenCV) demands to define such points in clockwise direction. Moreover, it is important that resolution of the original and the transform frame should be the same. To change perspective, there is no need for development of new functions or formulas.

Sector scanning detects white pixels, which should be lines at the road, which are extracted from the binary filter. The method consists of a few steps. Sector scanning is based on sliding window search. It functions in a way to highlight wanted frame characteristics by some filter. Then the sliding window is defined. This window slides through the frame and records positions with desired characteristics. Figure 2 shows an overview of the used algorithm. It can be described in 5 steps:

- The input frame is transformed to so called "bird perspective" (birdseye view), which means that the frame view look like seeing from the sky.
- If the color space is not appropriate to the functions in software package, the color space is changed.
- Signal filtering.
- Sector scanning for lines.
- Output – frame with traced lane.

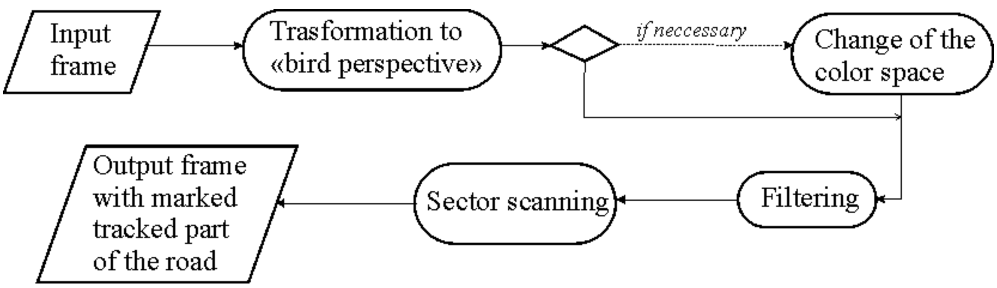
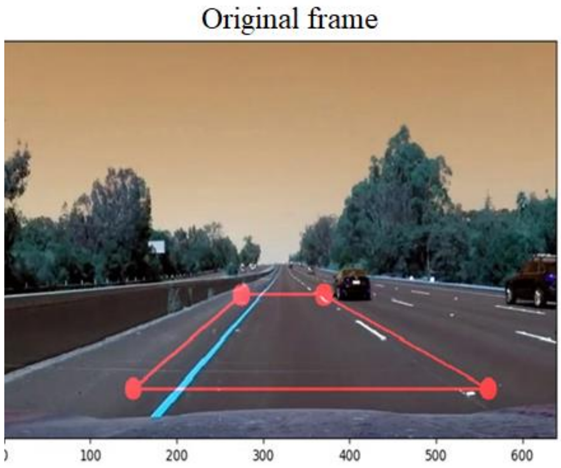
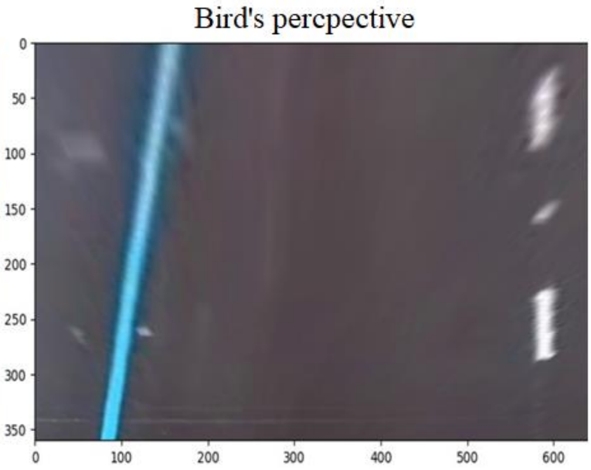


Figure 2. General overview of the implemented algorithm.

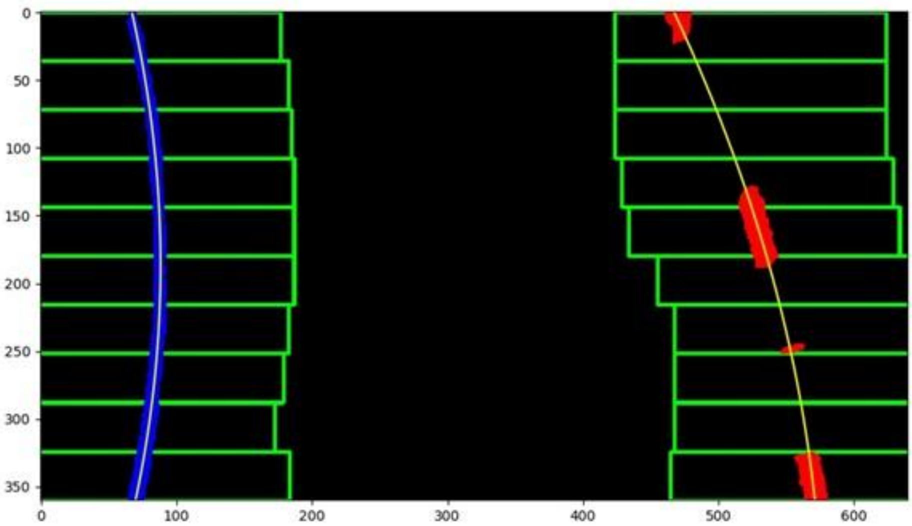
Figure 3 shows important steps in the execution of the algorithm. Figure 4 shows results of the histogram analysis for black and white result of line detection. Full line has higher amplitude, which is expected.



a)



b)



c)

Figure 3. Operation of the algorithm: a) ROI, b) detecting lines, c) tracking lines by sectors in frame.

RESULTS

Experiments are performed in real-world scenes by attaching a camera to a car. Analysis software is implemented in Phyton.

Figure 4 shows how the thesis algorithm works. Operation of the algorithm is relatively better in urban environment due to higher level of road development. However, it also needs improvements. Figures 4. a, b show correct lane detection. Figure 4.c shows wrong lane detection. It is possible that car in the other lane confused the detection algorithm. Alternatively, it could be because of increased gradient by houses near the road, which are of the similar color to road's lines.

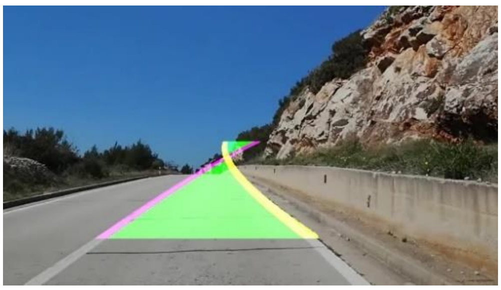

a) b)

c)

Figure 4. Example of operation for urban road.

In order to better illustrate operation and problems of the lane detection algorithm Fig. 5 is included. Fig. 5.a. shows correct operation. However, Fig. 5.b. shows that adaptable thresholding cannot distinguish between rock and old lines (not newly painted, gray instead of white). Fig. 5.c. shows confusion in line tracker due to the same reason.


a) b)



c)

Figure 5. Example of operation for island non-urban road: a) correct lane detection, b) incomplete lane detection, c) partially correct.

CONCLUSIONS

Autonomous vehicles, AI, and machine learning are present in ever day life. In this paper, initial stage is presented for a part of autonomous vehicles – computer vision in lane detection. Further research should include situation awareness at real-world scenes. Used algorithm does not provide sufficient results in curved roads, but with additional experiments and development, it has a potential of improvements. Efficiency of the algorithm is a product of many factors, which should be considered during programming. Detection problems are caused by too much illumination, sudden change of the illumination (i.e. entrance/exit from the tunnel), running to the shadowed part of the road (binary margin filter does not operate with the same quality), etc. Adaptive thresholding could solve some of the problems. In such case, illumination should be measured, which should be an input to the definition of filter margins. Example of hardware problem is in installation of the camera in the car.

Testing in various roads lead to the conclusion that it is practically impossible to generalize and produce universal algorithm (without tuning for specific roads) for all situations in real life at this time. Hence, most of the algorithms are designed for some situations, and used for assistance. Roads in Croatia are badly maintained, which discourage implementation of computer vision algorithms in real-world situations (Šimunović, 2019).

Most of algorithms are tested in arbitrary video sequences. As it is known, various sequences could be suitable for some algorithms, but not to all of it. Hence, it is necessary to establish referral database, which includes all problems, from weather and illumination changes, various types of roads and environment, etc. Only in that case, we will be sure that some algorithm is the best.

All of this can be a good example how students can get into the field of computer vision for autonomous vehicles. This paper shows that students (Šimunović, 2019) can produce interesting data for research. Student in this work performed an experiment, and transfer-knowledge programming. Situations are novel. Student learnt to produce interesting results. An objective of knowledge transfer is satisfied.

From the experiments, one can see that there are various types of algorithm failures. Some failures are fatal and emergency actions need to be executed. Some of failures are less important. Hence, failures should be classified into several groups. Further interesting thing would be to perform research about interframe change of classification (time line of failure change).

Data is publicly available at Dabar (https://repozitorij.pfst.unist.hr/) as data from the project "Establishment of reference database for studying the influence of weather conditions on marine video surveillance" (also currently at: http://brod.pfst.hr/~ivujovic/ERDBSIWCMVS_webpage.html).

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The Cyber Threat Landscape in the Maritime Sector

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The paper addresses current issues of cyber resilience in the maritime sector. The most significant malwares affecting the maritime sector and their impacts are presented. The focus is on the main APT (advanced persistent threat) groups and malicious actors involved in these types of attacks. Their signatures and methods of compromise are analyzed. The different attack surfaces they use are presented. The main motives of malicious actors to compromise different sites in the maritime industry are highlighted. Some of the issues that make the maritime industry vulnerable to cyber attacks are presented.

KEY WORDS

Cyber resilience, Malwares, Malicious actors, Compromise, Vulnerable.

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INTRODUCTION

The maritime industry has been a crucial driver of economic growth for thousands of years and remains a vital element in the globalization of world markets and economic relations between countries. Today, with a greater emphasis on global trade and commerce, shipping plays an even more vital role in connecting people and businesses around the world. The sector contributes significantly to the global economy, accounting for about 80% of global trade by volume and over 70% of its value (SDG Knowledge Hub, 2015). As the industry adapts to new technologies and developments, each new innovation implies improved efficiency and reduced costs. However, this constant evolution also brings with it new risks.

In times of peace, insider threats and cybercriminals pose the main risks to the sector, with the threat of state-sponsored cyber attacks (APT) being lower. However, during times of conflict, state-sponsored hacking groups become a serious danger, especially for countries that have direct influence over the maritime industry. The exponential increase in the number of malicious hackers puts every system at risk, and human resources are a proven, effective and common attack vector. The weakness of the human mind in recognizing malicious attempts is what makes it such a successful attack vector. Exploiting the human factor can give hackers access to valuable resources, and in the maritime sector, anyone with access to a corporate internet network and computers can be vulnerable to such attacks. Malicious and well-trained hackers can exploit such vulnerabilities to gain access to critical systems and parts that may be of interest to them. Their main goal is to carry out certain activities undetected in exchange for financial gain or to show their affiliation to a certain political cause or social trend, i.e. hacktivism.

APT groups are frequently utilized by nation-state actors to carry out cyber operations for military or intelligence purposes, encompassing domestic and foreign policy aspects, including the economic sector, which also comprises the maritime industry. While some ransomware groups, such as APT Sandworm's NotPetya, from Russia, and other smaller entities, seek financial gain through extortion, APT groups are typically associated with countries such as the United States, Israel, Russia, Iran, North and South Korea, which have integrated cyber activities into their military doctrines. Large APT groups have not traditionally targeted the maritime industry for other objectives, given the significant resources required. For such attacks to occur, a specific target is essential to provide necessary motivation. Until early 2022, such a target was lacking. The orchestrated attack on Ukraine, involving classic warfare and sophisticated tactical malware, exemplifies the potential of APT groups in warfare. Multiple targeted attacks were successful in paralyzing the Ukrainian military's information systems and damaging their primary satellite-internet links, received by Viasat's Ka-Sat satellite. This attack highlights the need for enhanced cybersecurity measures to protect against such threats to critical infrastructure.

Information infrastructures in the maritime sector are also vulnerable to such attacks, as the industry relies heavily on ground and satellite-based communication and navigation. Each component of these dependencies has been attacked, exploited, and taken advantage of at some point in the last 20 years. The concept of information security acknowledges that there is no system that cannot be hacked, and any system, no matter how sophisticated, can be hacked. The key is managing risk in a way that balances the needs for confidentiality, integrity, and availability of information with the costs and benefits of protecting it. Ultimately, the goal of information security is not to create an impenetrable fortress but to achieve a balance that effectively manages risk.

This paper will commence by highlighting the crucial role of the maritime sector and the related cyber risks. It will proceed to explore the various forms of cyber threats that can affect the industry, comprising insider threats, cybercriminals, and state-sponsored hacking groups. The analysis will delve into the diverse attack vectors utilized by these groups and the sector's vulnerabilities they exploit. Furthermore, it will evaluate the potential ramifications of cyber attacks on the maritime industry, including financial losses and reputational harm.

TYPES OF HACKERS AND HACKING GROUPS TARGETING THE MARITIME SECTOR.

The maritime sector is a complex and multifaceted industry that plays a crucial role in global trade and commerce. As such, it has become a prime target for various types of malicious hackers who seek to gain unauthorized access to its information systems and sensitive data. These hackers include cybercriminals, hacktivists, state-sponsored threats, and insiders.

Cybercriminals are individuals or groups who engage in malicious activities with the goal of financial gain. They use various methods to gain unauthorized access to a target's information systems or confidential information, allowing them to manipulate systems in ways that serve their interests. Cybercriminals have different motivations and ways of compromising, and each threat actor has its own set of tactics that distinguishes it from others. With the proliferation of modern technologies, cybercriminals have evolved and continue to develop new and more sophisticated methods of compromising their targets. One method that has become increasingly popular among cybercriminals is the use of ransomware. Ransomware is a type of malware that encrypts data or exfiltrates it, rendering it unusable until a ransom is paid. The maritime sector is particularly vulnerable to ransomware attacks because of the potential for significant financial losses resulting from a shutdown of critical port systems and related activities. Hackers who use ransomware often demand payment in exchange for the decryption key, and victims who pay the ransom may be targeted again in the future if they fail to implement measures to prevent future attacks. Another popular activity among cybercriminals is the sale of confidential documents and information. In the maritime sector, any information relating to a competitor can be highly valuable. Cybercriminals infiltrate their competitors systems, take documents or install spyware, and exchange them for money. Breaking into systems can also be crucial for drug and human trafficking, enabling the manipulation of documents for shipments, containers, and other assets useful to traffickers.

Unlike cybercriminals, hacktivists are not motivated by financial gain but instead are driven by their own beliefs and goals. They often carry out political attacks, using leading events of social phenomena that are highly exciting and socially relevant to gather sympathizers, funds, and even cause social riots. The skills of hacktivists vary, ranging from script kiddies to former NSA employees. They often rely on events to provoke them, making their structure unstable and their skills and actions questionable in the future. Typically, they use the leading events of certain social phenomena that are highly exciting and socially relevant. This helps them to gather sympathizers, funds and even cause social riots. Their absence from the public sphere and reliance on events to provoke them makes their structure unstable and calls into question their skills and actions further into the future. A typical example of hacktivists is WikiLeaks and the Anonymous group. A typical example of hacktivist attacks on the maritime industry is Operation OpSaveTheArctic (The Register, 2012). This hacking attack involved the leaking of emails and passwords of companies such as Exxon Mobil, Shell, BP, Gazprom and Rosneft. This attack was the work of hacktivist Le4ky, part of the Anonymous group. The attack comes after Greenpeace protests against oil drilling in the Arctic. This indicates the relationship of hacktivists to social waves and trends.

State-sponsored threats, on the other hand, are highly sophisticated and dangerous. These advanced persistent threat (APT) groups operate at the highest level and are known for their ability to remain undetected for extended periods of time. More than 150 APT (Deloitte, 2016) groups are known to be involved in various fields, including the maritime sector. Their aim is to commit data extortion or infiltrate systems, often remaining undetected for months or even years. Unlike conventional hacking and malware attacks, which operate for a few days or weeks, APTs can operate for months or even years without being detected. Hence their name - attacks that are sophisticated in terms of their persistence on the victim's network or system. Their methods typically focus on writing special tactical malware, exploiting unknown exploits and vulnerabilities in systems, and high-level reconnaissance. The resources at their disposal are at a high level, which increases the extent of their reach. When considered in the context of the maritime sector, Chinese APT 10, Russian FIN7, North Korean Lazarus Group, Iranian APT 42, and Vietnamese OceanLotus are commonly discussed. At the highest level, are APT groups directly linked to state institutions or are their branches. Examples include the Federal Security Service (FSB), including FSB Center 16 and Center 18, the Russian Foreign Intelligence Service, the Main Intelligence Directorate of the Russian General Staff (GRU), the 85th Main Center of Special Services, the GRU Main Center of Special Technologies, the Russian Ministry of Defense (CISA, 2022) and US’s Equation Group (NSA). Their interests may vary depending on the objectives of the countries they serve. Some APT groups, such as Lazarus, FIN7, and APT42, are focused on ransomware campaigns aimed at raising capital for the countries they serve. Few of the most lucrative campaigns specifically targeted the maritime industry, the work of the North Korean WonnaCry and Russian NotPetya. Over the past year, APT groups have also proven to be an effective method of waging cyber warfare. Their effectiveness is also determined by how they get their information.

Sometimes intelligence requires too many resources to get the job done. Sometimes it takes someone who knows the systems well and knows how they can be penetrated. These people are willing to assist in opening doors into the system or provide important information about how defenses can be breached. These workers are called insiders and their numbers are growing exponentially. They may sell company secrets, compromise sensitive data, or sabotage critical systems. Their goal is to benefit financially from the information or service they are willing to offer. Often, it's a large sum that makes it such a successful tactic. Knowing the perimeter and its peculiarities, insider threats can evade detection and cover their tracks perfectly. This nearly seamless bypassing of defenses saves hackers resources and allows them to penetrate the company more easily. These dangerous characteristics and their increasing prevalence make insider threats one of the major cybersecurity concerns, and the maritime industry has yet to address them. While external threats such as cybercriminals are often in the spotlight, insiders pose an equally significant risk. According to a Ponemon Institute report (Proofpoint, 2022), in the past year, the time it takes to detect insider threats has increased from 77 days to 85, and those that take longer than 90 days cost an average of $17.19 million in losses on an annual basis. Preventing insider threats requires a multi-pronged approach. Organizations must carefully screen potential employees and contractors, conducting thorough background checks and vetting processes to ensure that they are trustworthy and have a low risk of engaging in malicious activity. Once individuals are hired or given access to sensitive systems, they should be closely monitored and audited to ensure that they are not misusing their access privileges. Among the most notable examples is the hacker group Lapsus$. The Lapsus$ (KrebsOnSecurity, 2022) group is known for their successful insider attacks, which involve the use of compromised employee accounts or other insider information to gain access to sensitive data and networks. Trough insiders managed to infiltrate companies such as Nvidia, Okta, Samsung, and Microsoft.

APT GROUPS IN THE CONTEXT OF TACTICAL CYBER. THE END GOALS.

The cohesion achieved by modern society predisposes to these types of malicious activities. The majority of critical infrastructures in the maritime sector are connected and communicate in some way through the global internet. This creates the necessary conditions for the management of systems, data, and controls. However, when building these systems, the right cybersecurity decisions need to be made. Cybersecurity may not be urgent at the time the infrastructure is being built, but in the future, cybersecurity and risk management are crucial. Besides the underthought of a cyber resilience strategy, incompetently built networks are another big problem. When built, connected to the global network, and configured by incompetent individuals, it poses a significant risk to the service, network, and infrastructure. In addition, dealing with newly discovered vulnerabilities and exploits requires the expert knowledge of cybersecurity professionals, who are hard to find, especially early in the development of such vulnerabilities. These issues contribute to the perception of the internet as insecure and problematic. Consequently, states with developed intelligence and counterintelligence capabilities are beginning to create strategic state-sponsored hacking groups to exploit these weaknesses. To understand the ultimate goals of an APT, it is important to examine the targeted sector and conduct a deep threat analysis of its actions. APTs typically target critical infrastructures, technology and engineering firms, political systems, and organizations to obtain patents, newly discovered technologies, and other sensitive information through cyber espionage. APT attacks are based on the classic Cyber Kill Chain created by Lockheed Martin, which outlines the steps taken by hackers to achieve their goals. However, APTs take the Cyber Kill Chain to the next level by applying their tactics and methodologies atypical of other threat actors. They can use their technological prowess to evade detection, cover their tracks, and conceal their identities. The consequences of APT attacks can be severe, as they can cause significant damage and disruption to the targeted sector. This template description may also apply to the maritime sector, with different tactics varying between sectors, but the main targets remain. The focus of APTs can be divided into several categories.

Tactical Intelligence and Tactical Risk Operations.

Gathering classical intelligence information on an adversary's forces, infrastructure, and attack plans provides a crucial advantage during warfare, but comes at a high cost to states, both financially and in the lives of their agents. To address this problem, states are increasingly turning to tactical espionage malware that is not only cost-effective but also eliminates risk to agents or informants. Using malware to gather tactical information and assess the potential risk posed by a country is a key application of this technology. Government agencies, such as the NSA, deploy ROCs. Government-affiliated APT groups, such as those of the Russian government, may also be responsible for conducting these activities. Their primary purpose is to gather intelligence and determine the capabilities of other countries in various sectors, such as military or academic. Of particular interest to the United States is China, which was the primary focus of some of the earliest U.S. ROCs and NTOCs (NSA Archive, 2014). In these cases, the goal was to obtain tactical intelligence by using malware and cyber attacks to gain access to academic and military facilities.

Sabotage.

Sabotage is a key objective in military operations aimed at paralyzing an adversary by compromising its critical infrastructures and institutions. The strategic importance of this task requires the integration of malware as a tool to achieve the goal. Although existing sabotage methods are effective, they are limited in scope, complex to plan, and difficult to carry out. In contrast, using cyber weapons such as malware provides a cheaper, faster, and nearly unlimited approach. Malware such as Stuxnet can impact critical infrastructures that are difficult to reach using conventional warfare, because it has access to locations that no soldier can reach. The lower the level of action, the greater the potential for damage. Therefore, the use of malware as a means of sabotage presents a powerful opportunity to impact an adversary's critical infrastructure.

Destabilizing the economy.

A popular tactic of attackers is to target vital companies and government bodies in order to extort monetary ransoms or impose conditions. Although a relatively new phenomenon, this approach is rapidly gaining popularity due to its effectiveness. Such attacks often use ransomware, a type of malware that encrypts data. The term "Ransomware as a Service" (RaaS) has been coined to describe this method, which is used by countries such as North Korea and Iran to generate funds to support their authoritarian regimes. Such attacks have repeatedly caused global economic paralysis in recent years, with examples such as WannaCry, Petya, GandCrab, and Black Basta racking up billions in ransoms.

Violation of political sovereignty: Propaganda and fake news.

Recently, there has been a significant increase in the number of hacking attacks during political elections in several countries around the world. It should be noted that these tactics do not always involve direct interference in the electoral process. Instead, a relatively new and increasingly popular approach involves the dissemination of fake news and the promotion of radical propaganda to manipulate the psychological attitudes of the public towards particular issues or individuals. The main aim of this approach is to influence public opinion about a political candidate or program, often with far-reaching consequences.

AI'S IMPACT ON THE THREAT LANDSCAPE.

As cyberattacks continue to evolve and become more sophisticated, it is crucial for organizations to constantly assess and improve their cybersecurity strategies. One way to do this is by leveraging emerging technologies such as machine learning and artificial intelligence. When a malware is detected, it not only poses a threat to the targeted organization but also presents an opportunity for cybersecurity experts to improve their defense and response strategies (ENISA, 2020). By analyzing the behavior of malicious files, early detection and remediation can be achieved. Combining this with traditional antivirus programs can provide an advantage over new and unknown malware. The use of machine learning and artificial intelligence-based tools can further enhance an organization's ability to keep up with ever-evolving cyber threats. These tools can automate threat detection and response, enabling organizations to respond more effectively than with traditional software-based approaches.

Furthermore, artificial intelligence can be used to identify the strengths and weaknesses of an organization's security measures and anticipate potential vulnerabilities. Unfortunately, this technology can also be leveraged by cybercriminals to develop intelligent malware that can evade detection and respond more effectively to cyber defense. As a result, this may enhance their overall ability to evade detection and strengthen their malicious intent. The implications of AI in the realm of malware are best exemplified by the work of IBM researchers. During the 2018 Black Hat conference (BlackHat, 2018), Dhilung Kirat, Jiyong Jang, and Marc Ph. Stoecklin introduced DeepLocker (Security Intelligence, 2018), a next-generation malware that employs existing AI models in conjunction with conventional malware techniques to create an exceptionally formidable form of malware.

The first line of action is to be hidden behind a seemingly ordinary application. The second line of action is that this AI-powered evasive malware masks its malicious intent until it identifies a specific victim, then executes its harmful actions using indicators such as facial recognition, geolocation and voice recognition. The third line of action is that through the application of a Deep neural network model, which functions as a "black box" that hides the trigger conditions. A basic "if this, then that" trigger condition is transformed into a complex convolutional network of the AI model. The utilization of AI by DeepLocker makes its trigger conditions highly challenging to reverse engineer, as the malicious payload remains locked until it reaches the intended target. IBM researchers have demonstrated the ability to conceal the WannaCry ransomware using these methods, effectively facilitating its spread.

As emerging AI tools such as ChatGPT are becoming more prevalent, it is crucial to consider the potential ramifications of a malware equipped with artificial intelligence, capable of combining the impacts of NotPetya (Industrial Cybersecurity Pulse, 2018). The potential consequences could be catastrophic, highlighting the importance of proactively addressing cybersecurity threats in the maritime sector. To mitigate the risk of such catastrophic consequences, it is imperative that the maritime industry implements a comprehensive cybersecurity strategy that includes the harnessing of emerging AI tools for threat detection and response. This should be complemented with regular employee training on cybersecurity best practices, and the use of robust encryption protocols and access control mechanisms to limit unauthorized access to sensitive data.

CONCLUSION

The maritime sector is an essential aspect of the global economy as it serves as the primary means of transporting goods, people, and services around the world. The exponential growth of this sector is driven by the integration of new information technologies, automation processes and support systems. However, However, the adoption of these technologies has also made the sector attractive target for cybercriminals, hacktivists, and state-sponsored threats. Malicious actors use a range of tactics to gain unauthorized access to a target's information systems, and they do so with different objectives. Some hackers do so for financial gain, while others aim to carry out malicious activities in support of an anti-political or social trend. The most dangerous are state-sponsored threats, such as APT groups, which may conduct activities in aspects of domestic and foreign policy, including economic sectors such as the maritime industry. While external threats pose a significant risk to the maritime sector, there is also the issue of insider threats. Insider threats can serve the interests of all other malicious actors, regardless of their end goal. These actors already have access to internal systems and protocols, making it easier to breach defenses and providing them with a direct way to attack internal systems. Given the ever-evolving cyber threats and the increasing interconnectedness of the maritime industry, the importance of cyber defenses cannot be overstated. The maritime sector must remain vigilant and proactive in its approach to cyber defense, focusing on identifying and mitigating risks and implementing effective cyber security measures. In addition, training staff to recognize and respond to cyber threats is essential. Continuous adaptation and threat hunting should be a top priority for all components of the maritime sector. Implementing advanced technologies and protection methods is critical to combating hackers, who are always one step ahead. The industry must prioritize and dedicate sufficient resources to maintain robust cyber defenses to ensure the continued growth and prosperity of the maritime sector.

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Application of Satellite-Derived Bathymetry in Hydrographic Activity of the Republic of Croatia

Nenad Leder[1], Tea Duplančić Leder[2]

Hydrography is the branch of applied sciences that deals with the measurement and description of the physical features of oceans, seas, and coastal areas. Sea depth measurements were primarily carried out for the purposes of navigation safety, especially in shallow coastal areas. Historically, bathymetry was mapped based on ship soundings when different types of depth sounders were used. The International Hydrographic Organization (IHO) has "tightened" the minimum standards of horizontal and vertical accuracy of the bathymetric survey in different orders of the survey over time. In the Republic of Croatia, the Hydrographic Institute of the Republic of Croatia carries out a hydrographic survey including a survey of the sea depths, without legal obligation to apply the satellite-derived bathymetry (SDB) method which is significantly cheaper than the expensive acoustic method of measuring sea depths. The main aim of the paper is to obtain information about the possibilities of the SDB method to meet the demanding standard of bathymetric measurement in the coastal mapping area of the Republic of Croatia, up to 20 m deep, i.e. up to depth areas where the largest number of ports and access waterways are located. The purpose of the article is to increase the safety of navigation of ships in the coastal area of the Republic of Croatia. Three SDB methods for determining sea depth are presented: optical, SAR sensors, and altimeter bathymetry. The basic technical characteristics of the satellite missions used in the paper and the spatial resolution and accuracy of the satellite images are described. Furthermore, the results of all published scientific papers that used all three SDB methods for the marine area under the jurisdiction of the Republic of Croatia are presented. The results of the research show that an extremely small number of scientific papers have been published that use SDB methods applied in Croatian territorial waters. It is concluded that all SDB methods presented in this paper do not satisfy the International Hydrographic Organization (IHO) Standards for Hydrographic Surveys S-44 (2020). This means that the results of SDB depth determination methods presented for the Croatian part of the Adriatic Sea have, until now, only scientific value and cannot be used for the publication of official nautical charts.

KEY WORDS

Hydrographic surveying, Satellite imagery, Coastal mapping, Croatia.

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INTRODUCTION

According to the definition of the International Hydrographic Organization (IHO, 2010), which is implemented in the Croatian "Law on hydrographic activity (2014)", "hydrography is the branch of applied sciences that deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes, and rivers, as well as with the predictions of their change over time, for the primary purpose of safety of navigation." Croatian Law on hydrographic activity (article 2) defines that "Hydrographic activity is the branch of applied science that covers survey of the depths of sea, rivers and lakes, geodetic survey and other surveys of structures in the coastal area, in the sea, on the seabed and under the seabed; marine geodesy; oceanography (recording of the sea level oscillations, surface waves, sea currents, and thermohaline parameters), marine geology and geophysics, environmental protection in the parts of the sea under the sovereignty of the Republic of Croatia, and in the exclusive economic zone and the continental shelf over which the Republic of Croatia has sovereign rights and jurisdiction". Furthermore, in article 5 it is defined that "Hydrographic Institute of the Republic of Croatia shall carry out hydrographic survey including: survey of the sea depths, marine geodesy, geodetic survey and other surveys of structures in the coastal area, in the sea, on the seabed and under the seabed, marine geology and geophysics, and oceanography".

It should be pointed out that the term "survey of the sea depths" primarily means bathymetric measurement of sea depth using the acoustical method when different types of depth sounders were used. As can be seen in the "Law on Hydrographic Activities" from 2014, the Satellite-derived bathymetry (SDB) method of determining sea depths was not defined, although it is relatively cheap in comparison with the acoustical method of measuring depths that have been very expensive.

Thematic nautical chart 101G "Adriatic Sea – the Republic of Croatia boundaries on the Adriatic Sea" is shown in Figure 1.

The main goal of the article is to obtain information about the possibilities of the SDB method to meet the demanding standard of bathymetric measurement in the coastal mapping area of the Republic of Croatia, up to 20 m deep, i.e. up to depth areas where the largest number of ports and access waterways are located. The article's purpose is to increase the safety of navigation of ships in the coastal area of the Republic of Croatia.

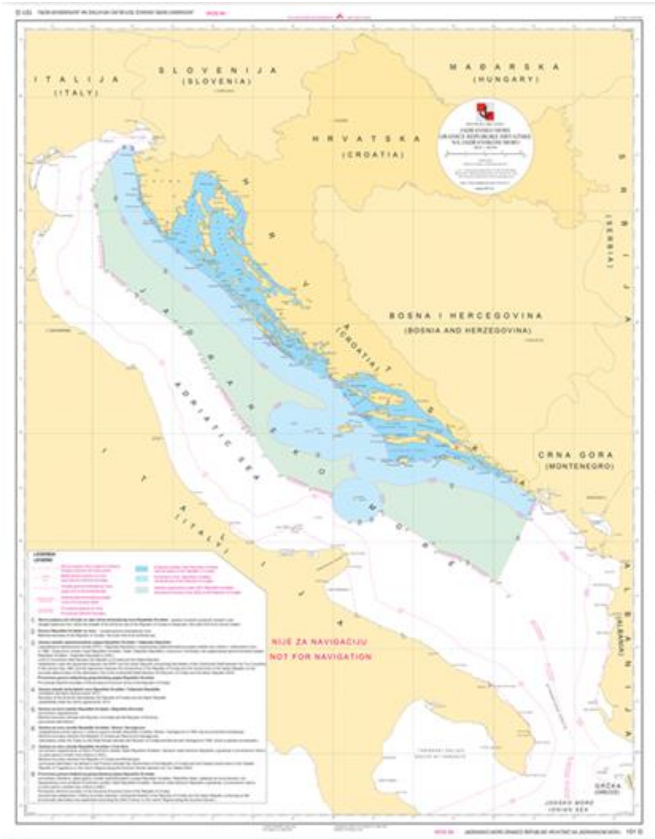

Figure 1. Thematic nautical chart 101G: Adriatic Sea – the Republic of Croatia boundaries on the Adriatic Sea (Source: Hydrographic Institute of the Republic of Croatia, 2021).

SATELLITE-DERIVED BATHYMETRY (SDB) METHOD

The concept of single-image Satellite-derived bathymetry (SDB) began in the late 1960s, and it has been investigated by international hydrographic offices over the past five decades (Ashphaq et al., 2021). Bathymetry has historically been expensive due to the need for on-site collection methods, making it very costly. The acquisition technique of bathymetric data has evolved from a shipborne platform to airborne (airplanes, helicopters, and Unmanned Aerial Systems (UAVs) of all types) and space-borne (active or passive satellites) acquisition. In recent times satellite-derived bathymetry, a rapid and cost-effective method has appeared that determines shallow-water bathymetry from space or satellite sensors. This is a physics-based method suitable for use in calm clear waters, while in the shoal and adjacent waters where the water was turbid or larger waves were present, this method derived a low noise. The accuracy of the method is also influenced by image atmospheric correction. There are three such remote sensing methods: optical satellite remote sensing method or optical SDB, SAR sensors SDB and radar altimeter or Altimetry SDB (Figure 2). Bathymetry products range from Optical Bathymetry (high-resolution images used for shallow water) and Synthetic Aperture Radar (SAR) Bathymetry (moderate resolution images for intermediate water depths) to Altimetry Bathymetry (for deep and open oceans with low resolution, benefits satellite data are free or cheap) (Ashphaq et al., 2021).

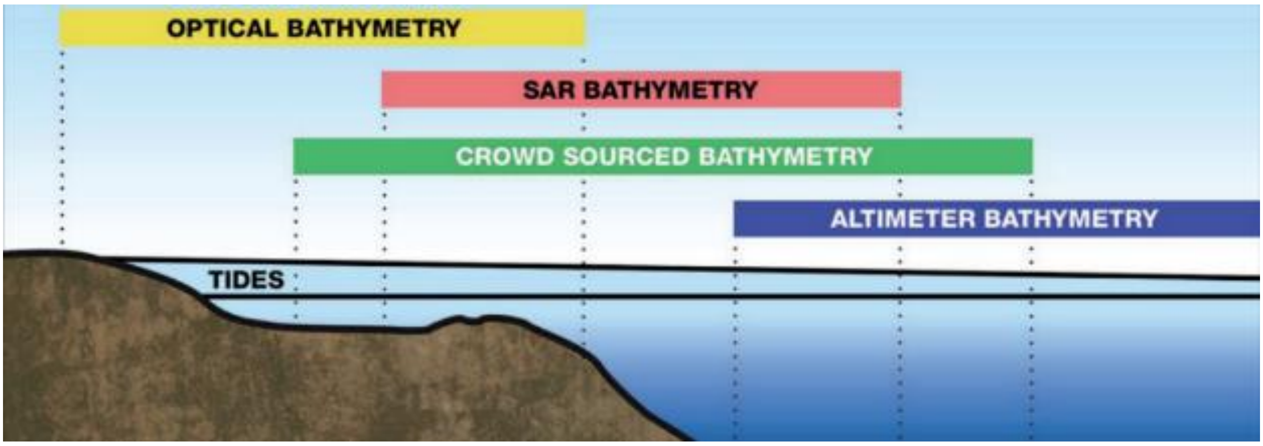

Figure 2. Depth ranges of the different SDR techniques: optical bathymetry cover shallow waters, SAR bathymetry medium depths while altimeter bathymetry covers the deepest areas (Source: Hartmann et al., 2017).

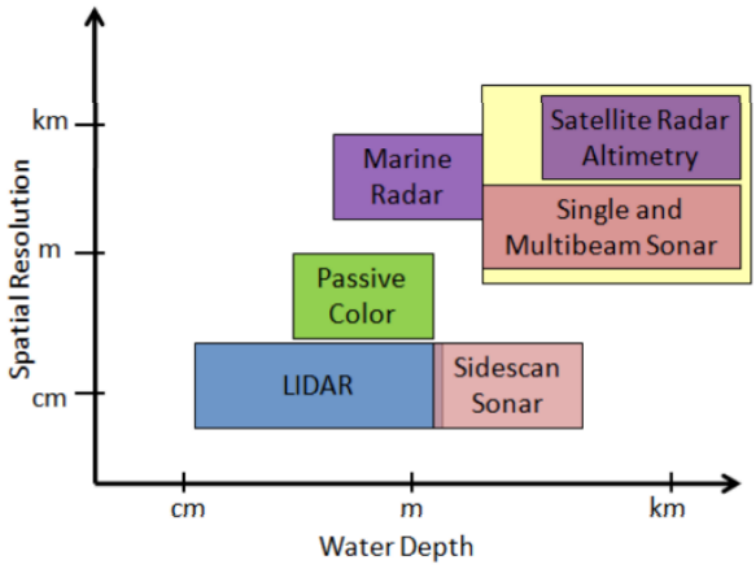

Figure 3. Schematic showing the applicability of different techniques for estimating bathymetry in terms of spatial resolution of measurement and the range in water depths that can be sampled. The yellow box indicates the datasets that are integrated and interpolated to form the global gridded bathymetry datasets at 1 arcminute resolution (Source: Dierssen and Theberge, 2014).

Optical SDB uses the multispectral satellite image data of multiple missions (e.g., Sentinel-2) and physics-based inversion methods to determine water depth from seafloor reflectance intensities at different wavelengths. With this method, depths can be determined from 0 to 30 m, and results depend on an image’s spatial resolution, which can range from 1 m to 30 m. The maximum water depth mapped by optical SDB is similar to the maximum penetration depth of sunlight and varies by season and location. Company EOMAP declares, based on their experimental research, the following mapping depths: Red Sea (20–30 m), Gulf region (5–15 m from north to south), Mediterranean Sea (20–30 m), Baltic Sea (2–15 m from north to south), Caribbean Sea (20–30 m), US West Coast (5–15 m) and Pacific region (20–30 m) (EOMAP, 2023).

Synthetic Aperture Radar SDB is a method of collecting data that allows the middle level of the sea and the calculation of the Earth's acceleration fields of gravity, which are basic geodetic tasks in the formation of the geoid surface. SAR SDB uses the SAR data of multiple missions (e.g., Sentinel-1 and TerraSAR-X) and waves shoaling effects (wavelength reduces in shallow water) to determine the depth that ranges from 10 to 100 m with a spatial resolution of up to ~100 m (Strump et al., 2003; Hartmann et al., 2017). As radar rays cannot penetrate directly the ocean surface to determine the seabed topography, so SAR used the so-called "shoaling effect" that causes the waves shorter and steeper as they approach shallow waters, so there is a direct relationship between waves and depths. The waves are then determined by the fast Fourier transformation (FFT) and data filtering, so it is possible to automatically analyze the radar scene. The algorithm for SAR bathymetry use multiple missions: DLR's TerraSAR-X and ESA Sentinel-1 data, as well as data from other SAR satellite mission which can also be used for this method.

The altimeter SDB method uses altimeter satellite data (e.g., Jason-1 and Sentinel-3 A) from satellite missions that measure changes in gravity affecting sea surface levels caused by large underwater structures (~10 km to 200 km), and based on these measurements, they determined, or rather assumed, the depths of deep waters with a spatial resolution of 1 km (Lyzenga, 1985). In the last 40 years, there have been and still are many satellite altimetry missions (Figure 4).

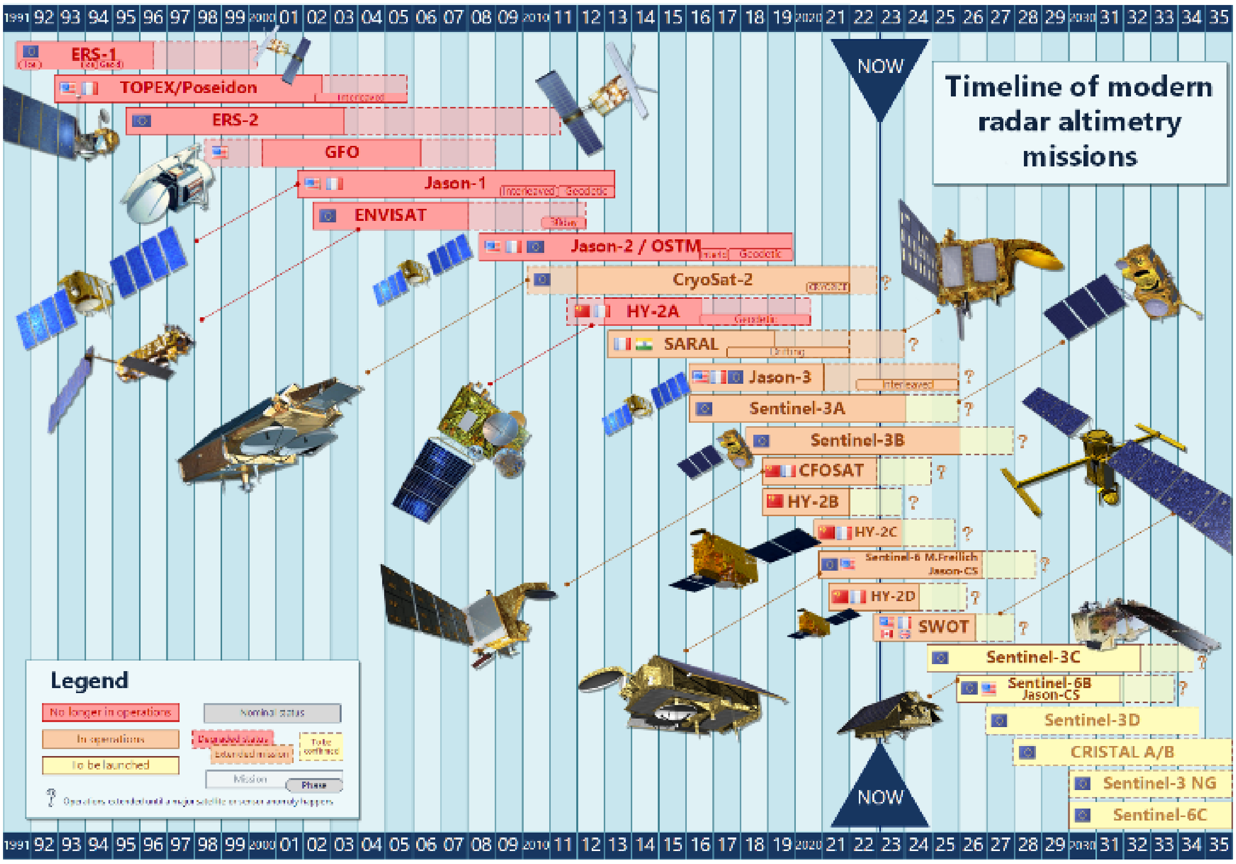

Figure 4. 50-year timeline of former, current, and planned altimetry mission (Source: Grgić et al., 2020).

RESULTS OF THE SDB METHOD IN THE REPUBLIC OF CROATIA

Optical SDB

One of the first articles in which the optical SDB method was used in the area of inland waters of the Republic of Croatia was published by Duplančić Leder & Leder (2017). In this article, the SDB method was applied by using Landsat 8 satellite images on December 2016 to get bathymetric data in the area of Kaštela Bay in the Middle Adriatic. The procedures and algorithms of SDB processing, as well as the reconnaissance tool, were taken from Gao (2009). The bathymetry algorithm was calculated according to Stumpf et al. (2003). By comparing the "preliminary" bathymetric map shown in Figure 5 with Electronic nautical chart 47 (Hydrographic Institute of the Republic of Croatia) it can be seen that generally depth gradients and coastline are very well surveyed by using the SDB method, while individual shoals are not detected because of low spatial resolution of the SDB method. It was concluded that the optical SDB method is suitable for the bathymetric survey of shallow areas with clear water (approximately to the depth of 2 Secchi disc depth).

The influence of the optical characteristics of seawater in the Adriatic Sea on the results of the SDB method is analyzed in the paper by Duplančić Leder & Leder (2018).

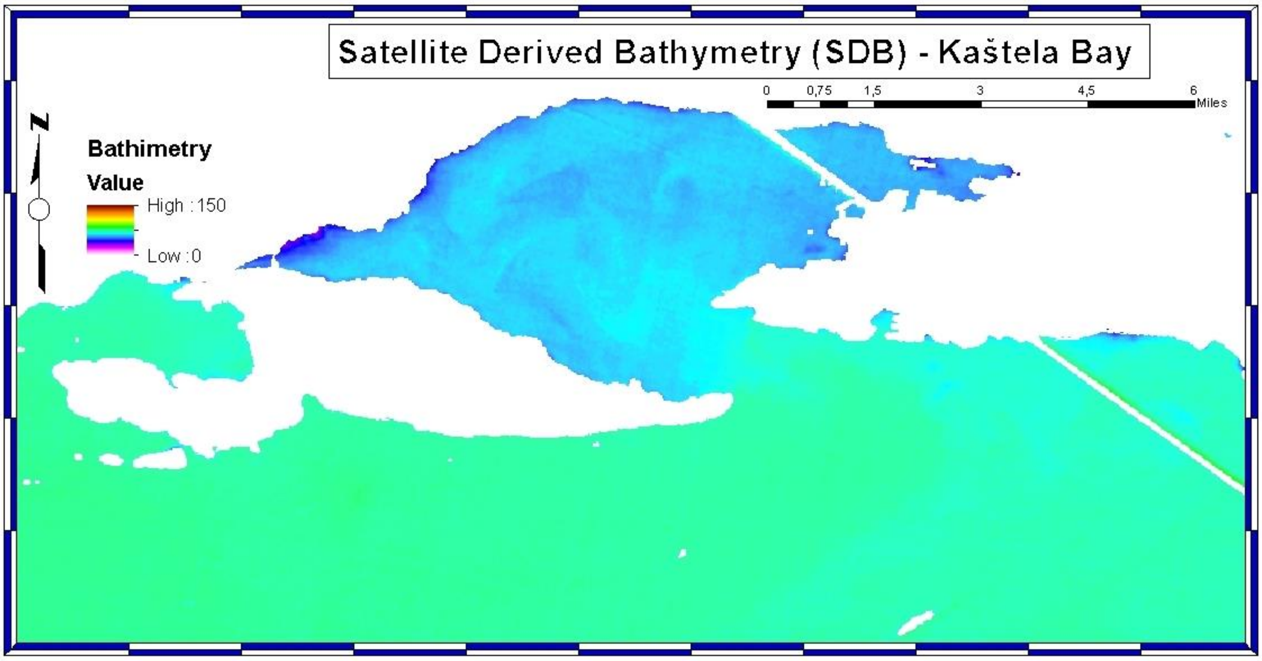

Figure 5. Optical SDB of Kaštela Bay (Source: Duplančić Leder & Leder,2017).

Duplančić Leder et al. (2019) obtained similar results and conclusions for the area of Hramina Bay in the Middle Adriatic (Figure 6).

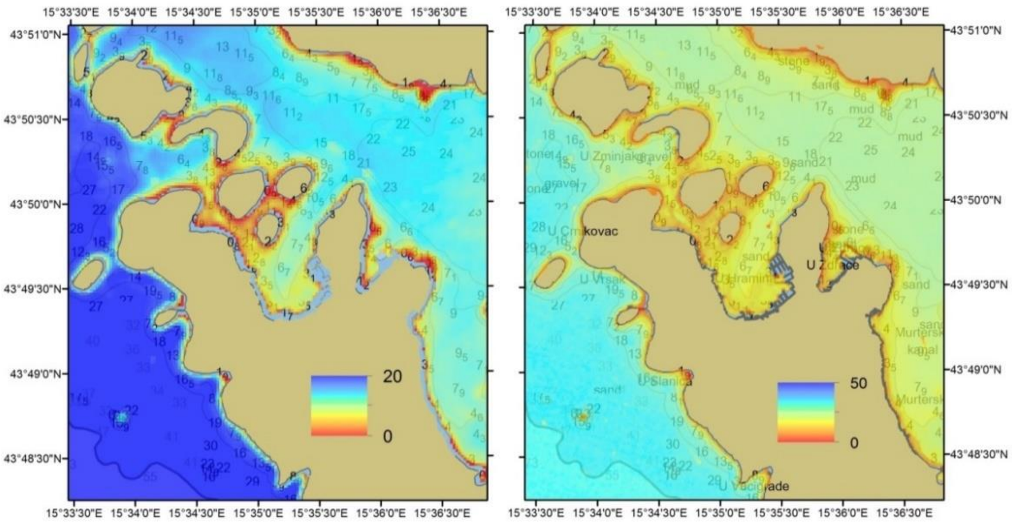

Figure 6. Satellite-derived water depth of Hramina Bay was obtained from Landsat 8 (left) and Sentinel 2 (right) (Source: Duplančić Leder et al., 2019).

The result of studying the SDB method on the Murter channel area (Figure 7) and two free-of-charge satellite missions were presented in the article for FIG Working Week 2020 conference. Article: *Duplančić Leder, T. & Leder, N. (2020) „ Optimal Conditions for Satellite Derived Bathymetry – Case Study of the Adriatic Sea"*, was proclaimed for Article of the Month - May 2021. In this article SENTINEL 2 satellites free of charge data are used to estimate the sea depths in the wider area of Murterski Kanal channel in the middle Adriatic Sea. SDB method which is founded on analytical modeling of light propagation from sensors through the atmosphere and the water column and back was used, because scientific oceanographic research indicated this area as oceanic optical water type II where the euphotic zone reaches below 45 m. It is concluded that the depth gradients and coastline are actually very well surveyed by using the SDB method, while individual shoals are not revealed because of the low spatial resolution of the SDB method.

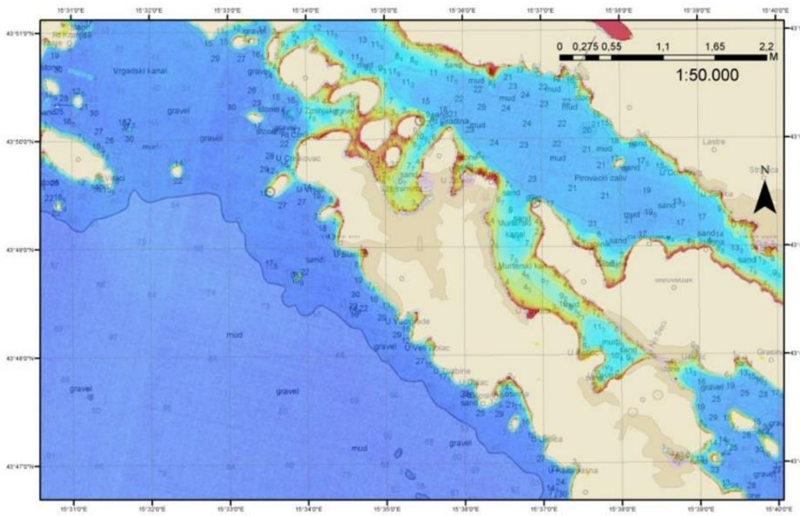

Figure 7. Satellite-derived water depths in the Murterski Kanal channel were obtained from Sentinel 2 satellite images on 03 January 2020 (Source: Duplančić Leder & Leder, 2020).

Landsat 8 and Sentinel-2 multispectral imagery MSI were used to estimate channel the bathymetry of the shallow coastal area around Medulin Bay in the North Adriatic using the log-ratio method (Vrdoljak & Kilić Pamuković, 2021). Both satellites have passive optical sensors. The result of the

Stumpf (2003) formula applied to blue and green channels was the Pseudo depth (Figure 8a). The results of the SDB algorithm were two models of a coastal marine area with depths shallower than 20 meters: Landsat 8 with 30 m resolution and Sentinel 2 (Figure 8b) with 10 m resolution.

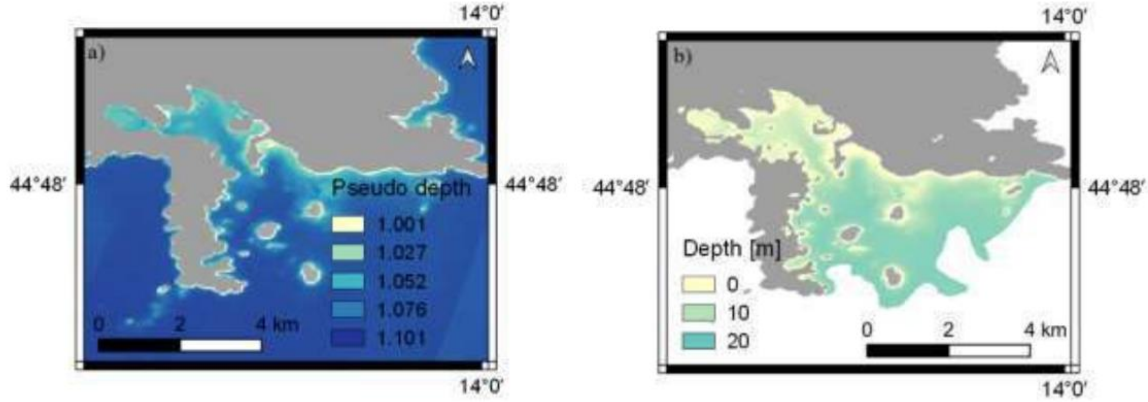

Figure 8. Satellite-Derived Bathymetry using Sentinel 2 images: a) Pseudo depth, b) 10 m bathymetric model (Source: Vrdoljak & Kilić Pamuković, 2021).

Results of the assessment of AC processors for SDB retrieval and the switch model from Sentinel-2 MSI of the Šibenik channel in the middle Adriatic are presented in Figure 9 (Vrdoljak & Kilić Pamuković, 2022).

Sen2Cor algorithm designed by the European Space Agency was applied for atmospheric correction to model the atmospheric path of the electromagnetic signal. The empirical log band ratio algorithm was applied to a time series of Sentinel-2 MSI in the middle Adriatic. It was concluded that although the accuracy of the SDB is still not comparable to the classic bathymetric techniques, this research demonstrated it can be improved by the choice of AC processor and optimal spectral bands.

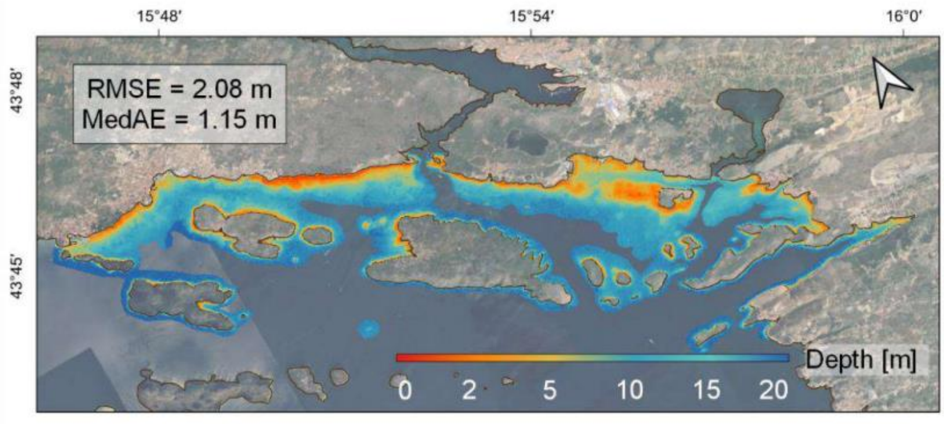

Figure 9. Switch SDB model of the Šibenik channel covering depth range 0-20 m estimated from Sentinel-2 image acquired on 30 September 2017 using the LBR algorithm with band combinations with blue, green, and red bands (Source: Vrdoljak & Kilić Pamuković, 2022).

Synthetic Aperture Radar (SAR) SDB

A study of literature on the topic of SAR SDB has been conducted, but no scientific papers have been found for the area of the eastern part of the Adriatic Sea.

Altimeter SDB

Vrdoljak & Bašić (2022) estimated bathymetry of the Adriatic Sea from altimeter-derived gravity anomalies. Figure 10 shows digital bathymetry models estimated from altimeter-derived gravity anomalies: (a) DTU10 (global ocean tide model) DBM15 (Digital Bathymetric Model) – (Bathymetry model from Space Institute of the Technical University of Denmark), (b) SS DBM15 (Smith and Sandwell Digital Bathymetric Model), and (c) absolute differences between models. It needs to be emphasized that the digital bathymetry model of the Adriatic Sea was estimated with 1/16 arc-minute grid spacing (gravity-geologic method GGM + Digital Bathymetric Model DBM) from the DTU10 model (Technical University of Denmark) of marine gravity anomalies by the GGM method. The model was augmented by depth soundings from the EMODnet grid (The European Marine Observation and Data Network) in the West Adriatic and nautical charts in the East Adriatic. GGM + DBM is well adjusted to the topography of the Adriatic Sea, with an RMSE of 13 m. As compared to modern shipborne bathymetric surveys, bathymetry estimated from altimetry has a coarse spatial resolution and lower accuracy, especially in coastal areas. The greatest discrepancies between the global grids and the GGM+ DBM are along the eastern Adriatic coast due to altimetry limitation and diverse input bathymetry. As compared to chart soundings, this model had the lowest accuracy in the coastal area shallower than 20 m.

Quality increased up to 10% of the depth in the deepest parts of the Adriatic, but it still does not meet Standards for Hydrographic Surveys S-44 Edition 6.0.0 (2020) for *"Order 2 area of the survey"*.

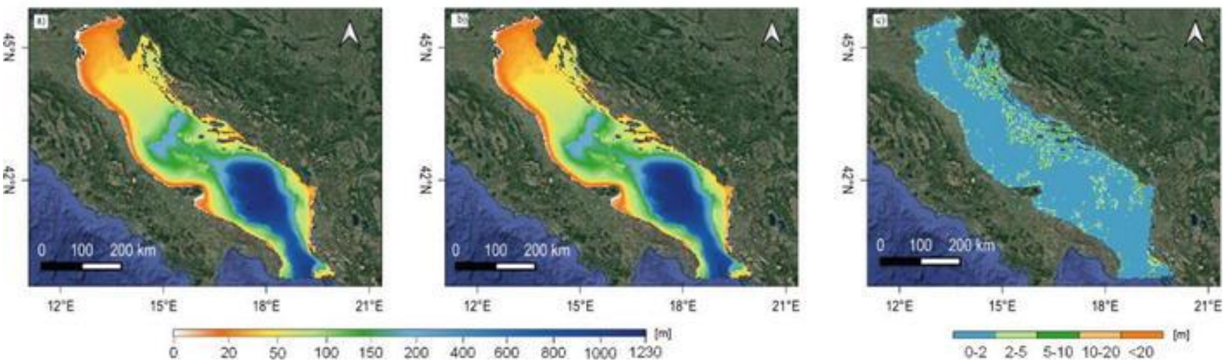

Figure 10. Bathymetry model of the Adriatic Sea produced from altimetry data (Source: Vrdoljak & Bašić (2022).

DISCUSSION

According to our knowledge, there is no published article to date that systematically and quantitatively evaluates the scientific development of the articles referring to shallow and deep water satellite-derived bathymetry (SDB) along the Croatian part of the Adriatic Sea.

In this article, three different optical SDB methods were analyzed in the shallow coastal area of the Republic of Croatia (Figures 5 to 9) and it is obvious that the accuracy of the methods does not meet current IHO Standards for Hydrographic Surveys—S-44 Edition 6.0.0 (2020) for "Order 1 area of the survey" where multibeam echo-sounder (MBES) data typically met the quality of data: positional data accuracy of ±5 m + 5% with respect to depth and vertical or depth accuracy of ±0.50 m + 1% with respect to depth.

Synthetic Aperture Radar (SAR) bathymetry method, which is commonly used for intermediate water depths (Figure 2) was not applied along the Croatian part of the Adriatic Sea.

Altimeter SDB was applied to estimate the bathymetry of the Adriatic Sea from altimeter-derived gravity anomalies (Figure 10). As compared to chart soundings, this model had the lowest accuracy in the coastal area shallower than 20 m. In the deepest parts of the Adriatic Sea quality of the model increased, but it still does not meet Standards for Hydrographic Surveys S-44 Edition 6.0.0 (2020) for *“Order 2 area of the survey”*.

The application of SDB methods in the Croatian part of the Adriatic began in 2017 and is relatively new. However, in the world's scientific literature, new SDB methods have recently been developed, such as, for example, the machine learning method (e.g. Zhou et al., 2023).

CONCLUSION

Primarily the purpose of depth measurement was safe navigation, and it was later used for many other applications. Historically, bathymetry was mapped based on ship soundings when different types of depth sounders were used. This “acoustical” method of measuring depths has been very expensive. Since even today large parts of the oceans and seas (including the Adriatic Sea) in the coastal zone, which is the most important for surface navigation, are un-surveyed or have been surveyed with inadequate methods, new "electromagnetic" methods of bathymetric surveying have been researched since the 1970s. In this paper, we discussed the Satellite-Derived Bathymetry method (one of many known electromagnetic methods) applied in the Adriatic Sea, with an emphasis on the Croatian part of the Adriatic Sea. Satellite methods have proven to be very effective in very shallow coastal areas (up to a depth of about 20 m) worldwide and their biggest advantage is that the depth data obtained in this way are relatively very cheap. On the other hand, in order to strengthen the safety of navigation, the International Hydrographic Organization (IHO) has over time "tightened" the minimum standards of horizontal and vertical accuracy of the bathymetric survey in different orders of the survey.

The latest version of the IHO Standards for Hydrographic Surveys S-44 (Edition 6.0.0) is from 2020 and, in our opinion, is very "demanding", especially in the shallow coastal area. In the Republic of Croatia, the Hydrographic Institute of the Republic of Croatia (HHI) is the responsible institution for hydrographic surveys. It is important to point out that the HHI adopted the IHO standards for hydrographic surveying.

The authors of this paper have no knowledge that HHI used the results of the SDB methods presented in this paper in order to publish official nautical charts, most likely for the reason that all SDB methods: optical bathymetry, SAR bathymetry, and altimeter bathymetry do not satisfy IHO Standards for Hydrographic Surveys S-44. This means that the results of SDB depth determination methods, presented in Chapter 3, have, until now, only scientific value.

Therefore, one of the most important conclusions of this paper is a recommendation to scientists to apply the latest sophisticated SDB methods in the Adriatic Sea.

ACKNOWLEDGEMENTS

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Maritime Alternative Fuels and Technologies for Sustainable Future

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Globally, 97% of ships are powered by traditional systems and fuels, but new IMO regulations are forcing us to look at new alternative energy sources and technologies. As early as 2030, 5% of energy for shipping is expected to come from carbon-neutral fuels, requiring huge investments in onboard technologies and onshore infrastructure. Navigating between options is complex because there is no single 'winner-takes-all' solution. This article considered and simulated various alternative fuels with an emphasis on blending hydrogen into diesel fuels to achieve emission reductions. The analysis was conducted to determine the percentage of hydrogen additives in engines to meet the requirements of the International Maritime Organization (IMO) Tier III regulations. It was concluded that, when the allowable NOx levels are met, higher hydrogen content in the fuel results in lower effective efficiency. The advantages and disadvantages of various new technologies such as dual fuel and hybrid propulsion systems in combination with non-polluting or renewable energy sources were also discussed. Marine energy systems were analyzed with special attention to hybrid systems using hydrogen. Ship hybrid energy system consisting of a fuel cell and a battery as energy sources, with a specific load profile, was presented.

KEY WORDS

Emission regulation, Hybrid propulsion, Alternative fuels, Energy efficiency, Marine technologies

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INTRODUCTION

IMO 2023 regulation is part of the International Maritime Organization (IMO) 2023 greenhouse Gas Strategy (GHG), which aims to reduce CO_2 emissions from international shipping at least 40% by the year 2030, pursuing efforts towards 70% by 2050, versus the 2008 levels. The total annual GHG emissions intended to be reduce at least 50% by 2050, compared to 2008. (IMO, 2023.). The IMO 2023 regulation affects both commercial and non-commercial vessels. It introduces mandatory reductions in carbon emissions for both new and existing ships, using energy efficiency indicators: The Energy Efficiency Existing Ship Index (EEXI) and The Carbon Intensity Indicator (CII), to determine these levels. EEXI is a rating system that assesses the energy performance of existing ships based on energy consumption data and other key metrics such as speed, power, and engine size. Non-compliant vessels that receive an EEXI rating below a certain threshold may be subject to IMO 2023 penalties and restrictions and need to make modifications to engines or systems. CII is used to rank and monitor the efficiency of individual ships. It links the GHG emissions to the amount of cargo carried, and the distance travelled ratio. To support the shipping industry's transition to a cleaner future, DNV developed the Alternative Fuel Insight (AFI) platform. This platform gives an overview on developments of new technologies and alternative fuels. It covers marine energy system as well as port (DNV, 2021). LNG (liquified natural gas) is the fuel that will be used in transition period while new green fuels come. LNG as the fuel can be use both the main and auxiliary engines and running on this fuel the NOx emission can be significantly reduced, compared to using HFO (heavy fuel oil) or MDF (marine diesel fuel) (Sui et al., 2020). In the future, Hydrogen will be widely used in energy systems and when used in compression ignition engines, with optimum conditions, provides significant reductions over 50% in CO_2, HC, CO, and smoke. (Dimitriou et al., 2017). Methanol and Ammonia are intended to be energy carriers for internal combustion engines in foreseeable future. (Valera et al. 2019). Ammonia is a carbon-free fuel that produces zero CO_2 emissions, but it has to be renewably sourced. With the Ammonia, marine industry could reduce GHG emissions by 90%, which depends on the propulsion type and the fuel production method. (Kim et al 2020). First part of our research is based on a two-stroke low-speed marine engine run on alternative fuels and determine how much those fuels manage the emissions. Second part deals with marine diesel engines running on hydrogen additive in diesel fuel. The aim is to do necessary adaptation on existing engines and to manage lower emissions than the 3.4 g/kWh of NOx that IMO requires for Tier III engines.

MARINE ENGINE RUNNING ON ALTERNATIVE FUELS

Two stroke engine model

A two-stroke low-speed marine engine model was developed using AVL Boost tool. Mainly in merchant ships two stroke engines are used, and the most important is to find an alternative fuel to lower toxic emissions. A large portion of shipping industry is based on those engines. The basic model of a 6-cylinder 500mm bore, 94 revolutions per minute (rpm) is used and calibrate with available data (Muše et al 2020). The multi zone combustion model is used during simulations with possibility to analyze NOx and CO_2 emissions. Different alternative fuels were used during analyses performance of the engines running on: mixture 91% diesel-9% methanol, 90% ammonia-10% hydrogen (Figure 1.), methane and hydrogen. diesel + methanol and ammonia + hydrogen. To achieve the goal of having lower than 3.4 g/kWh of NO_x using alternative fuels, two things needed to change from the original calibrated model. The first thing is the rate of injection (ROI) and the other thing was to change the amount of fuel going in the cylinder per cycle.

Primary, simulation was performed to analyze influence parameters to achieve lowest NOx emissions. Figure 1. shows that all the alternative fuels meet the IMO Tier III requirements for NOx emissions. And it clearly says that mixture of 90% ammonia – 10% hydrogen has the lowest emissions.

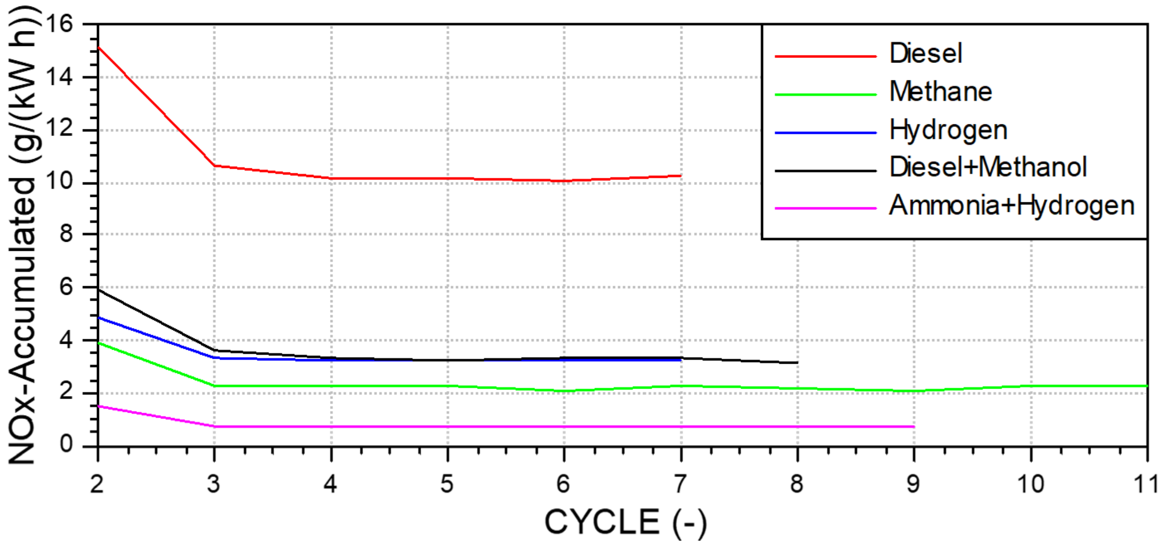

Figure 1. NOx emissions using alternative fuels

Engine power was the same for all simulation, and all the alternative fuels achieved lower NOx emissions than the standard diesel engine. The efficiency of engine running on ammonia-hydrogne mixture, gives also the best results. Advantage of using ammonia-hydrogen as fuel is not only that these fuel produce zero carbon emmisions, also many ships have experience with ammonia storage tanks for use in Selective Catalytic Reduction systems (SCR). But there are a lot of other things to be consider in future for safety reason, such as:ammonia is highly toxic.

Two stroke low speed engine running on diesel fuel and hydrogen

In order to analyse internal combustion engine running on diesel blended with hydrogen, a calibrated and validated model of a two-stroke low-speed diesel engine were used. Low speed, two stroke marine diesel engine (MCR 8813 kW at 103 RPM) running at 75% load were analysed in AVL Boost. Calibration and validation of the model is done with measuring unit obtain during sea trials. Hydrogen is added in diesel in percentage from 10 %- 90% and also with pure hydrogen engine process was analysed as well (Figure 2.). To keep power the same, in all simulation other parameters are adjusted, such as: the rate of injection per cycle. The aim of simulations was not to exceed NOx of 3.4 g/kWh according to the current IMO standards for low-speed engines.

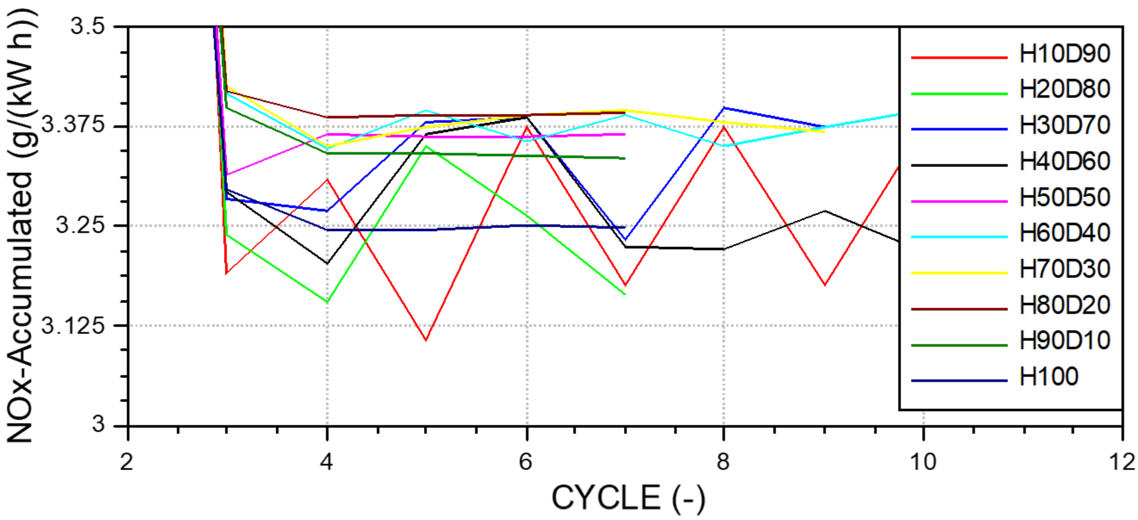

Figure 2. NOx accumulated (g/kWh) using different fuels

As shown on Figure 2., all blended fuels give lower NOx emissions. During simulation it was noticed that with higher percentage of hydrogen, efficiency is lower. Engine running with 100 %of hydrogen has efficiency 40.5 % compared to engine running on diesel that has efficiency of 50%. The reason why we have such difference in efficiency is that we limited the maximum cylinder pressure and upper limit of cylinder temperature to keep NOx in permissible value. When considering hydrogen as a fuel, there are few things to be consider such as hydrogen storage, pressurised system, safety issue that needs to be resolved before installing it onboard. Future investigation will include also the correct blend to achieve requested parameters need to be determined to define the capacity of storage tanks.

Marine technology supporting alternative fuels

Up to now manufacturers of low speed two stroke engines are still reconsider use of hydrogen since hydrogen is still not widely available. A few concepts of hydrogen engines are being developed and tested. Important is the fact that hydrogen is less knock-resistant than LNG, this is because of its low methane number, low ignition energy and high flame speed which results in high pressure increase. The methane number is a measure of the resistance of natural gas to detonation when it is burned as a motor fuel in an engine. Pure Methane is assigned a Methane Number of 100 and pure Hydrogen is assigned a Methane Number of zero (Gary Palmer, 2017). Ammonia (NH_3) is being considered as the most promising hydrogen carrier. The use of dual fuel engines that as a second fuel use green ammonia are planned to be in production by 2024. Figure 3.

Methanol's use as a clean-burning, low-carbon fuel, is growing with many engines already in use today Figure 3. The biggest obstacle is complex production of green methanol. Advantage of using methanol compared to other alternative fuels is easy handling and the possibility of storing it as a liquid at ambient temperatures and pressures. Highly pressurized methanol is being injected into the cylinders and being injected by pilot fuel. This concept is easier and less expensive to retrofit marine two stroke diesel engines than other concept such as the dual fuel concept (Selma et. al, 2014.; Hardikk et. al, 2019.).

Figure 3: MAN B&W dual-fuel two-stroke low-speed engines running on alternative fuels (MAN, 2021)

SHIP HYBRID ENERGY SYSTEMS

Hydrogen – battery hybrid energy system

An analysis of the energy needs of a passenger catamaran 21m, 160 passengers, speed 12 knots, using four-stroke high-speed diesel engines (2x800 kW) was performed and compared with a hybrid energy system that uses energy obtained from hydrogen fuel cells in combination with batteries for electric propulsion. By using hydrogen tanks as a source of energy on board, it is possible to completely eliminate the use of diesel fuel and thus reduce harmful emissions, which is especially important for ships sailing in ports and coastal areas. Batteries as an energy storage can be easily used on ships and can provide a source of additional energy in cases where it is needed for peak loads, and in case of failure of other energy sources, the battery provides enough energy to return to the nearest port. Based on recommendations and experience, Li-ion battery technology was chosen for our model. Li-ion batteries are also suitable for marine use because they are 7 times lighter than lead-acid batteries and 2 times lighter than Ni-MH batteries for the same energy density. For the observed case, tanks of highly compressed hydrogen are used. The required number of hydrogen tanks can be determined after calculating the amount of hydrogen required from the daily energy requirement or according to hydrogen consumption in the model (Corvusenergy, 2019). Syncora's AC motors (2x300kW) are used to power the ship and thus eliminates the need for a gearbox and shaft line, and also eliminates the need to install special generators for the production of electricity. The boat's cruising speed is 12 knots. At a certain time before the start of the first daily trip, the fuel cells start working and during the short periods of rest in the port between trips, they remain lit and the battery is charged with this energy. Ship systems and consumers operating during idle time are supplied with energy via fuel cells or the power grid on land.

Energy consumption

Calculation of energy consumption when we have data for the load profile in a simple analytical way. By multiplying the necessary propulsion power (full power 600kW, maneuvering 100kW) and considering the losses of electric motors (0.925) and time (2.13h - total time for one trip) , the energy required for one trip is obtained. This amount of energy is calculated 661.26 (kWh) per trip.

When we multiply the energy required for one route by 6 routes that are performed daily, we get the daily energy requirement (E_{day}) according to the expression:

$$E_{\text{day}} = E_{\text{trip}} \times 6 = 3967.56 \text{ [kWh]} \tag{1}$$

The daily need for diesel fuel is calculated according to the expression (Goodwin, 2015):

$$m_{\text{diesel,day}} = \frac{E_{\text{day}}}{E_{\text{diesel}} \times \eta_{DM}} 836.26 \left[\frac{\text{kg}}{\text{day}}\right] \quad (2)$$

E_{diesel} – energy content of diesel $11.861 \left[\frac{\text{kWh}}{\text{kg}}\right]$

η_{DM} – diesel engine efficiency – 40 %

Calculating harmful emissions due to the use of diesel fuel is according to (Goodwin, 2015):

$$NO_{\text{x,day}} = y \times C_{\text{diesel}} = 30550.21\ [\text{gNO}_{\text{x}}] \quad (3)$$

C_{diesel} – $coeff.NOx\ fuel$ =7.7 [gNOx/kWh]

According to the literature (Goodwin, 2015) and if we assume the same daily need for energy and with the upper calorific value of hydrogen and the average efficiency of the fuel cell, we obtain the required daily amount of hydrogen according to the expression:

$$m_{\text{H2,day}} = \frac{E_{dan}}{H_g x\, \eta} = 223.78\ [\text{kg/day}] \quad (4)$$

H_g – $Calorific\ value\ of\ hydrogen$ $39.4 \left[\frac{\text{kWh}}{\text{kg}}\right]$

η – $efficiency\ of\ the\ fuel\ cell$ – 0.45

Hybrid energy simulation

By using the AVL CRUISE™ M program, that is, by using individual components and connections between components that are defined within, a model of full electric propulsion with hydrogen PEM fuel cells and batteries was created, shown in Figure 4.

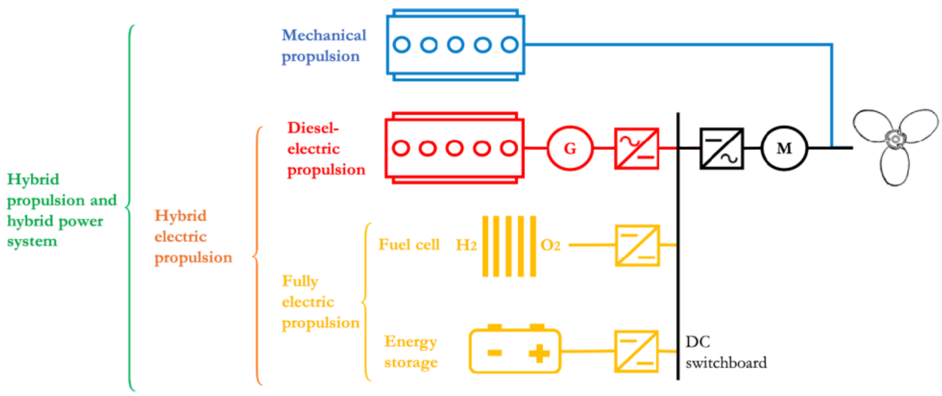

Figure 4. Presentation of different propulsion systems (Kvinnsland et al., 2019.)

The simulation was performed on the ship during 245 seconds and the acceleration of the ship from 0 to 13 Nm/h was monitored. The rotation speed of the propeller is 500 rpm and 400 kW of power from the fuel cell are given (Figure 5), the rest of the energy needed to drive the ship comes from the battery, whose state of charge at the beginning of the simulation is 80%.

At the end of the simulation, the speed of the ship is 13 Nm/h (Figure 4.), and during this time the ship travels a distance of 1098.84 m.

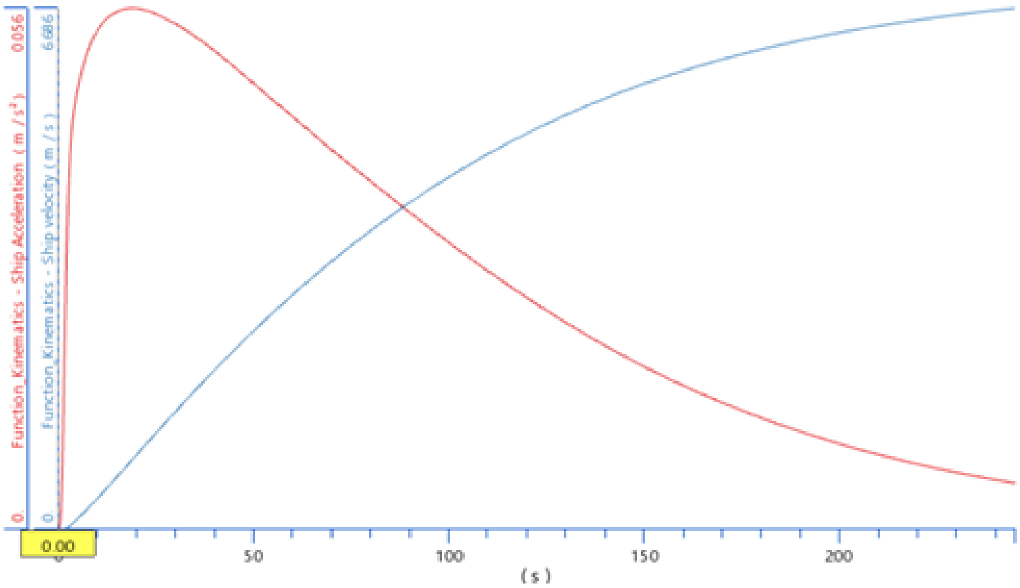

Figure 5. Graph of speed and acceleration of the ship

In the AVL CRUISE™ M program, simulations were performed with two objective functions: battery charge level at the end of the simulation and total hydrogen consumption at the end of the simulation. The goal is to charge the battery as high as possible and consume as little hydrogen as possible. In Figure 6. the graph shows the total amount of hydrogen consumed during the simulation for different size of fuel cell stack.

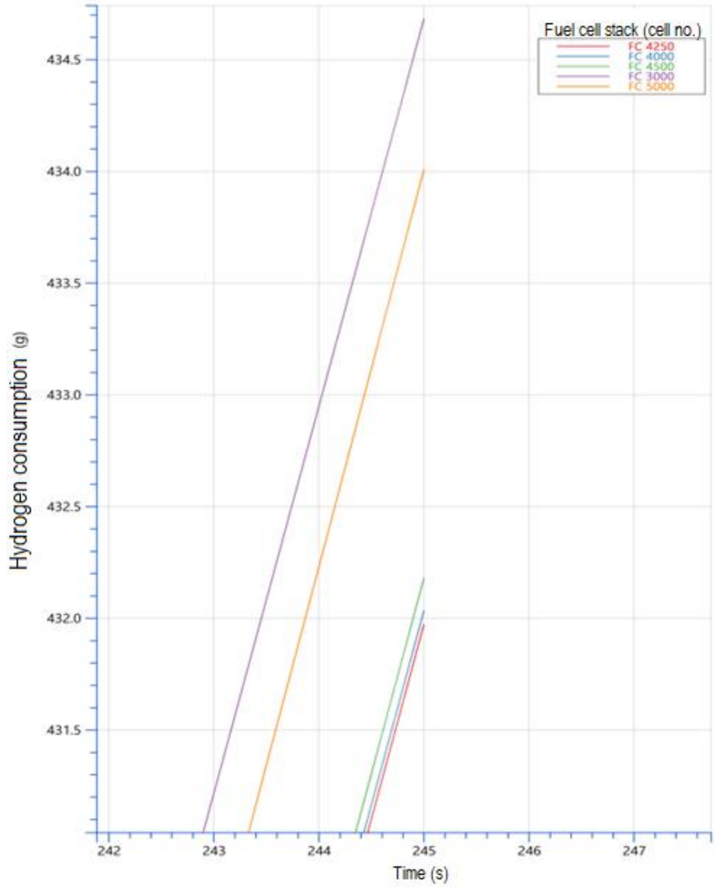

Figure 6. Total hydrogen consumption

CONCLUSION

The aim of this research was to analyzed different technology for marine energy system and different alternative fuels to conclude which will be the best possible solution for greener marine transport. Simulations were performed on marine two stroke low speed engine running on different alternative fuels. Engine running on hydrogen and diesel with hydrogen as additive was also analyzed in order not to exceed IMO- Tier II, NOx emission level. During simulations, maximum cylinder pressure and temperature were limited. To keep NOx emissions in permissible value during simulations with hydrogen and hydrogen blends, the results shows that efficiency decrease. Future investigation must include parameters optimization to achieve higher efficiency and keeping emissions with permissible limits. There is other consideration that has to be resolve in order to safely use hydrogen on board, such as: hydrogen storage, pressurized system, safety rules to be establish, correct blend to achieve requested output parameters, etc.

To understand the benefit of using hydrogen in marine hybrid systems, the consumption of diesel and hydrogen for a ship with the same load profile was compared, and the amount of harmful emissions and hydrogen consumption for an application of a passenger ship was calculated. In future works, the research should be extended to all parts of the hybrid ship's energy system and the balance of plant for hydrogen-battery hybrid system should be carried out. An economic analysis was not conducted here and economic criteria were not considered when dimensioning the fuel cell-battery system, because the technologies are new and the investment costs are high, but the investment costs will fall in the future due to the increasing application and development of these technologies. Future research should include and consider goals that would lead to prolonging the life of components, or reducing battery and fuel cell degradation.

ACKNOWLEDGMENT

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Strength and Performance of a Composite Gilson Mast for Steel Deck Fishing Vessels

Büşra Osma[1], Ebubekir Akarsu[1], Kaan Bilge[1*], Şebnem Helvacıoğlu[2], İsmail Hakkı Helvacıoğlu[1]

This work presents a framework for findings on the modelling effort to re-design of a 35 tonnes Gilson Mast (GM) profile for a fishing vessel attached to A36 steel deck. Full-scale finite element analysis of steel deck with GM attached is performed via ANSYS static structural and ACP modules. An example case study for material, sub-laminate selection and identification of failure locations taking Tsai-Wu based effective material properties and first ply failure safety factors is provided. The material selection was made with 7 different commercially available laminate candidates with three different sub-laminate sequences such as $(0)_{16}$, $(36/-36)_{4s}$ and $(54/-36/-36/-54)_{2s}$. Following that a pre-defined material in ANSYS is used to explain the changes in the modes of failure and potential reinforcement strategies. Results suggested that strength-wise CFRP materials are suitable for GM application and may provide weight savings up to 490% even when they are considered as completely brittle materials with no progressive failure. Furthermore, found failure locations due resulting in material failure are local which means they can be easily engineered with additional structural members.

KEY WORDS

Steel, Composite, Structural analysis, Fishing vessel, Gilson mast

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INTRODUCTION

According to the last developments in the marine industry composite materials, they have become popular construction materials. These developments affect some class society rules such as DNV (Weitzenböck, Hayman, Hersvik, McGeorge, Noury, 2010) rules for composite materials application in the marine industry. Developing class rules about composite materials in the marine industry base on some advantages related to saving weight with a lighter hull (Sanchez-Heres, 2015), low corrosion effect (Natarajan, Freitas, Santhosh, Markandan, Al-Talib, Hassan, 2022), high hull girder stiffness (Morshedsoluk, Khedmati, 2016), buckling resistance (Chen N., Soares C.G., 2007), and underwater shock resistance (Achor C.H., Kwon Y.W., Didoszak J.M., Crow N.E., Hardman D.J., 2022). Using composite material in the marine industry was observed in some applications such as leisure(canoes (Bharath, Saravanan, Sha, Ghimire, Bhagat, Sherstha, Ghimire, Sha, Madhu, 2022), kayaks, surfing, etc.), rigging (Pemberton, Graham-Jones, 2016), yachts (Kim, Hennigan, Beavers, 2010), lifeboats(Ringsberg, Heggelund , Lara , Jang, Hirdaris, 2017), naval vessels(Chen, Yan, Lu, 2021), submersibles(Natarajan, Freitas, Santhosh, Markandan, Al-Talib, Hassan, 2022), dock infrastructure(Lowde, Peters, Geraghty, Graham-Jones, Pemberton, Summerscales, 2022), oil and gas exploration and exploitation(OGEE) structures(Babu, Baksi, Srikanth, Biswas, 2009), and marine/offshore renewable energy(MRE/ORE) systems(Pérez-Collazo, Greaves, Iglesias, 2018). In the marine industry, steel and aluminum are utilized as normal materials for large-scale construction. In the last decade, the competitiveness and cost-effectiveness of composite materials have increased thanks to their high specific mechanical properties, low density, excellent corrosion resistance, low maintenance, and cost-effectiveness.

Recently reported results of RAMSSES (EU Horizon 2020 grant agreement 723246 Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships, 2017–2021) and FIBRESHIP (EU Horizon 2020 grant agreement 723360 Engineering, production, and life-cycle management for the complete construction of large-length FIBRE-based SHIPs, 2017–2020) projects (RAMSSES, Deliverables, D 5.1 Public Project Website) suggests that advanced composite engineering efforts are needed for full-scale integration(RAMSSES, Deliverables, D 6.1 1st Official Draft of PUDF and Business Plan). There are three objectives in RAMSSES project, these are using new materials in real applications with high market potential, proving full technical and economic feasibility of solutions on the project level, and using lightweight applications. In RAMSSES project, the vessel type wasn't identified, but composite materials on the structure of RAMSSES were applied for the RoRo deck, custom-made hull, cabin system, superstructure, aluminum panels, and versatile walls (RAMSSES, Deliverables, D 5.1 Public Project Website).

However, RAMSSES project improved the quality of the research with a design solution, lessons learned, and test results of ongoing or previous projects (RAMSSES, Deliverables, D 6.1 1st Official Draft of PUDF and Business Plan). One of them is about FibreShip and its area is the ship hull and superstructure which entirely is made of FRP (Fiber-reinforced plastic). In this project, special services vessels, passengers' transportation&leisure vessels, and light commercial vessels are objective to develop various solutions such as innovative FRP materials, new detail design, production guidelines and procedures, efficient production, inspection methodologies, and new software analysis tools(Mullor, 2017).

Another important project is the ADAM4EVE project, which is finished in status related to the development and assessment of applications of applicable and smart materials and structures in the marine field. Applicable and smart materials which were developed by the ADAM4EVE project had been explored for potential applications in the marine industry with more efficient, environmental, friend and safety conditions (ADAM4EVE).

Ongoing and finished large-scale projects on the implementation of composite materials to steel marine structures suggested that with the use of novel composite engineering approaches and novel materials even more competitive marine structures can be engineered. This article reports the initial findings for an all-composite Gilson Mast (GM) structure for a fishing vessel that is to operate under significantly high combined loading. GM profile was designed so that 126.9 tons of perpendicular load can be pulled out with 360 pulling angle. The overall structure was designed according to A36 with a weight of 16.5 tonnes and Von Mises and Tsai Wu of safety factor of 1.25 and is kept the same for carbon fiber-reinforced plastic (CFRP) design. Initial attention was given to demonstrate the perspective in material and lay-up selection where 7 types of different materials were evaluated as assigned to 3 types of sub laminates. Results suggested that with correct implementation CFRP GMs can be competitive with steel with a significant weight reduction up to 490% and they are suitable to GM profiles with less load capacity. Reasons and solutions to failure is than discussed with a pre-defined digital material available in ANSYS with 5 different sub-laminates such as $(0)_s$, $(0/90)_s$, $(+45/-45)_s$, $(+30/-30)_s$ an $(0/90/45/-45)_s$. A pathway to further increase stress-based safety factors and potential reinforcing member locations is underlined.

MODELLING PROCEDURE

Structural Model

All the defined members of a pre-designed GM were modelled as plates using ANSYS SpaceClaim module as depicted in Figure 1. Formed geometry is than assigned to Ansys Composite PrepPost (ACP) module where fiber directions were assigned to each profile carefully such that the longitudinal fiber direction is towards the length of each profile whereas the transverse direction is towards the width. Such fiber orientation definition paved way to work with general lamination sequences that may be applied to all profiles. Whole shell model is then meshed with 2D Quad elements prior to analysis. Loads and boundary conditions applied are provided in Figure 1.

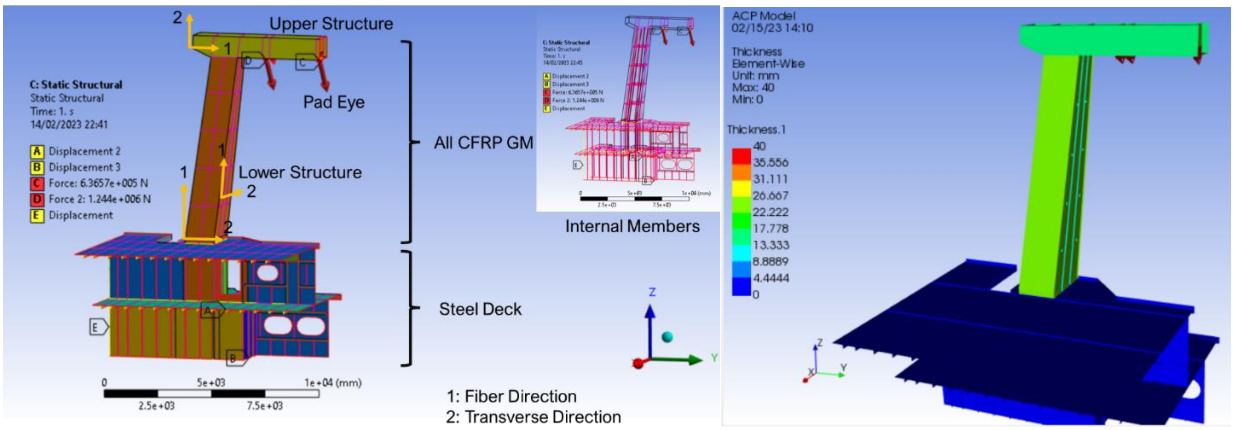


Figure 1: Design of GM profile with internal members, principal fiber directions boundary conditions applied and thicknesses assigned

In the case of material assignment, the database available in MicMac 5.0 by Stanford University(Tsai S.W., 2008) is employed where material elastic constants and strength parameters are defined according to test values. MicMac 5.0 LAM3D module also employed for determining the effective elastic constants and Tsai-Wu strength parameters of employed sub-laminates to make comments related to response of structural model to changing material properties. Strength and elastic constants reported in Table 1 as $(0)_s$ are assigned to FEA model out of which Tsai-Wu based safety factors associated with assigned sub-laminates are extracted. Then Tsai-Wu based strength limits belonging to sub-laminates are used as guiding material limits that defines the behavior GM. 3 different sub-laminates, and 7 different real materials are investigated to choose potential material candidate for manufacturing.

A second set of runs were made with pre-defined UD Carbon/Epoxy Wet 230 GPa material in ANSYS to provide repeatability and to discuss the types of failure that may be encountered in a full CFRP GM.

RESULTS AND DISCUSSIONS

Material and sub-laminate selection

Initial attention was given to $(0)_{16}$ sub-laminate configuration to determine the main failure mode on the overall GM structure. Static analysis suggested that minimum safety factor occurred at the hole in the pad eyes where a tensile pull break load with an angle of 36^0 applied. Since the fiber direction at the pad eye was defined parallel to Z direction the applied load causes a significant transverse tensile load around the hole which resulted in very low safety factor values for all materials considered. On the other hand, the laminate strength in the fiber direction was very high so that no failure event occurred in the tension dominated parts of GM. Originating from this point the fiber angle was rotated by 36^0 which will eventually decrease the effective longitudinal tensile strength while increasing the transverse tensile strength. To keep the laminates balanced and to exemplify the behavior of an angle ply laminate equal amount of -36^0 plies were inserted which resulted as $(36/-36)_{4s}$ sub-laminate. Effective material properties for such sub-laminate are shown in Table 1.

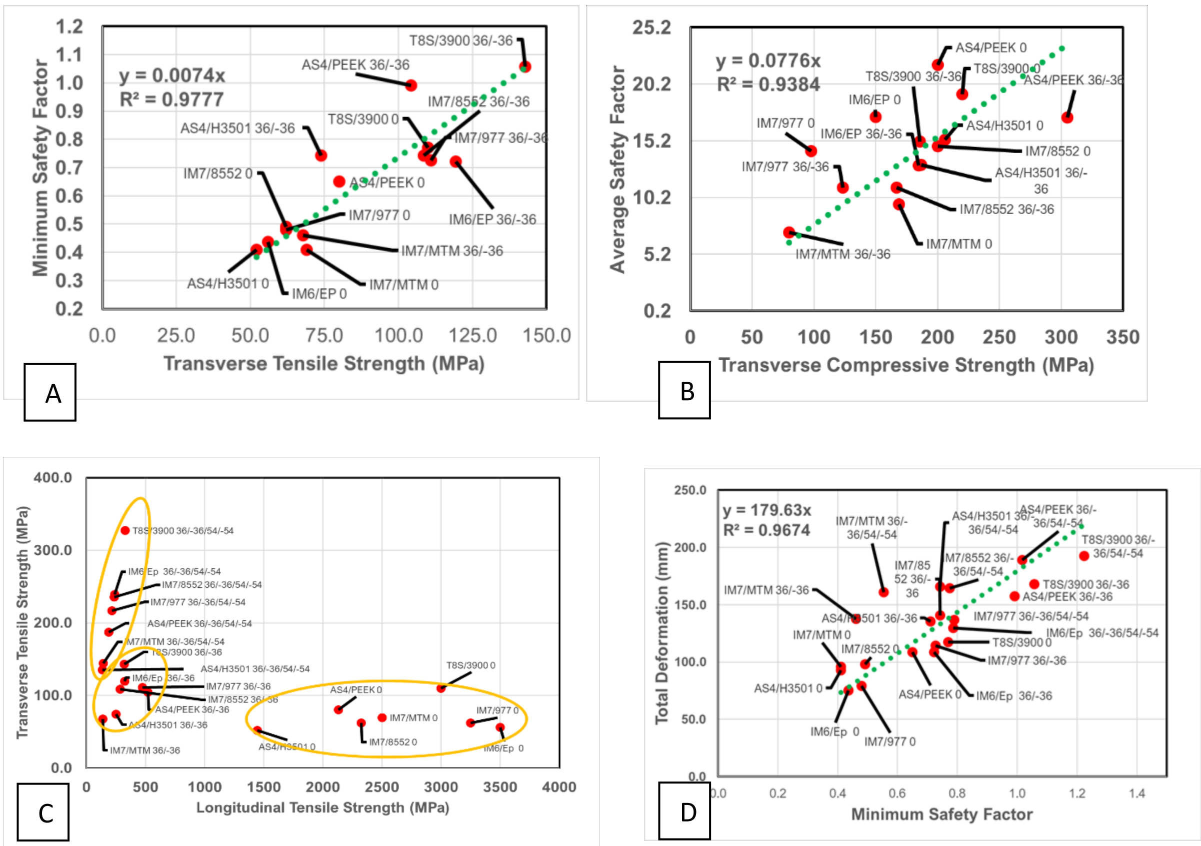


Figure 2: a) Dependency of minimum safety factor to effective transverse tensile strength of evaluated sub-laminates b) Dependency of average safety factor to transverse compressive strength c) Trade of between transvserse and longitudinal tensile strength d) Trade off between total deformation and minimum safety factor.

When overall fiber direction was oriented towards the applied load, the minimum safety factor observed for all of the materials increased up to 1.05 (for T8S/3900 laminate).The dependency of minimum safety factor to transverse tensile strength of the laminates is shown in Figure 2a where a linear dependecy is found. When evaluated for a minimum safety factor of 1.25, the value of Yt must be at minimum 168 MPa. This requirement is only approximated by T8S/3900 $(36/-36)_{4s}$ laminate with an effective Yt value of 143 MPa. Failure mode for that case is than reverted to transverse compression Parallel to that results suggested that the average safety factor of the whole system shows a linear dependency with transverse compressive strength of the investigated plies. Hence it can be concluded that the major limiting strength factor for the pad eye is transverse tension whereas it is transverse compression(Yc) or in-plane shear (S) for the rest of GM maximizing severely on the deck/GM joint region. A final sub-laminate type of $(54/-54/36/-36)_s$ was exemplified which will reduce the effective longitudinal tensile strength and increase the transverse tensile strength (Figure 2c). Results suggested that the minimum safety of material types having enough transverse compressive strength(Yc) and in-plane shear strength (S) has increased and a minimum safety factor of 1.2 is achieved for T8S/3900 material that is numerically equivalent to A36 steel.

It is vital to note here that the safety factors observed in this small framework belongs to first ply failure of laminates which is not realistic due to presence of progressive failure in all CFRP material. To avoid more complexity results of these analysis has not been provided. But it is certain that significant improvements in the observed safety factors would occur. Furthermore, obtained minimum safety factor and deformation results suggested that it there exists a trade off between strength and the stiffness in GM structure. In order to achieve a higher safety factor higher deformation should be allowed which eventually increases the amount of strain available on each member that may cause failure due to strain. Hence the overall solution asks for a rather larger optimization problem.

Material	Sub Laminate	E1 (GPa)	E2 (GPa)	v12	G12 (GPa)	Xt (MPa)	Xc (MPa)	Yt (MPa)	Yc (MPa)	S (MPa)	Min SF	Avg SF	Def. (mm)
AS4/H3501	0	138.0	9.0	0.3	7.1	1447.0	1447.0	52.0	206.0	93.0	0.4	15.3	93.0
	36/-36	39.3	16.2	1.0	33.0	251.5	174.0	73.9	186.6	216.5	0.7	12.5	135.5
	36/-36/54/-54	31.3	31.3	0.6	33.0	135.2	202.5	135.2	202.5	200.0	0.7	13.1	165.8
AS4/PEEK	0	134.0	8.9	0.3	5.0	2130.0	1100.0	80.0	200.0	160.0	0.7	21.9	108.5
	36/-36	31.2	12.4	1.1	31.8	519.4	208.1	104.3	305.1	204.8	1.0	17.2	157.5
	36/-36/54/-54	26.1	26.1	0.6	31.8	186.8	219.7	186.8	219.7	177.4	1.0	14.9	189.2
T8S/3900	0	151.0	8.2	0.3	4.0	3000.0	2500.0	110.0	220.0	98.0	0.8	19.3	117.6
	36/-36	27.1	10.1	1.3	35.4	318.5	268.3	142.8	185.6	754.2	1.1	15.1	168.1
	36/-36/54/-54	24.9	24.9	0.7	35.4	327.0	355.2	327.0	355.2	759.5	1.2	19.6	192.7
IM7/977	0.0	191.0	9.9	0.4	7.8	3250.0	1600.0	62.0	98.0	75.0	0.5	14.3	79.2
	36/-36	46.2	44.9	1.1	44.9	474.6	203.9	110.9	123.2	474.6	0.7	11.1	114.5
	36/-36/54/-54	38.3	38.3	0.6	44.9	216.4	222.6	216.4	222.6	479.1	0.8	13.0	136.9
IM7/MTM	0	175.0	8.2	0.3	5.5	2500.0	1700.0	69.0	169.0	43.0	0.4	9.6	95.8
	36/-36	35.2	13.1	1.2	40.9	137.5	123.1	67.7	79.9	479.3	0.5	7.1	137.5
	36/-36/54/-54	30.9	30.9	0.7	40.9	143.9	150.0	143.9	150.0	483.0	0.6	9.0	161.1
IM7/8552	0	171.0	9.1	0.3	5.3	2326.0	1200.0	62.0	200.0	82.0	0.5	14.7	98.0
	36/-36	34.2	12.9	1.2	40.1	284.7	203.8	108.5	167.0	398.7	0.7	11.1	140.6
	36/-36/54/-54	30.1	30.1	0.7	40.1	235.7	252.4	235.7	252.4	403.5	0.8	12.0	164.6
IM6/Ep	0	203.0	11.2	0.3	8.4	3500.0	1540.0	56.0	150.0	98.0	0.4	17.3	75.3
	36/-36	49.7	19.5	1.1	47.9	323.1	238.0	119.3	184.6	403.5	0.7	13.0	108.5
	36/-36/54/-54	41.0	41.0	0.6	47.9	239.1	277.4	239.1	277.4	404.7	0.8	13.8	129.8

Table 1: Effective elastic constants- laminate strengths calculated in MicMac LAM3D and FEA results

As the best candidate minimum safety factor value of 1.2 was achieved with T8S/3900 that provided an example on the fact that with very advanced and high cost ply types, GM structures can be strength-wise safe. However, this type of ply is a very high cost ply type that is being used mostly in advanced aerospace applications. High cost of the material may restrict its usage significantly. On the other hand AS4/PEEK can be considered as the second material alternative. The atttractive part of this material is that PEEK resin is a thermoplastic based resin which may provide recyclability. When the level of minimum safety factors are considered with given profile thicknesses (Figure 1) loads up to 60-70 tonnes in average can be carried with one-to one converted GM. More importantly, given that the average density of all of the CFRP assigned is around 1.6 t/m^3 with compared to the value of 7.8 t/m^3, thus CFRP GM is 3.36 tonne and steel GM is 16.5 tonne.This can be achieved with a lighter GM structure up to 490%.

First ply failure types and locations

Significant difference between average safety and minimum safety values suggests that addition of local reinforcing members such as brackets or a connection design to composite/steel joint region can significantly improve the safety of the structure. To exemplify the types of failure and their locations due to varying sub-laminate orientations UD Carbon/Epoxy Wet 230 GPa material was used. Types and comments on the observed failure types are provided in table 2. Different than the previous analysis the safety factors occurring on the pad eye section was avoided for that case in order to see the critical locations in GM.

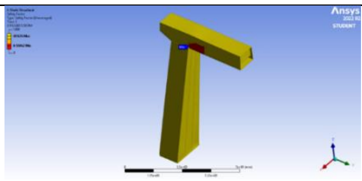
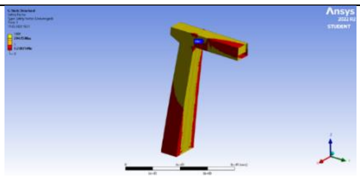
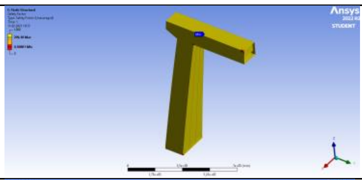
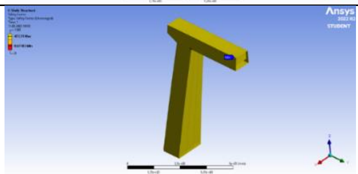
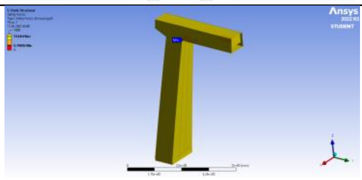
Sub-Laminate	Min Safety Factor	Avg. Safety Factor	Analysis Results	Failure Location
$(0)_s$	0.59	12.37		In the cross-section of upper and lower profile due to transverse compression and in-plane shear. Some area of the upper profile is also critical. Solution: Bracket insertion or stronger sublaminate to shear and compression. $(0/90/+45/-45)_s$
$(0/90)_s$	0.24	5.88		On the surface of lower profile due to transverse tension and longitudinal compression. Overall failure of upper profile. **Solution:** Sub-laminate change
$(+45/-45)_s$	0.51	7.67		On the cross section of the top plate and connecting plate of upper structure due to in-plane shear **Solution:** Additional stiffener insertion
$(30/-30)_s$	0.67	11.15		On the tip of the plate that is probably due to a singularity effect on the structure. Structure is almost safe **Solution:** Additional stiffener insertion, finer mesh onto region
$(0/90/+45/-45)_s$	0.80	14.75		Just at one point at the overall GM that is the cross-section of upper and lower structure. **Solution:** Bracket insertion

Table 2: Safety factor results for UD Carbon/Epoxy Wet 230 GPa and failure locations on GM

CONCLUSION

Results of a framework study on the strength based material and lamination sequence selection was presented for an all CFRP Gilson Mast profile attached to a steel deck of a fishing vessel. GM profile was designed so that 100 tons of perpendicular load can be pulled out with 36^0 pulling angle. The overall structure was designed according to A36 with a weight of 16.5 tonnes and Von Mises and Tsai Wu of safety factor of 1.25 and is kept the same for CFRP design. Initial effort was given to a small-scale evaluation of laminates with tested data that are manufactured with commercially available constituents. 3 targeted sub-laminates such as $(0)_s$, $(36/-36)_s$ and $(36/-36/54/-54)_s$ was evaluated with 7 different materials having different effective laminate properties. Initial results suggested that within the investigated range of plies, local failure on the hole in the pad eye region and joint region at the intersection of CFRP GM and steel deck is problematic. The failure in the pad eye is governed by the transverse tensile strength and the failure in the joint region is dominated by the transverse compressive strength. The values of the measured first ply failure safety factors suggested that only two types of laminates such as AS4/PEEK and T8S/3900 had contained enough material properties when assigned to $(36/-36/54/-54)_s$ laminates to compete one to one with steel. A large difference between average safety factors and minimum safety factors for investigated laminates suggested that the local failure can be omitted either by a progressive failure analysis where last ply failure is considered or addition of structural members. To portray the whole range of available failure locations and to present more repeatable results the safety factor distributions belonging to a pre-defined digital material available in Ansys has been analyzed with the use of 5 different sub-laminates. In overall results suggested that even with one-to-one conversion use of CFRP ca provide weight savings up to 490% with similar safety factors with A36 steel. This value can be higher if the structure was designed solely for CFRP or additional structural members were added to the structure.

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Estimation of CO_2 Reduction due to Flettner Technology based on Online Calculator for Panamax and Capesize Bulk Carriers

Marko Zubčić, Nediljko Kaštelan, Miro Petković, Maja Krčum

A variety of technologies are available to help achieve the IMO vision, which states: "reducing GHG emissions from international shipping and, as a matter of urgency, aims to phase them out as soon as possible in this century". The following technologies are available: Air lubrication systems, wind assisted technologies (kites, Flettner rotor, rigid sails), solar energy, waste heat recovery, hull coating, bow optimization, post-swirl fins, renewable fuels. In this paper, we focus only on Flettner rotor technology. Flettner rotor technology was first introduced in 1924. Technology implies a rotating cylinder mounted on the deck of the ship to provide additional thrust. The application of the technology ended in the 1930s. In 2010, the first commercial ship with Flettner rotors entered service, and nine more ships with Flettner technology entered service by 2023. Calculating fuel and therefore CO2 savings on routes is a complex task, as many factors must be considered: Wind conditions, number of rotors, vessel type (vessel data), speed, etc. This paper examines the Flettner Rotor Saving Calculator, a software developed by Lloyd's Register, for Panamax and Capsize bulk carriers.

KEY WORDS

Flettner rotor, Bulk Carrier, Emission reduction, Lloyd Register software.

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INTRODUCTION

The motivation for this work is the International Maritime Organization's (IMO) Greenhouse Gas Strategy, whose vision is "reducing GHG emissions from international shipping and, as a matter of urgency, aims to phase them out as soon as possible in this century" (250_IMO submission_Talanoa Dialogue_April 2018, 2018). There are a variety of technologies that contribute to the IMO vision: air lubrication systems, wind assisted technologies (kites, Flettner rotor, rigid sails, ...), solar energy, waste heat recovery, hull coating, bow optimization, post swirl fins, renewable fuels (Petković et al, 2021; Agarwala et al, 2021). In this paper, we focus only on Flettner rotor technology.

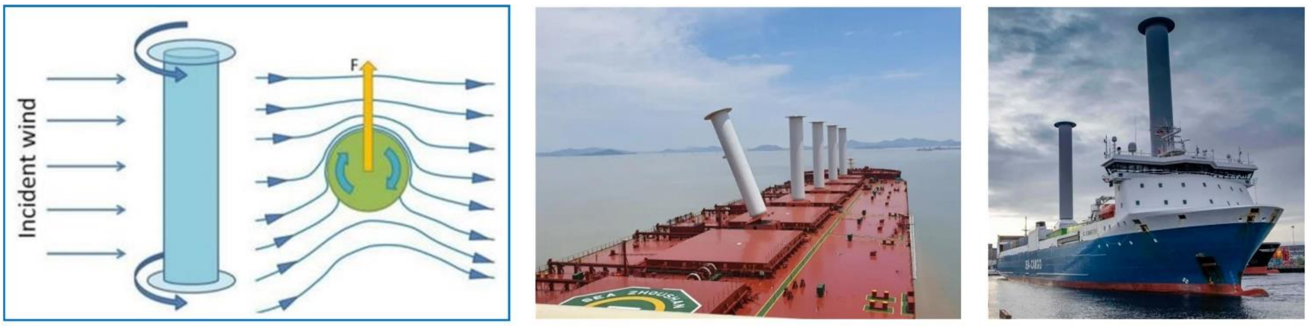
Flettner rotor technology, i.e., a rotating cylinder mounted on the deck of the ship to provide additional thrust, was first introduced in 1924. The inventor of the idea, Anton Flettner, went to great lengths to bring the concept to life. The physics behind the technology is based on Magnus effect. Spinning body, in this case a rotating cylinder, moving in a fluid experiences force perpendicular to the relative flow of fluid (Lele and Rao, 2017). This concept is shown on Figure 1a. The schooner Backau was retrofitted with two metal cylinders 15.6 m high and 2.8 m in diameter. After the successful sea trial across the Atlantic and arrival in New York (under the new name Baden-Baden), the new ship was commissioned by the German Admiralty under the name Barbara. The ship was launched in 1926 and had three rotors, each 17 m high and 4 m in diameter. Despite the technical success, the economics of the time and the advent of steamships led to the removal of the rotors from the Baden-Baden (Backau) and the Barbara, and the Flettner rotor technology was put on hold (Seufert W. and Seufert S., 1983; Carlton, 2019).

In 2010, the first commercial ship with Flettner rotors entered service. Table 1 shows the new ships built or retrofitted with Flettner rotors from 2010 to 2023. Ships Sea Zhoushan and SC connector are shown in Figure 1b and 1c respectively (*Norsepower,* 2022.)

Ship Name	Ship Type	DWT	No. of rotors	Rotor dimensions H x D (m)	Rotor installation year
E-Ship 1	General Cargo/Ro-Lo	10 020	4	25 x 4	2010
Estraden	Ro-Ro	9 741	2	18 x 3	2014
Epanastasea*	Tanker	109 647	2	30 x 5	2018
Afros	Bulk Carrier - Ultramax	63 233	4	16 x 2	2018
Adria Kvarner**	General Cargo	4 250	1	18 x 3	2018
Copenhagen	Ferry	5 088	1	30 x 5	2020
Annika Braren	General Cargo	5 023	1	18 x 3	2021
SC Connector	Ro-Ro	8 843	2	35 x 5	2021
Sea Zhoushan	Bulk Carrier - VLOC	324 268	5	24 x 4	2021
Berlin	Ferry	4 835	1	30 x 5	2022
* former names: Timberwolf, Maersk Pelican; ** former name: Fehn Pollux					

Table 1. Ships with installed Flettner rotors (Source: Marine environment protection committee, 2022)

Predicting fuel savings from Flettner technology is complex because weather conditions along the route must be considered. From a ship design perspective, the number of rotors, the sizing, and the position of the rotors must also be considered. In this paper, CO2 emission reduction is investigated for three size categories of bulk carriers. The emission reduction is calculated using the Flettner rotor savings calculator (FRSC) software



a) b) c)

Figure 1. Flettner rotor: a) Magnus effect b) VLOC Sea Zhoushan c) SC Connector
(source: Lele and Rao, 2017; *Norsepower,* 2022)

from Loyd's Register Ship Performance Group (*Flettner Savings Calculator*, 2022). Flettner Rotor System Tool is a copyright work of the Energy Technologies Institute, sub-licensed to authors by Lloyd's Register under this FRS Tool License.

The software consists of 3 basic steps: Vessels, Rotors and route, Print summary. In Vessels, there are predefined vessel types: Tankers, Bulk Carriers, Ro-Ro and Passenger/Cruise vessels. In each vessel type category there are predefined size categories, e.g. for tankers: MR Tanker (50 000 MT DWT), Aframax (110 000 MT DWT), Suezmax (155 000 MT DWT) and VLCC (300 000 MT DWT). Each size category can also be customized by the following subcategories: Main data (length overall, length between perpendiculars, waterline length, beam, ..., propeller diameter, number of propeller shafts), additional data, propulsion, propeller and fuel consumption. After defining the ship data, the next step is rotors and route. In this step, users must define the route, ship speed, loading conditions (ballast, heavy ballast, loaded, scantling), rotor dimensions (diameter and height), number of rotors and rotor position. The result of the software is a table showing the monthly savings in propulsion consumption and emissions, a graph showing the savings along the route, and a polar diagram showing the savings in relation to wind speed and direction. The third and final step is the print output, which summarizes the selected data and results in paper form.

In this paper, the Flettner Rotor Savings Calculator is used to calculate CO2 emission reductions along 14 routes for three types of bulk carriers: supramax, kamsarmax, and capesize. Supramax and Kamsarmax are considered as subtypes of Panamax class ships in this paper. Two scenarios are studied, ships with 1 and with 4 Flettner rotors. The achieved emission reductions are distributed among the total number of Panamax and Capesize ships in the merchant fleet. The contribution of the paper is to evaluate the CO2 reduction for the scenario in which all the mentioned ship types are equipped with Flettner rotors.

FLETTNER ROTOR SAVINGS CALCULATOR - CALCULATION AND RESULTS

Fourteen routes were selected by the authors for calculation. The routes along the ports of departure and arrival were selected based on the map of the main sea routes and strategic passages (Rodrigue, 2017). In the second step, route definition is performed using the FRSC by graphically entering waypoints on a map. For route definition between ports, the Searoutes application was used (Searoutes, 2022). For defined ports, the application draws the route. The defined routes are then visually copied by authors to FRSC map interface. The only criterion that had to be considered in the route definition was the distance between ports specified by the Searoute application. The distance specified by FRSC had to be within ±2% of the distance specified by Searoute.

The next step was to select the bulk carrier type. All data on main and auxiliary data, propulsion, propeller, and fuel consumption were set to default values. Once the ship type is set, the rotor size, number of rotors, loading conditions, and ship speed are set in the Rotors and Routes step as follows:

- Rotor size (diameter x height): 4 x 28 m
- Ship speed: 12 knots
- Number of rotors: case: a) one rotor b) four rotors
- Supramax: Loading cond.: Loaded T: 10.7 m
- Kamsarmax: Loading cond.: Loaded T: 12.4 m
- Capesize: Loading cond.: Loaded T: 15.5 m

The result of the FRSC is a table of monthly savings in propulsion consumption and emissions, Figure 2 shows all the steps in the calculation process. The calculation process was repeated for each of the fourteen routes. Variations in the calculation were the number of rotors and the direction between ports.

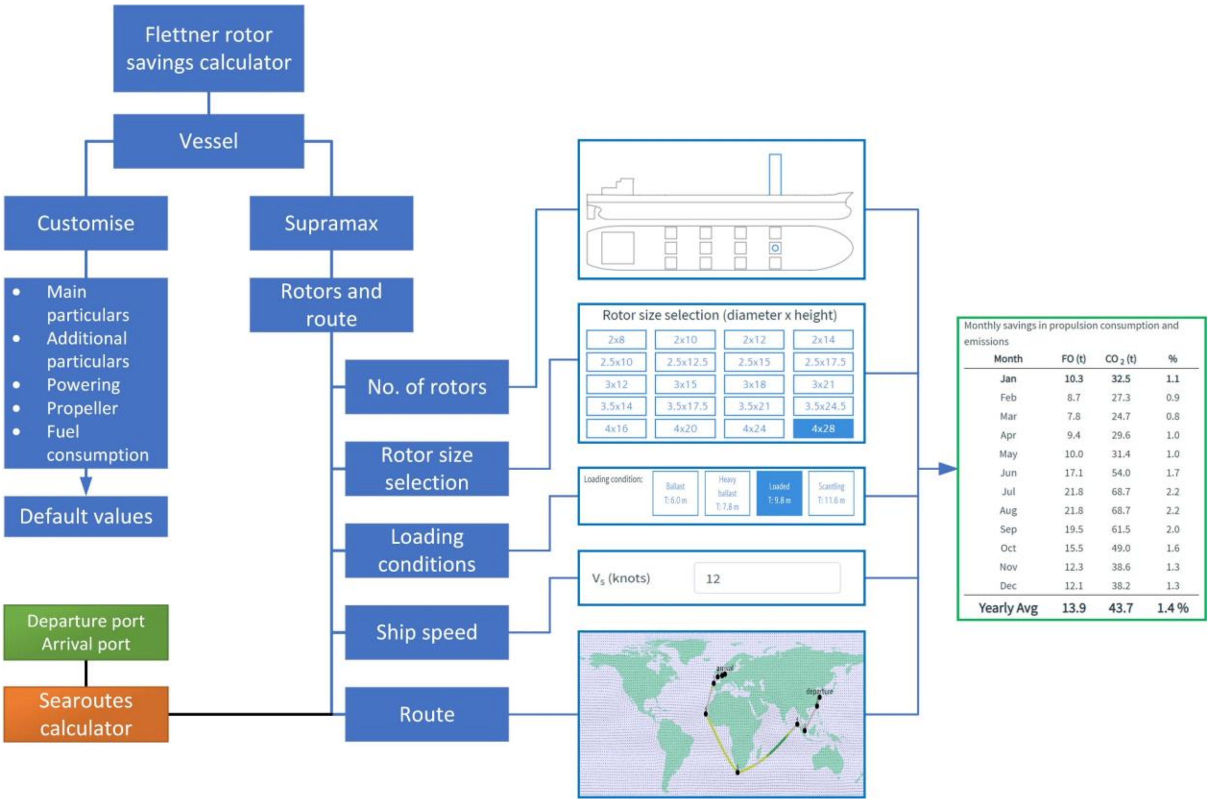


Figure 2. Calculation process (Source: Authors)

The CO2 savings on each route are shown in Table 2.

Bulk carrier category			Supramax		Kamsarmax		Capesize	
No. of rotors			1	4	1	4	1	4
No.	Port A	Port B	CO_2 (t) per year					
1	Houston (USHOU)	Shanghai (CNSHA)	506	1693	431,7	1507	510,2	1902
2	Santos (BRSSZ)	Shanghai (CNSHA)	797	2849	1090	4126	1043	3970
3	Newcastle (AUNTL)	Shanghai (CNSHA)	383	1410	402,7	1171	447,3	1701
4	Newcastle (AUNTL)	Cochin (INCOK)	205	739,1	222,3	833,6	223,9	852,9
5	Santos (BRSSZ)	Rotterdam (NLRTM)	283	962,5	307,1	1097	285,3	1040
6	Vancouver (CAVAN)	Shanghai (CNSHA)	140	469,6	143,8	507,9	153,7	572
7	Richards Bay (ZARCB)	Rotterdam (NLRTM)	136	465,6	112	400,1	115,7	429,8
8	Montreal (CAMTR)	Rotterdam (NLRTM)	77,3	297,1	82,2	322,8	84,5	330,9
9	Cabello (VEPBL)	Rotterdam (NLRTM)	122	386,7	133,1	447,3	128,9	473,7
10	Richards Bay (ZARCB)	Shanghai (CNSHA)	371	1158	407,2	1353	799,8	1494
11	Richards Bay (ZARCB)	Black Sea	225	801,1	236,5	872,1	258,1	973,7
12	Hedland (AUPHE)	Black Sea	354	1267	382,3	1425	367,2	1387
13	La Plata (ARLPG)	Shanghai (CNSHA)	1361	5016	1466	5578	1506	5743
14	Los Angeles (USLAX)	Shanghai (CNSHA)	165	509,6	177,9	592,2	182,1	659,7

Table 2. Estimation of CO2 savings, difference in emission with and without installed rotors, per route per year (Source: Authors)

The distribution of bulk carrier types/classes is taken from (Propulsion trends in bulk carriers, 2022). According to this distribution, 30.6% of the bulk carrier fleet is accounted for by the Panamax class and 23.4% by the Capesize class. The total number of bulk carriers taken from (Ricardo, 2020) is 12 522. From the data given, the number of Panamax vessels is 3 832 and the number of Capesize vessels is 2 930.

To estimate CO2 reductions, the following assumptions are made: all Panamax and Capesize ships operate on the selected 14 routes; the number of Panamax and Capesize ships is evenly distributed among the 14 routes (Pamamax: 273 ships per route; Capesize: 209 ships per route); each ship makes 12 trips per year (once per month).

According to Fourth IMO GHG study the total CO2 emissions of the shipping industry in 2018 are estimated at 1 056 million tons (Fourth IMO GHG Study 2020 - Full report and annexes, 2020). The distribution of CO2 emissions by ship type in 2018 is shown in Figure 3 (Table 81 from (Fourth IMO GHG Study 2020 - Full report and annexes, 2020)).

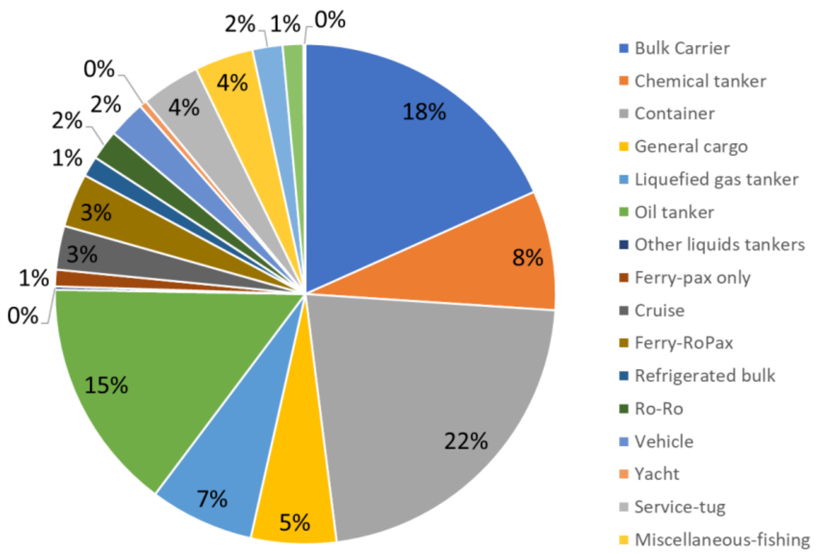


Figure 3. Distribution of CO2 emission by ship type (Source: Fourth IMO GHG Study 2020 - Full report and annexes, 2020).

CONCLUSION

The Flettner Rotor Savings Calculator was used to estimate CO2 emission reductions in a scenario where all Panamax and Capesize bulk carriers have one or four Flettner rotors installed. The estimated CO2 savings for one installed rotor is 0.39 % per year and for four rotors is 1.41 % per year, compared to the CO2 emissions of the entire shipping industry. If the bulk carrier fleet is considered, the CO2 reduction is 2.21 % per year for one rotor and 7.86 % per year for four rotors. This study provides an estimate for a specific scenario only: 14 routes, distribution of ships along routes, constant speed, specific rotor dimensions, loading conditions, representation of all Panamax and Capesize ships with predefined ships, average values for wind speed and direction (annual average wind conditions over all major trade routes as defined in MEPC 62/ INF.34).

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Autonomous Shipping: Current Status and Main Barriers to Large-Scale Diffusion

Mariah Kurtinaitis Joukes, Roland Ortt, Mark de Bruijne

Maritime Autonomous Surface Ships (MASS), in essence the maritime equivalent of autonomous vehicles, is a very interesting development. Different MASS applications are suggested, but there is confusion about the technology and its added value among practitioners and researchers. MASS faces many barriers to reach large-scale diffusion which are neither mapped nor fully understood in the maritime sector and academia. Based on literature review and interviews with maritime practitioners and MASS researchers, this article compiles a short history of MASS, which helps to identify current niche market applications in commercial shipping and to determine the current pre-diffusion stage of MASS. The state-of-the-art list of MASS barriers to large-scale diffusion from academic literature and maritime practitioners are analyzed to establish which key barriers prevent MASS from large-scale diffusion. Practitioners confirm the barriers identified in academic literature yet identify extra barriers for large-scale diffusion of MASS which are not yet addressed in academic literature. The article concludes that MASS has limited effect on reducing costs and is facing institutional and market rather than technical barriers to large-scale diffusion, with many of them revolving around the effect of MASS on various aspects of maritime safety.

KEY WORDS
Maritime Autonomous Surface Ships (MASS), Large-scale diffusion, Barriers, Market.

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INTRODUCTION

Practitioners and scientists have tried to describe what can be expected after the invention of a technology for a variety of reasons. It is fascinating to understand and map how technological innovations emerge, evolve, and are applied over time. Historians of technology carefully studied how specific technological innovations emerged and evolved over time, for example for ships (Gilfillan, 1935) or steamboats (Hunter, 1949). Although each case of a technological innovation may emerge and evolve differently, for example because of unique contextual circumstances and the powerful drive of individuals (Hughes, 1987), social scientists have nevertheless distilled and developed a generic pattern of development and diffusion of technological innovations.

We will unravel the pattern of development and diffusion for autonomous shipping (research question 1). Autonomous shipping has always sparked our fantasy and represents an interesting case of technological innovation. It is important to define autonomous ships carefully to prevent confusion about technologies and to distinguish between manned/unmanned and autonomous/human-controlled ships.

Autonomous shipping is the capability of a ship to navigate autonomously from A to B. It means that a ship can navigate autonomously on a particular level (meaning it needs limited to none human intervention, either on ship or elsewhere, to perform specific navigational tasks) by applying the technological principle of Artificial Intelligence and integrating that principle with subsystems to monitor the environment of the ship, its course and speed, as well its internal functioning, so the ship can adapt its navigation to the environment around it and reach the intended position.

Why did the pattern of development and diffusion for autonomous ships evolve rather slowly? We will explore reasons for this through the identification of barriers for large-scale diffusion (research question 2). It is interesting to look at initial applications for autonomous shipping. What pilots and niche applications are discernible for autonomous shipping? We will describe some of these applications (research question 3). The subsequent research questions also reflect the three steps in our work:

RQ1: Where is autonomous shipping in the pattern of development and diffusion?

RQ2: What are the main barriers or stimulating factors for autonomous shipping currently?

RQ3: What are current (niche) applications and pilots in autonomous shipping?

To answer these questions we adopt multiple methodologies, in particular literature research and personal interviews with various stakeholders involved with autonomous shipping. In the next section we will summarize the main theory after which the results will be described in section 3. We formulate our conclusions and discuss them in section 4.

THEORY

The pattern of development and diffusion

When the development and diffusion of a technological breakthrough is described as a historical phenomenon, the picture that emerges is different than the standard innovation-diffusion model that sees innovation as a project that precedes a smooth S-shaped diffusion curve. After documenting over 100 technological breakthroughs from their invention onwards, we notice several differences with the standard model (Ortt & Schoormans, 2004; Ortt, 2010), the differences are summarized below.

Between invention and introduction, there is more than one development project!

- The time between invention and initial introduction includes a period that is often much longer than the time needed to complete an innovation project.
- Instead of one coordinated innovation project, there are often multiple related, but uncoordinated, development processes taking place simultaneously in different organizations. It is impossible to consider the combination of those processes as one single project.

In short: the development between invention and initial introduction is different from a project.

After their introduction even (successful) technologies do not automatically 'shift' into steady diffusion!

- On closer inspection, it also turns out that it takes time before the start of the S-shaped diffusion curve follows the initial introduction of a technology. Although a diffusion curve does occur with successful technologies, it almost never starts immediately after introduction.
- Instead of a successful diffusion, there are often multiple small-scale, sometimes less than successful, applications of technologies. These applications do not confirm a lack of success (as the standard model implies); they are a result of technological breakthroughs and their market applications must subsequently be explored, understood and developed together with all complementary products and services and all other conditions.
- About 80% of all technologies experience a prolonged phase of niche applications prior to the start of large-scale diffusion (Ortt, 2010).

In short: a small-scale and chaotic start of the diffusion of a technological breakthrough does not signal that the technology in question has no potential.

These important objections to the standard innovation-diffusion model have led to modifications over time. In its current form, the innovation-diffusion model is widely considered to generate a more realistic representation of the development and diffusion of a technology as depicted in the first graph below. In practice variations on this model, referred to as scenarios, can appear in which the innovation and adaptation phase are either longer or shorter or in which the pattern is aborted in one of these phases.

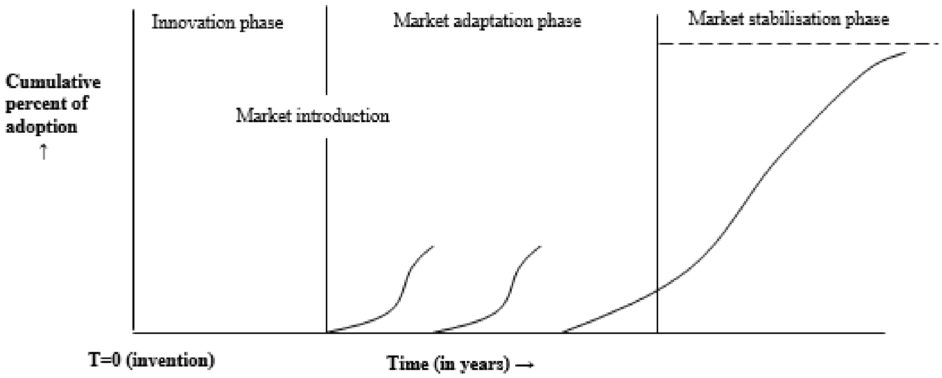

Figure 1: Generic pattern of development and diffusion of technological innovations.

- **The invention:** the first demonstration of the functioning of the technological breakthrough.
- **The first introduction in the market:** the first time that a technological breakthrough is applied, sold or implemented.
- **The start of industrial production** and large-scale diffusion and implementation of the technological breakthrough.

Using these three milestones, we distinguish three consecutive phases:

- **The development phase:** between invention and initial introduction. The invention is the demonstration of a functional principle that, in many cases, is not (yet) ready for production and market introduction. During the development phase research is designed to improve the principle and one or multiple development processes are initiated to create a product based on the principle.
- **The adaptation phase:** between initial introduction and the start of industrial production and large-scale diffusion. This phase includes trial-and-error processes in which product variations are introduced in a variety of market niches. Ultimately, the adaptation results in (a kind of) standard product.
- **The stabilization phase** starts with industrial production and large-scale diffusion. A more or less standard product can be produced on a large scale, and this is subsequently applied and diffused on a large scale. The product variations and applications have in essence stabilized.

There are various scenarios for the shape of the pattern of development and diffusion, scenarios that distinguish themselves by different phase lengths. There are examples of breakthroughs in which the first phase lasted almost a century (fax machines and the material PVC), and examples in which that phase lasted less than a year (dynamite). The same applies to the second phase. The pattern for autonomous shipping (AS) is described in section 3.1.

The Barriers to large-scale diffusion

The pattern *describes* what can happen after the invention of a new technology. It is also interesting to *explain* how actors, factors and specific interactions between them shape such a pattern. One way to explain the time interval of the development phase and to explain the emergence and time interval of the adaptation phase, is to look for barriers which hinder or even prevent development and diffusion. Or more generally, to look for actors and factors that can either stimulate or hamper development and diffusion of a technology.

Barriers (or stimulating actors and factors) can be active within markets or organizations. The original innovation diffusion paradigm envisions a diffusion curve after market introduction which focuses on the demand-side of the market. Important innovation barriers that follow from this paradigm thus focus on potential customers and factors such as resistance to innovation, lack of resources, lack of knowledge, and incompatibility between installed base and innovation. In practice, however, barriers to diffusion can also originate from the supply side of the market, or from non-market actors, such as government bodies and regulators. The interaction between barriers typically affects the ideal-typical smooth S-shaped pattern and produces more erratic types of diffusion as depicted in the adaptation phase. The barriers for AS are identified in section 3.2.

The relevance of first applications

The notion that, at the time of the first market introduction of a technology, multiple barriers are hampering large-scale diffusion, has important implications. First, although barriers may effectively block the development of large-scale applications, the development of small-scale applications which circumvent the barriers can occur. These small-scale niche applications produce specific versions of the technology that are adopted by small and specific customer segments. Such niche applications often diverge considerably from later large-scale applications (Ortt, 2010): they are not always 'just a new product niche' that later becomes a mainstream application. The first MASS applications are in section 3.3.

RESULTS

Where is Autonomous Shipping in the pattern of development and diffusion?

MASS' initial concept dates back to 1898 when a remotely controlled boat was demonstrated by Nikola Tesla (Bertram, 2016). However, it was only introduced as a commercial product in maritime shipping in 2019. Despite being the first to document and mention an unmanned vessel concept, Tesla's demonstration cannot be characterized as MASS invention because the technological principle then was not the same as today. AI, which is the basic technological principle guiding autonomous shipping, originates from 1943 (Russell & Norvig, 2010), thus it could not have been used by Tesla when he demonstrated the remotely controlled boat in 1898.

MASS as technological principle was first demonstrated in Japan in the Highly Reliable Intelligent Ship project (NFAS, n.d.) in the 1980s (Bertram, 2016). The Intelligent ship concept was based on the idea of a fully manned mother vessel followed by intelligent slave vessels (Bertram, 2016). This concept is known today as Vessel Platooning or Vessel Train (van den Boogaard, Feys, Overbeek, le Poole, & Hekkenberg, 2016), a fleet consisting of one fully manned lead vessel that takes over navigation, communication and situational awareness tasks while the remaining vessels follow its lead (Colling & Hekkenberg, 2019).

Despite not being fully documented, the name of the Japanese project and the functions performed by the vessels suggest the use of AI. Considering that AI dates from 1943, it is likely that MASS, as it is currently described, was thus invented and demonstrated for the first time in the early 1980s. Its commercial application, however, came 39 years later, when autonomous vessels became available to the maritime shipping market in 2019. During the nearly 40 years between demonstration of the technological principle and the commercial application of MASS, many studies regarding this subject have been published.

As explained in section 2, the second milestone in the pre-diffusion process of MASS is the first time that the technological breakthrough becomes commercially available. The first commercial application using MASS was offered to the market in 2019, when Kongsberg released the survey vessel Sounder (Kongsberg, 2020) for orders and purchase. Fugro introduced the survey vessels Blue Shadow and Blue Essence later that same year.

Despite no longer being the only MASS applications (see section 4.4), these are still the only commercially available MASS products. The history of its invention and introduction and the absence of large-scale production and diffusion suggests that MASS is currently in the adaptation phase of the pre-diffusion phase, as depicted in Figure 2. It is worth noting that the innovation phase spans nearly 40 years, almost 4 times the average 10 year period found in a large sample of radical new technologies.

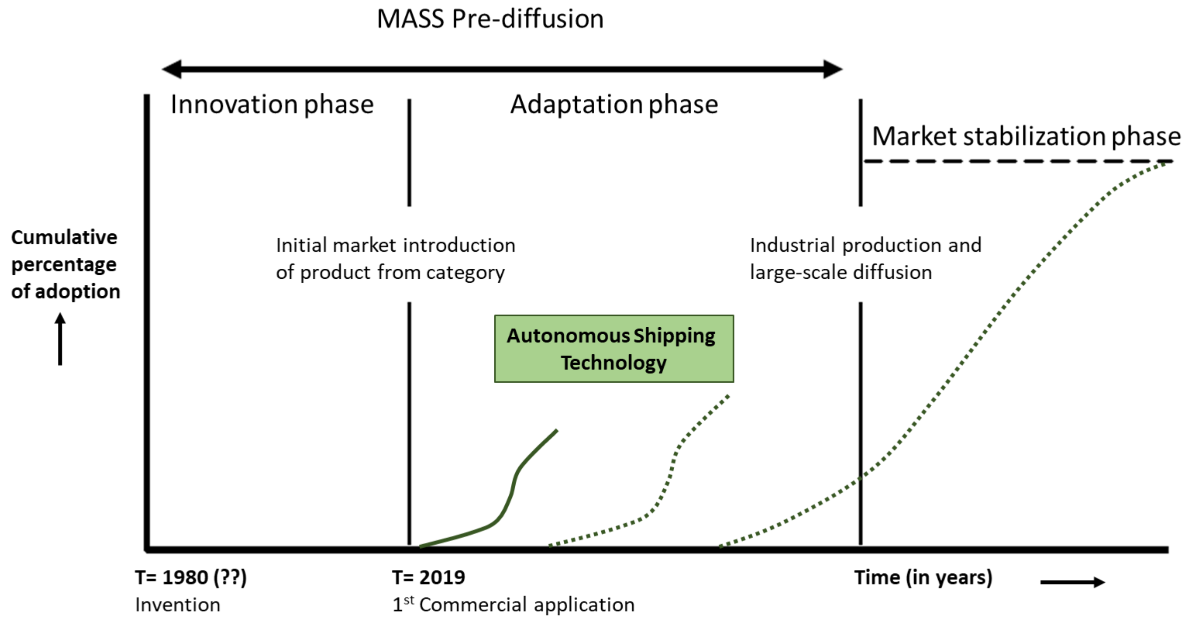

Figure 2: MASS pattern of development and diffusion

What are the main barriers or stimulating factors for AS currently?

The diffusion process described in section 3.1 suggests that MASS did not smoothly migrate from invention to market introduction. Instead, being stuck for 39 years in the innovation phase and the limited number of available commercial applications (on survey vessels only) points to a challenging transition.

Practitioners and academics we interviewed identify nine categories of barriers influencing MASS diffusion. Although academics and practitioners agree over many types of barriers, practitioners identify aspects in 3 additional categories that have not (yet) received attention in academic literature. Table 1 below summarizes the list of barriers to MASS diffusion.

Challenges to MASS diffusion		
Categories	**Literature Barriers**	**Practitioners Barriers**
Connectivity	Unreliable connectivity in some areas or due to bad weather (Vagale, Oucheikh, Bye, Osen, & Fossen, 2021)	Totally dependent on the internet (100% reliable Internet connection required)
	Cybersecurity – hackers might take unauthorized control of the ship (Wright, 2020)	Cybersecurity
		Lack of a data transfer standard
Loss of control/ (Cyber) Piracy	Piracy and hijacking of the cargo (Vegale et al.), cyberpiracy (Kobyliński, 2018; Wright, 2020)	Physical protection of the cargo (value/type of cargo) & piracy
Financial Considerations	Task based implementation path for autonomous ships (Kooij & Hekkenberg, 2021)	Cost-Benefit/ Business Case / Retrofit Costs/ ROI
Regulations & Legal Responsibilities	Definition of liability without captains onboard (Kim & Mallam, 2020)	Liability & Responsibility
	Unclear regulations about MASS requiring international cooperation (Komianos, 2018)	Legislation & Regulations
Safety	Possible increase of accidents caused by MASS (Wróbel, Montewka, & Kujala, 2017), reduced accident mitigation options in case of accidents (Ventikos, Chmurski, & Louzis, 2020)	Guaranteed Crew Safety
	Navigation Safety in poor weather conditions (Vagale, Oucheikh, Bye, Osen, & Fossen, 2021)	Weather Conditions
Maintenance & Equipment Reliability	Maintenance & reliability of equipment on board (Kooij & Hekkenberg, 2022)	Equipment Maintenance
		Propulsion System – Diesel Engines
		System & Technology Reliability
Cultural Aspects in shipping		Fear of unknown
		Difficulty to understand ROI
		Resistance to change
		Infrastructure problems – *interaction of ships with*

Operational Challenges		*harbours, personnel and operation with other vessels*
		Communication between vessels *and vessel with infrastructure*
		Clarity about when autonomy starts and stops
Knowledge and Technical Skills		Lack of practical knowledge
		Maritime schools & Training
		Knowledge transfer from pilots

The differences point towards an important distinction between 'practice' and 'theory' of MASS diffusion. The professionals working on board, at harbors, or shipyards identify a longer list of obstacles to overcome to ensure MASS diffusion.

The 3 specific categories of barriers that are not addressed in literature are: Cultural, Operational and Technical Knowledge. The cultural barrier is intrinsic to the conservative character of the industry, which is explained by its emphasis on crew and vessel safety and the longevity and costs of these assets. The other 2 categories, Operational and Technical Knowledge address obstacles which go against the current way of organizing. The technical knowledge category identifies what is currently missing to implement MASS, focusing on where change is needed to enable knowledgeable professionals to operate the vessels safely. This category of barriers is addressed by IMO by pointing out new seafarer skills for autonomous shipping. Such updates in skills took place before when ECDIS (Electronic Chart Display and Information System) certification became mandatory (Safety4Sea, 2018). This category, therefore, requires adjustments, but does not pose large impediments to MASS diffusion.

The operational category, on the other hand, presents impediments caused by MASS implementation; issues that are not a direct problem for the safe operation of a vessel but may become an issue with the introduction of MASS. Differences in port infrastructure worldwide, diversity in points of responsibility and the communication between vessels are currently dealt with by seafarers and these tasks will be jeopardized by the implementation of MASS. The qualitative nature of COLREGS regulations, for example, assumes radio communication with the navigator to evaluate the best course of action. If the navigator is no longer in command, another communication method must be foreseen to ensure safety at sea.

What are the current applications and pilots in Autonomous Shipping?

This next overview shows different types of vessel tests involving MASS and the goals. It is important to mention that the method does not generate an exhaustive list of all MASS trials and projects world-wide but portrays the categories of vessels in which tests are conducted at the time of our data collection and specifies the goals of the companies testing MASS intend to achieve.

Category	Vessel	Autonomy Goals
Cargo Vessels	Yara Birkeland	Transport efficiency - SCC Control
	Factofour	Crew Efficiency - Reduce Manning
	Vistula Maersk	Increase cargo onboard - Fully manned operation
Ferries	Falco	Safety
Harbour Tugs	Svitzer Hermod	Safety - SCC Control
	Recotug Project	Safety - SCC Control
	IntelliTug	Safety - Increase Efficiency
	Mayflower	Unmanned autonomy
Survey Vessels	Blue Shadow & Blue Essence	Unmanned autonomy - SCC Control
	Sounder	Unmanned autonomy - Local Remote Control

Based on our research, all current applications are performed in a controlled environment, including the commercially available Fugro Blue Shadow and Blue Essence (Fugro, n.d.) and Kongsberg's Sounder (Kongsberg, 2020), which do not fully operate autonomously in open waters (yet). The only exception, the Mayflower, is an autonomous survey sailing vessel (Mayflower 400, 2020). Current commercial applications are restricted to only two survey vessels, which capitalizes on the fact that most of the conventional survey vessel design and structure accommodates the crew onboard. Full autonomy allows these vessels to remove accommodation, reducing costs and increasing efficiency.

The difficulty of current MASS applications of operating in open waters poses a barrier to long-haul vessels, regardless of their cargo type, given the open-seas nature of their voyages. Another factor hampering the adoption of MASS in the long-haul sector is the financial attractiveness. The crews in long-haul marine shipping have a relatively small impact on the operational costs of a vessels' operation (Interviewee 10, 2021) (Interviewee 14, 2021). Therefore, investing in MASS is (still) unattractive for the sector. However, as shown in the table above, there are still MASS tests being performed, which indicates other goals other than crew elimination can be achieved with MASS.

CONCLUSIONS

This article focuses on autonomous shipping and answers four research questions. The first question sets the stage by defining autonomous shipping. The second question assesses the status of autonomous shipping in the evolutionary pattern of development and diffusion. The third question investigates the main barriers to large-scale use of autonomous shipping. The fourth research question explores current pilots, experiments and applications of autonomous shipping. In answering these research questions, we focus on commercial ships.

Where is MASS in the pattern?

The pattern is a general model of the evolutionary process of developing and applying technology. In the model three phases are distinguished: the innovation phase (between invention and first market introduction), the adaptation phase (between first market introduction and the start of large-scale diffusion) and the stabilization phase (after the start of large-scale diffusion). Autonomous shipping is currently in the adaptation phase, meaning that it is introduced in specific niche applications only, for example commercial survey vessels. In parallel technological developments are ongoing and changes in other parts of the ecosystem are prepared while the technology is already applied in practice.

What are the main barriers?

We explored diverse types of barriers that may explain why MASS is not yet applied on a large-scale. Results from literature research and from interviews with practitioners are combined to form a comprehensive list of the current barriers to large-scale application of MASS. A first category of barriers relates to the performance of the system, specifically its reliability and hence its effect on safety. MASS requires connectivity that, once disturbed, may create dangerous situations at sea. A related barrier is the notion that MASS may be vulnerable to misuse, for example terrorist attacks and hijacking. Other barriers relate to the financial consequences of developing, implementing and operating MASS. Its development and implementation are expensive while the cost savings of its operation are found to be quite limited because navigation represents only a minor part of the operations that humans perform on freight ships. Regulations and rules represent another barrier. Navigation at sea is based on the notion of good seamanship and hence the total number of rules can be quite limited and basically the same across the world's seas. MASS does not fit in this traditional type of regulation and hence large-scale application is hampered until regulations, and accompanying operational procedures, are changed.

Interestingly, the interviews confirmed all barriers that were mentioned in literature. That suggests that practitioners and scientists agree on these barriers. However, practitioners also mention some barriers that went unnoticed in the literature. Practitioners describe how cultural aspects of the community of practitioners at sea may hamper large-scale use of MASS. From a practitioner's perspective MASS does not fit with current operational procedures and work practices, and practitioners lack the required knowledge to deal with MASS.

What are the current pilots and applications?

Our results illustrate that Maritime Autonomous Surface Ships (MASS) is applied in several pilots and in specific niche applications. There are no autonomous freight ships navigating in international waters for prolonged periods of time. We found pilots and niche applications with other types of ships, such as survey vessels, local ferries and freight carriers. MASS is now possible for short trips, which means that the ships are less vulnerable to changing conditions in open waters and are only bound to local regulations. Most pilots and niche applications are scheduled in territorial waters to circumvent international regulations that hamper autonomous navigation.

Our analysis shows that Autonomous Shipping is in the adaptation phase and that several barriers block large-scale diffusion. We do not expect a sudden change towards large-scale use of AS because the main driver, financial aspects, is currently not obtainable for most commercial ships. That means that MASS can only be applied on a wide scale if the entire system of shipping is fundamentally changed. Such a change takes a while, especially when multiple countries and international regulations are involved. We believe that MASS will be applied more for niche applications such as local transport and survey until the technology and regulations evolve so it can also be used in international waters and safety can be guaranteed.

SCIENTIFIC DISCUSSION AND FUTURE RESEARCH

Barriers to MASS diffusion

This article has explored barriers to large-scale diffusion (research question 3). The barriers and some industry-specific characteristics can be used to further compare the pattern of development and diffusion for autonomous cars and ships. We can see a few interesting differences and commonalities. Firstly, cars have a significantly shorter (economic and technical) lifetime, are cheaper and are produced and used in much larger quantities than sea-going cargo ships. That means that improvements in cars, like providing autonomy, are developed and applied faster. This represents a tentative explanation why autonomous cars were introduced earlier than autonomous ships. However, for cars, like for ships, regulation is a major barrier. So, regulation is one of the explanations why both autonomous cars and ships took relatively long to be introduced and applied in practice.

MASS Niche Applications

This article also explored niche applications for autonomous ships (research question 4). It is interesting to see how different niche applications are emerging for cars compared to ships to deal with the 'regulation barrier'. For cars, lower levels of autonomy, where drivers stay tuned and responsible although the car drives autonomously, are now used widely. Adaptive cruise control, lane assist, and parking assistance are examples of features that enable autonomy while meeting the regulations. Autonomy in cars increases safety, convenience, and comfort. In contrast, for autonomy in commercial ships, financial benefits are most important, and these benefits are more limited than expected, since crew reduction is not (yet) allowed by international regulators. We conclude that the technology and the main barriers may be similar, yet the benefits and hence the niche applications differ for autonomous ships compared to autonomous cars mainly because car owners have a different perspective on the benefits of autonomy than ship owners. While the former is satisfied with comfort, safety and convenience, the latter has a bigger focus on cost efficiency and safety, which is not yet widely proven for vessels. So, we can observe industry-specific trajectories of development and diffusion for autonomous technology in transport.

Comparing results from interviews and literature research

In this article we explore barriers to large-scale use of autonomous ships in two ways: interviews with practitioners and literature research. It is interesting to note that practitioners identify more types of barriers than were found in scientific literature. Scientific articles tend to focus on a few specific barriers (depending on the disciplinary perspective of the authors), yet an overarching combination of barriers is lacking. In contrast, practitioners look at the combination of barriers and specifically add barriers related to the *transition* towards autonomous shipping. Practitioners also, because of their working practice, consider inter-ship contact and communication of vital importance whereas literature mainly considers the ship as an autonomous and isolated system. We conclude that interviews and desk research therefore complement each other and together provide a more comprehensive view on relevant actors and factors which influence large-scale diffusion and application of autonomous shipping.

Future research

This article provides an overview of the history and current state of development and diffusion of autonomous shipping. This overview reveals several pathways for future research. We identified a list of barriers to large-scale diffusion and the application of autonomous shipping from literature and practitioners. It would be interesting to compile a comprehensive list of barriers in a generic framework to explore and explain the market and technological conditions for radically new technological innovations in different industries.

Our findings indicate that specific niche applications are possible in the face of barriers to large-scale diffusion and application. It would be most interesting to explore which specific niche strategies thrive in the face of diverse types of barriers. Specifically for autonomous shipping it is interesting to explore how situations at sea that currently are saved by good seamanship, can be dealt with by autonomous technology.

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Career Development for Seafaring Officers to Meet the Requirements of the Maritime Industry

Ergun Demirel

People's career planning in light of society's requirements is highly important to realize the sustainable development and well-being of our civilization. To meet the existing and future requirements of society new professions are appearing and some professions are evolving and reshaping under the pressure of rapidly changing technology. The change in the business and industry also affects the education system including the organization of education institutes, course programs, and delivery methods.

The seafaring officer profession is an important element of the maritime industry which is an indispensable component of the world economy. Ships, ports, and shipyards are developing exponentially by getting benefits from sophisticated technology. The seafaring officers have significant competencies not only working on board but also assuming many roles and responsibilities at all maritime-related organizations such as ports, shipyards, and different types of transportation and logistics facilities.

This study aims to investigate seafaring officers' career development opportunities to meet the maritime industry's existing and future manpower requirements and introduce new job opportunities for seafaring officers.

KEYWORDS

Seafaring officers, Career development, Maritime industry, New job opportunities, Maritime manpower

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INTRODUCTION

Human capital is defined as the skills, knowledge, and experience possessed by an individual or population, viewed in terms of their value or cost to an organization or country (Stevenson, 2015), or as productive wealth embodied in labour, skills, and knowledge (OECD, 2017).

In today's world, the demand for the maritime sector is increasing depending upon the growth of the economy and the increasing requirement for maritime transportation. Seafaring officer candidates who want to step into this sector must primarily receive education at universities. The students who receive education must first finish their education in navigation or marine engineering. After having competency as a watch officer or marine engineer, the difficult part of working in the maritime sector starts. Firstly, they need to improve their knowledge and experience to gain new competencies for promotion in their profession. Secondly, they should follow a career path to be eligible for shore duties that are suitable for their background. Most importantly they need to increase their income to get better living conditions and secure their future. Another different way is to apply to crew management companies and get professional support in their career planning so that they can work in more than one company's ships as a deck officer or marine engineer. Most shipping companies do not interest in their employee's personal development and career planning. So ever seafaring officers need to create their career path and make plans to achieve it. The challenges of making a career in the shipping industry are not so easy and individuals spend the effort to apply their career path in the hard conditions of sea life. This situation causes an inevitable regression in their career. An issue that may not consider when planning their careers and may suffer from problems in the future is the lack of officers in the sector. Although there is a significant deficit of 18% between the supply and demand of seafaring officers, it is very hard to estimate the future of the supply of seafaring officers considering the increasing number of new newcomers and the negative effects of automation onboard which could reduce the manning requirement. Working on board is not the only job for seafaring officers and they should consider other suitable job opportunities at the shore. To have a chance to work ashore they should have a perfect career plan.

Career Development Plan is a written list of the short and long-term goals that employees have about their current and future jobs, and a planned sequence of formal and informal experiences to assist the employees in achieving their goals. These goals should be linked to each person's strengths and potential. Ultimately, the purpose of a Career Development Plan is to assist employees in achieving their goals. In doing so, an organization also increases the likelihood of retaining employees, because employees recognize that managers have helped employees achieve their career goals within the organization, rather than employees believing they need to leave to pursue these goals somewhere else (NCDA, 2008). Both individuals and organizations have had to make career plans for their employees. The important thing in this regard is to ensure harmony between the career plans of the individuals and the personnel development plans of the employers they work with.

RESEARCH METHOD

This study aims to investigate seafaring officers' career development opportunities to meet the maritime industry's existing and future manpower requirements and introduce new job opportunities for seafaring officers.

The research questions are defined as follows:

- What is the main basis of a career plan which is flexible to meet the requirements of changing working conditions at sea?
- What are the suitable jobs other than sea duties for seafaring officers?
- What is the role of the employers to assist the application of their personnel development plans and employees' career planning?
- What is the role of the Maritime Education and Training (MET) institutions to support career planning?

Meta-synthesis is applied to this study. The Reciprocal Translation method of meta-synthesis which is "Concepts in one study can incorporate those of another" is applied. Different approaches, considerations, and predictions from verified sources are reviewed, evaluated, and discussed to interpret the main issues of career planning for seafaring officers. The study starts with a review of related literature which is mainly based on a broad range of empirical research made by scientists and internationally recognized organizations. After summarizing new improvements in the maritime industry, it is intended to evaluate the impacts of the career planning of seafarers. As a result of this evaluation, some proposals are produced to obtain clear ideas for seafaring officers to make their career plans. The result of this study will also assist shipping companies to prepare their staff development plans.

RESEARCH

Working conditions at sea

The working conditions at sea are changing drastically. It is very difficult to find people who are eager to work at sea in developed countries. Nowadays approximately 80 percent of seafarers are from developing and underdeveloped countries. The new generation is looking for more comfortable jobs with a good salary and a job at sea with many hardships is not attractive for them.

The interest in the sea as a place to work decreases not only in reach countries- - those with a strong maritime tradition. This also applies to countries in transition, where work on the sea used to be perceived as attractive. The situation changed - work at sea is no longer seen as an opportunity to leave the country. Also, wages are not attractive enough to compensate for the disadvantages of seamen work (Skrzeszewska, 2017).

Generation Y is optimistic and focused on its goals. It has a lot of expectations and wants to achieve professional success (Caesar & Cahoons, 2013). Growing up in the digitally connected world, uses the Internet as a tool for learning, building relationships, socializing, and working. In the case of maritime labour, conditions change in the functioning of all the listed areas. No access to the Internet, a limited number of people around, limited space, lack of opportunities to interact with people outside of the ships reflect negatively on the perception of maritime labour for young people. (Cahoon & Haugstetter, 2008). Nowadays youngsters want to get the benefits of their social environment as well as get in touch with their friends through the internet. They spend 4-6 hours on social media, and it is very hard for them to live in a world without an internet connection. Unfortunately, this is still impossible for seafarers when they are at sea. 20 years ago, people were socializing in clubs, pubs, and cafes.

Since the beginning of the 2000s, strong social media has emerged and has become the centre of socialization. Due to the working conditions, the sailors did not have the opportunity to socialize in social spaces before. Unfortunately, there are no or very limited opportunities to reach social media.

This situation is an important reason that prevents the new generations' desire to work at sea. In many studies, it is seen that the most important reason why young people are reluctant to work at sea is staying away from the social environment. It is very difficult to direct the new generation to work at sea without ignoring this important element. An alternative solution for them would be to leave the sea after a certain period and find a suitable job at the shore. This will only be possible with carefully designed and realistic career planning.

Work at sea is regarded as an alternative to working on land in a situation where the labour market is unfavourable to new entrants, and the employment rate rises. Given the slow, but still, growth of standard living in Poland (A European Country), reflecting the level of European standards – Poles, like other nations of Western Europe will choose to work in their country. The work is safer, equally attractive in terms of salaries, and less demanding. The work, will not terminate them, even for a short time, from an active family and social life. (Even if it is limited to the use of application platforms and social networking.) (Skrzeszewka, 2017)

Career Planning

Career planning aims to identify needs, aspirations, and opportunities for individuals' careers and the implementation of developing themselves to reach their goals. Stewart and Brown (2019) and Monolescu (2003) explain career planning as "a continuous process of discovery in which an individual develops his occupational concept as a result of skills or abilities, needs, motivations, and aspirations of his value system".

Career planning targets career development and it requires the establishment of strategies, analysis of weaknesses and strengths of individuals, and existing opportunities and obstacles. Career Planning Process is under both Individual and Organizational Responsibility.

The development of professional career planning skills: self-cognition, self-management (self-education), labour world cognition, adjustment to work, lifelong learning, and social skills is defined as a process enabling persons to plan their professional career as a consistent and managed process. Therefore, the mission of professional career planning skills development is to encourage a personality to be responsible for the planning and improvement of their professional activity. (Kalvaitiene & Sencila, 2013)

The role of employees in Career Planning

Regardless of the operating organization, the individuals must be actively involved in managing their careers and motivated by their beneficial effects on welfare.

Beneficial Effects:

- The economic standpoint
- At a basic level, the work provides an income to the individuals to ensure their needs.
- The source of extrinsic motivation (external) for employees
- The psychological standpoint – as a source of spiritual comfort, the work provides a sense of accomplishment and gives meaning to the individual existence.
- Psychologically, career opportunities are an important source of intrinsic motivation (internal) for employees.

- Psychological contract suggests that employees can become more valuable to employers by taking responsibility for their career planning.
- Regardless of the complexity of the career planning system, employees should take the following actions:
- To take the initiative in the sense of requiring feedback from peers and chiefs regarding the strengths and weaknesses of their skills;
- To identify the stage of career development and the development needs;
- To seize as many opportunities as possible to learn
- To interact with employees from different work groups within and outside the organization

Career Planning for Seafarers

The maritime sector is the sector where international competitive conditions are valid and where there are extremely heavy and exhausting working conditions. The fact that ships are constantly on the move makes this profession different from other professions. As a result of this mobility, officers stay away from their families and social circles for a long time during their working lives, but they have to continue their professions under severe sea conditions. These factors distinguish business life on land and business life at sea with a sharp line. Seafarers are members of a difficult and exhausting profession. (Koseoglu, 2010).

Seafarers, who are away from their social circle for months, can only follow the developments in the world and their countries from the media, most social media. This creates the feeling that they are missing out on many of the opportunities available on land. Moreover, due to physical distance, many training opportunities are limited. Even when they want to take distance education, the opportunities to benefit from this education, which is connected to the Internet, are very limited. This results in them not being able to take advantage of the training opportunities necessary for their career plans.

Those individuals who stay in the seafaring profession are perceived to be the more practical-minded, often with a long-held ambition to become a Master or Chief Engineer. They are people who appreciate the job and the seafaring lifestyle, and the rewards that this brings. Some find fulfillment in their ambitions outside their working life and find seafaring conducive to the pursuit of these other activities. Perhaps they are very active in other areas, for example, managing small private businesses while ashore. In contrast, there are also the more academically inclined, who may from the outset, regard the officers' vocation as merely a step on the ladder to a maritime career ashore and who will often plan for additional education. Another factor that may determine the length of time spent at sea by an individual is ''fast track'' promotion, which in some companies has become the rule rather than the exception. Within a few years, an officer's salary may be at a level that is difficult to match in a normal shore job (Southampton Solent University, 2005).

Individuals will make a career decision based on several factors, which they experience during the course of their seagoing life. In the case of ratings, many regard life as a seafarer as a passing phase of life anyway, but many have also been forced to leave the profession because of a lack of employment opportunities (Southampton Solent University, 2005). (Popescu, 2003) has defined factors that are affecting individual's Career Planning [for seafarers] as follows:

- The location of the home or place of upbringing.
- Family Influence.
- Good Career Prospects.

- A Long-term Interest in the Sea.
- Travel

Kalvaitienė and Senčila (2013) have improved a model for the Process of professional career planning (Figure 1). This model starts with self-assessment and follows a research and decision-making process reaches prepare for a professional career plan

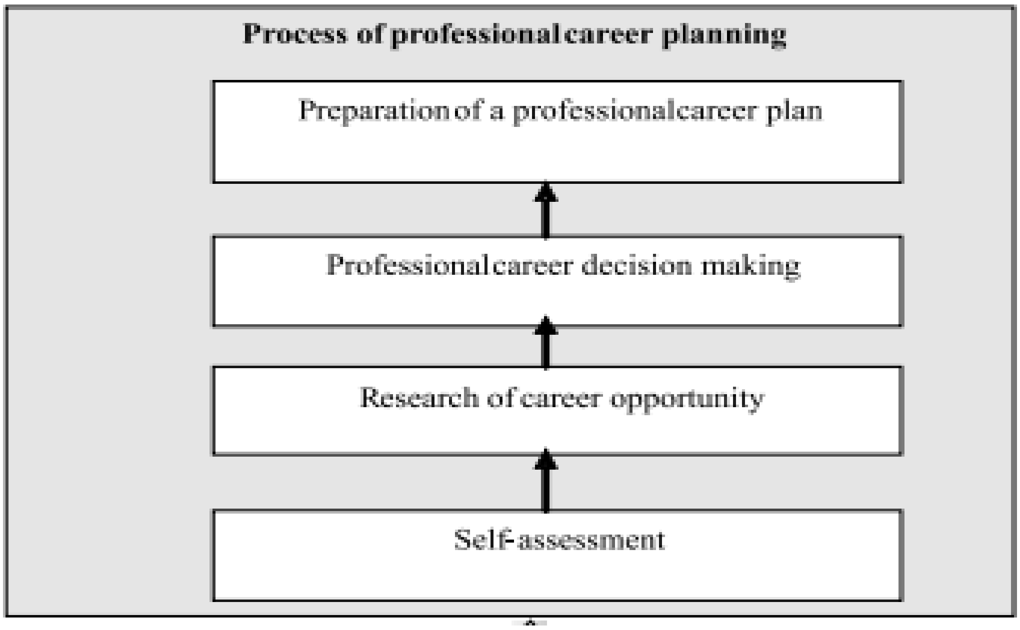

Figure 1: Process of professional career planning

The major incentive to leave the sea stems from the requirements of the modern family, where it is expected that both parties will pursue a career, making the efforts of both necessary for the child-caring demands made by the young family. This economic development during the last forty years has resulted in a growing pressure on young seafarers with families to find a shore job. This reason for coming ashore will generally occur when an officer is in his twenties or early thirties when many couples are building families (Pekcan et al., 2006). Family building is a significant issue for human nature and should be considered when establishing a career plan. This is also an important reason for looking for a shore-based job as a seafaring officer after some years spent at sea.

Maritime Education is mainly based on the programs created to meet the vocational requirements of the maritime industry. Although the program covers academic courses such as foundation science, these courses are not sufficient to start a new profession. For this reason, their only option for transferring to other professions is to attend short-term courses in a maritime-related field and to take post-graduate education in their field, even if it is difficult.

To learn if any of the professions within the shore-based part of the maritime sector seemed interesting to the respondents, they were asked to choose one or several alternatives from a list suggesting different career options. The students in the practical and shipping program were mostly interested in manufacturing, repairs, and maintenance, whilst the students in the theoretical program were equally interested in research and development and design and naval architecture. (Hammarstedt & Zaar, 2011)

Many seafarers noted that they planned to work at sea temporarily and expressed plans to leave the sea after accomplishing the goal they had set out to achieve (i.e., gaining transferable skills, earning enough money, or traveling the world). In this context, seafarers' plans to leave can be largely divided into whether they have plans to continue working ashore in the shipping industry or whether they intend to enter an entirely different industry. (Baum-Talmor, 2018)

Flexible careers emerged as individuals' response to the breakdown of organizational support and the diminishing availability of bureaucratic careers within organizations. As such, flexible careers supposedly empower individuals to be at the helm of their career development, where they proactively navigate their occupational paths (Sennett, 2011).

Continuing Professional Development (CPD) refers to the process of tracking and documenting the skills, knowledge, and experience that users gain both formally and informally as they work, beyond any initial training. It is a record of what they experience, learn, and then apply. The term is generally used to mean a physical folder or portfolio documenting one's development as a professional (jobs.ac.uk, 2020).

CPD is a useful tool for career planning and it may be a perfect tool for companies and institutes when preparing their personnel developments plan. A new role for Human Resources departments is planning CPD programs for their employees as well as assisting employees to analyse their CPD requirements and assist them in planning their CPD activities. If a sufficient CPD plan is obtained, both employers and individuals can track the recent development in their profession and obtain the required knowledge, skill, and competency required ensuring their efficiency in their job.

Career Development and Organizational Responsibility

Career planning is not only a personal but also an organizational responsibility. Organizations trying to make a sustainable business have to include their employees' career planning in their staff development programs. This should be accepted not only as an organizational requirement but also as a social responsibility of the organization towards its employees.

The mission of the Maritime Education and Training (MET) institutes is not to prepare the students for existing duties but also for future roles. That means MET institutes should inform the students about career planning and provide the foundation of career planning. Lau et al. (2021) explain the role of MET institutes with the following sentences: "We could provide short-term and long-term career planning and development for students. Indeed, it would enable employers to design and implement appropriate staff selection and training programs to achieve industry competitiveness and national economic growth in the future. Moreover, it creates a perfect match between the demands of maritime industry development and the supply of human capital. In the future, we may suggest some methods to facilitate knowledge transfer from academic institutions to the maritime industry by generating collaboration networks, conducting private-public development programs and scholarly activities, and setting up specialized units".

It is crucial to promote careers at sea, enhance maritime education and training worldwide, address the retention of seafarers, and continue monitoring the global supply and demand for seafarers regularly (BIMCO/ICS, 2015). BIMCO/ICS (2021) Maritime Work Force Report predicts the need for 89,510 more officers by 2026, to operate in the global merchant marine field. Currently, 1.89 million seafarers serve the global shipping fleet operating in at-least 74,000 vessels around the world. The maritime industry requires qualified manpower to handle ships, ports, shipyards, and all related businesses. The international maritime organizations and NGOs which regulate the shipping industry should also assume a responsibility to facilitate and assist in the realization of career plans for seafarers.

Due to a shortage between supply and demand of oceangoing watchkeeping officers in the shipping industry, especially well-trained officers, there are more options for choosing a vessel type during their careers. At this point, after graduation, the correct decisions of officers become very important for their career plans. Because their career plans identify all careers both at sea and within the shipping companies post their sea career. (Kaya et al., 2018)

Changes in the labour and capital levels for maritime enterprises and marine labour markets are analysed. The first factors of production in the maritime sector are labour and capital. ''No matter how many different ship management is the shipment involved in the operations of the ships'' For this reason, especially professional international companies make their shipman preferences meticulously. It pays attention to the employment of qualified seafarers who will ensure the operation processes smoothly (Muslu, 2018). Shipping companies are growing day by day and they are becoming big logistics companies. This situation requires them to create more comprehensive manpower. Seafaring offices are suitable for many important tasks in these companies. This requires maritime companies to carefully consider career planning for officers.

The flexibility seafarers have to shift between different shipping companies but remain within the shipping industry does not necessarily have a detrimental effect on the industry as a whole, since the human capital (i.e., seafarers) remains within the boundaries of the industry. However, seafarers' employment temporarily suggests that they lack formal commitment towards a particular employer which may create problems for shipping companies planning their future workforce. Another potentially detrimental effect flexibility might have on ship owners is the number of incidents associated with inadequate training and the unexpected cost incurred as a result. (Sampson & Tang, 2015)

The evidence suggests that the current benefits of flexible employment for employers in the shipping industry may not endure in the future, with the drawbacks of flexible employment outstripping the benefits in the long term. To prepare for a possible, future supply-side problem current flexible recruitment practices need to be adjusted in two ways. First, employers in the shipping industry should consider the improvement of seafarers' employment conditions. Second, employers in this industry should implement a tailored career path for individuals according to their needs and expectations. In this context, employers could consider providing support to employees by building career progression around flexible contracts of employment (Baum-Talmor, 2018).

The Organization's Role in Career Planning:

- Career workshops
- Career centers or information systems
- Career planning guides
- Career counseling
- Career paths (directions)

The organization must monitor the career planning system to ensure that both managers and employees use it properly and especially to assess how it is useful in achieving its business objectives.

Changing roles and skills required for seafarers in modern shipping are considered to affect seafarers' career prospects. After several years of working at sea, seafarers often shift ashore to take shore-based jobs in areas such as ship survey, port management, marine insurance, ship broking and finance, ship classification, maritime law, and offshore work. (Kitada & Baum-Talmor, 2019)

The European Union's "SAIL AHEAD" project aims at providing an online guidance tool for a second career for Ship Masters. It covers a report with transferable skills, the result of a survey in nautical academies to identify competencies acquired through formal learning, and a survey in the ships to identify competencies through non-formal ones. The outcomes of this project are; a mapping of competencies and profiles required for at least 10 alternative career paths ashore and an online tool to be used by students or captains that will help them assess the possibilities to work on shore. As a result of the SAIL AHEAD Project the following job profiles are found suitable for deck officers at the shore: Coast Guard Officer, Chief Executive Officer (CEO), Operations Manager, Designated Person Ashore (DPA), Quality Manager, Occupational Health and Safety Manager, Maritime Lecturer, Maritime Auditor, Maritime Surveyor (Inspector – Auditor), Marine Advisor/Consultant, Port Authority Officer, Pilot, Arbitrators.

Additionally, the above-mentioned job profiles can include Stevedore Captain, Lashing Manager, Cargo Inspector, and Port Facility Security Officer (PFSO). Many shipping companies also started to operate as logistics companies and/or have a logistics component. As a result of this development, logistics companies became a significant occupation for seafaring officers.

Structured Interviews to define seafarers' opinions on career planning

A series of structured interviews were conducted to learn about the experiences and suggestions of the Seafaring Officers, who worked especially at sea, regarding the Career Planning process. These interviews were made with 10 unlimited Captains with sea experience and working at the shore facilities. The questions asked for this purpose are below.

- Q1: When did you start your work on your career planning?
- Q2: What was your goal while making career planning?
- Q3: Were you able to implement your career planning? What difficulties did you encounter?
- Q4: What would you suggest people should do to carry out the career plan?
- Q5: What should companies do to implement the career plan?
- Q6: What can be the role of MET (Maritime Education &Training Institutions in Career Planning?
- Q7: What are your other suggestions about this subject?

The responses to these questions have been evaluated one by one and the answers given are below.

Q1: When did you start your work on your career planning?

10% When Cadet, 30% When OOW/EOW, 40% 1st Officer/2nd Engineer, 20% Master/Chief Engineer

Q2: What was your goal while making career planning?

40% To find a job at the shore, 30% to Family Life, 30% Not bearing the hardship of sea life

Q3: Were you able to implement your career planning? What difficulties did you encounter?

10% Fully, 40% Sufficiently, 20% An acceptable level, 20 %10 Limited Level

Difficulties:

- To continue education program when working at sea (%80 of 100 percent)
- No sufficient support from Shipping companies (%90 of 100 percent)
- No sufficient time to handle career plan (%90 of 100 percent)
- Lack of internet connection to conduct distance learning (%40 of 100 percent)
- Loss of income to continue to join long education programs at the shore (%30 of 100 percent)
- To find suitable domestic training/courses availabilities (%30 of 100 percent)
- High costs of suitable abroad training/courses availabilities (%60 of 100 percent

Q4: What would you suggest people should do to carry out the career plan?

- Start your career planning at an early stage of the profession (%60 of 100 percent)
- Your plan should be suitable to your (%60 of 100 percent)
- Your career plan should be applicable in all aspects (%60 of 100 percent)
- Your career plan should be acceptable concerning time, period, and cost (%80 of 100 percent)
- Try to find suitable courses and training for your projected profession (%80 of 100 percent)

Q5: What should companies do to implement the career plan?

- The shipping companies should support personal career plans in line with their Staff Development plans (%80 of 100 percent)
- Support of shipping companies is not expected in the short or mid-term (%80 of 100 percent)
- International regulatory authorities should legally enforce companies to support personal career development (%30 of 100 percent)

Q6: What can be the role of MET (Maritime Education &Training) Institutions in Career Planning?

- MET institutes should open programs on maritime-related professions such as maritime business, port management, surveyors, Safety, etc. (%30 of 100 percent)
- MET institutes should distance learning programs on maritime-related professions such as maritime business, port management, surveyors, Safety, etc. (%30 of 100 percent)
- MET institutes should arrange blended (in-class and distance learning) programs on maritime-related professions to facilitate student enrolment. (%30 of 100 percent)

Q7: What are your other suggestions about this subject?

- A course should be added to the Maritime Faculties programs to brighten the students on this issue at the early stage of the profession ((%30 of 100 percent)
- Maritime administration should make necessary arrangements to provide opportunities for seafarers to make their career plans (%20 of 100 percent)

Issues to consider when making career planning

When the studies conducted by other authors (Kalvaitiene & Sencila, 2013; Kitada & Baum-Talmor, 2019; Baum-Talmor, 2018; Sennett, 2011; Kalvaitene, G., & Sencila, 2013) on career planning are examined, the common points to be taken into account are determined as follows.

- *Ambition (A):* Personal desires, wishes, and expectations.
- *Competency (C):* Existing skills, knowledge, background.
- *Opportunities (O):* Available jobs, and positions.
- *Finance (F):* Available financial support.
- *Place (P):* Suitable physical place to achieve plans.
- *Time (T):* Suitable time to achieve plans.

The individual who makes a career plan for himself must take these factors into account. All of these factors mentioned above should be carefully reviewed and defined. To make a realistic plan, it has to determine the cross-section ($A \cap C \cap O \cap F \cap P \cap T$) of these 6 factors. If these factors have a common point with others, career planning should be built according to this common work (see Figure 2).

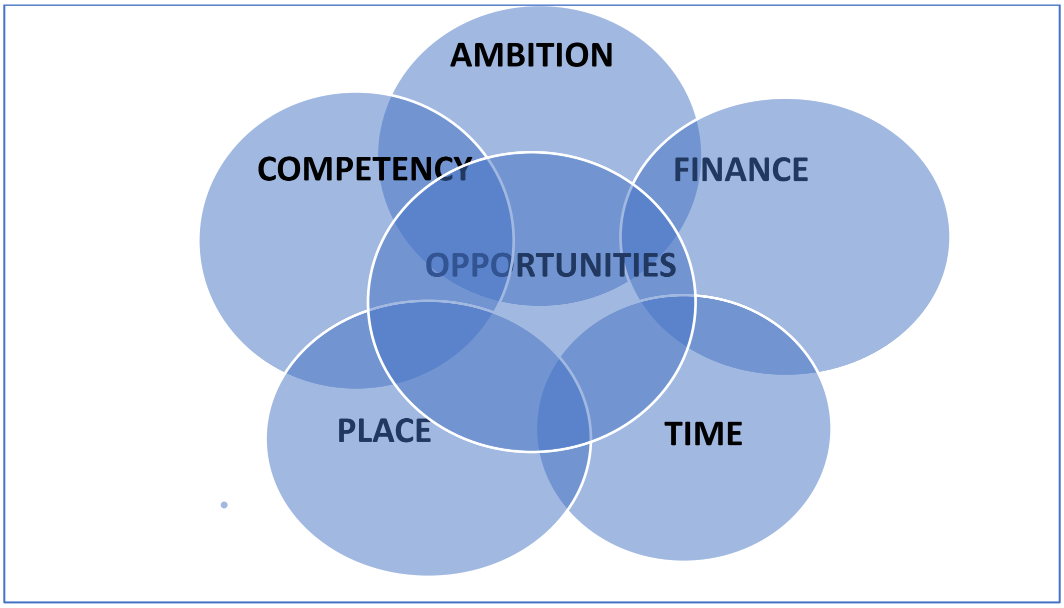

Figure 2: Issues to consider when making career planning

The conditions of such a working environment eventuate in the seafarers' inability to unfold their special skills. The frequent change between sea service on board and time off duty at the shore is another important factor affecting the profile of seafaring. The profession is characterized by insecurity and difficulty in career-making, even for the seamen that are members of a company's pool. Crew turnover can encumber the application of unified HRM [Human Resource Management] systems, and eventually, leads to a frequent loss of resources and tacit knowledge (Progoulaki, & Theotokas, 2010).

DISCUSSION

Reason for career planning

Major intrinsic motivational factors influencing choosing the career (Gopinath, 2019c; Gopinath & Shibu, 2015): High Earning, Opportunity to see the World, Internationally recognized job, Passion to be a seafarer from childhood, Job security, Helps to increase my socially status, Wished to stay at Sea, etc.

But once you start your career and learn about the maritime industry's challenges and other opportunities it offers, these intrinsic motivational factors begin to change. Due to the difficulties of sea life, they begin to look for jobs on land that are suitable for their skills and provide an adequate income. It is after this moment that the young seafaring officer starts to think about a new career plan for himself.

Cadets should learn about their future career opportunities during their education period and start their careers by knowing them. Shibu and Rengaraj (2019) conclude that maritime education and training institutions will clarify all the benefits of the maritime profession to the young cadets and provide them with the opportunity to find the maritime profession will be effective in achieving their goals and interest among the young cadets.

Creating a realistic Career Plan

People need to prepare a career plan that is suitable for their purposes and applicable under working conditions. And it should be acceptable in the face of existing availabilities and current conditions. To achieve this, first of all, the person must determine his/her expectations for the future very well. Without determining these expectations, a plan that will be possible to implement cannot be prepared. Another important factor is to determine the possible opportunities for the person perfectly. These opportunities will also serve to set attainable goals after a certain amount of effort. These determined opportunities should be compatible with the existing competency of that person. When the opportunities are examined, the skills, knowledge, and competency necessary for their realization will emerge. If the existing competencies are not sufficient to take advantage of that opportunity, additional competencies needed should be determined at the very beginning.

Of course, plans are subject to several constraints. These will be the suitability of time and place and the financial support that the person has. Every person should have sufficient time, a suitable place, and sufficient financial resources to achieve this by continuing his life to develop himself. Seafarers must have a certain income to survive. Working at sea presents a serious problem of time and space. They are also limited in terms of time; many self-development plans need sufficient time to be spent on land. This emerges as an important factor, especially when making long-term education plans.

Well-done planning is the prerequisite for success. It will not be possible to make sustainable career planning without the comprehensive study mentioned above.

The Role of the employers in career planning

In the challenging world, we live in, the most important problem for companies is to realize a sustainable business. For a company to do a sustainable business, it is a prerequisite to use human elements, materials, and capital feasibly. The human element is the most important of these factors.

In our age, where technology is developing rapidly, there is a need for manpower that can best achieve the use of sources and make innovations to ensure competitiveness. This is only possible if the personnel is prepared according to a staff development plan. Today, in quality assurance audits, first of all, the existence of a staff development plan of that organization is taken into consideration. This plan is a vital tool for the company to acquire the personnel it should have in the future. The basis of personnel management is to find suitable personnel for the job, to prepare the personnel for future tasks, and to create a sense of belonging in the personnel.

There is a very close relationship between people's career plans and the company's staff development plans. The compatibility of these two plans will make it easier for both people and the company to reach their goals. For this reason, companies should inform their personnel about their staff development plans and people should make career plans taking this into account.

The tool in which Career Planning can be observed most easily is Continuous Professional Development (CPD). CPD concerns individuals as well as the companies they work with. The compatibility of the CPD plans of the individuals with the CPD plans of the organization will ensure that both parties are compatible with each other and reach their goals more easily.

The role of the MET institutions for Career Development

MET institutes should be oriented to Life-long learning which an important part of the education system is now. This is necessary for them to start their career plans at the early stages of their professional life.

The MET institutes are not only for teaching new academic and vocational skills but also delivering the conceptual issues which will assist them to plan their future. John Holland (1997) addresses the interaction between conceptualizations of the college student and the college environment, looking at behavior as a social function of the person and the environment.

The person-environment theory of John Holland confirms the result of the study where the University brings positive perspectives on how maritime students are being developed and guided towards achieving their full potential to become future professional seafarers not only in the country but also in the international community (Agena et al., 2017).

Career offices are necessary for universities and institutes providing maritime education. These offices should convey information that will be the basis not only for sea training places or finding a job after graduation but also for their career planning after graduation. These offices should also announce the opportunities created by the University for the Career Development of seafarers and be able to respond to requests in this regard.

The modern MET Institutions try to attract professional Masters and Engineers, who are ready to change their scene of contribution. Such Lecturers have professional and scientific experience, accumulated during their professional careers and are the best choice for solving the abovementioned problems. The close-quarter cooperation between Shipping and Education is a step in the right direction for the recognition of Lifelong Learning as a necessary practice in shipping companies (Belev, 2016).

A course should be added to the Maritime Faculties programs to brighten the students on this issue at the early stage of the profession. Maritime administration should make necessary arrangements to provide opportunities for seafarers to make their career plans.

CONCLUSION

Well-designed Career Planning will assist to improve the quality of seafaring officers and adapt them to future requirements of the maritime industry. It is strongly believed that more effort should be spent to introduce the importance of career planning for mariners. IMO and other respective maritime organizations to enforce shipping companies to pay attention to career planning for their employees.

Seafarers should start their career planning at an early stage of the profession. This plan should be suitable to their projected goal. The plan should be applicable in all aspects and acceptable concerning time, period, and cost. They should try to find suitable courses and training for their projected profession (%80 of 100 percent)

Both MET institutes and shipping companies should realize the importance of career planning for seafarers to meet the requirements of rapidly changing technology and the challenging maritime world.

Career Plans for seafarers should be in line with the staff development plan which offers education and training opportunities to employees. The employees should be well aware of the company staff development plan and try to match their career path and this plan as much as possible.

Nowadays the training provided by shipping companies is limited to short-term complementary courses and certificate courses on a required basis. Human resource management is now a key issue for handling a sustainable business. The companies should enhance their education programs to provide certificate courses and academic programs including post-graduate studies for their prospective middle-level managers.

The shipping companies should support personal career plans in line with their Staff Development plans. International maritime regulatory authorities should legally enforce companies to support personal career development.

Approximately all Career plans are closely related to education and training activities. MET institutes are the best place to organize these activities and are capable to assist companies to organize their education programs. Companies should define their staff development plan in coordination with MET providers.

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Geomorphological Factors to be Considered in the Case of an Oil Spill in Northern Adriatic

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If a major oil spill occurs in the Northern Adriatic, it is likely that part of the region's coastline will be affected. Different geomorphological types of coastline react to oil and are affected by it in different ways. At the international level, this is represented and parameterised in the form of NOAA's Environmental Sensitivity Indices (ESI). However, not every coastal type defined by the ESI can be found everywhere. So far, no sensitivity mapping has been carried out in the northern Adriatic. Therefore, three countries that share the territory, namely Croatia, Italy, and Slovenia, decided to study the coasts of the region and assign ESI values to them as part of the North Adriatic Incident Response System project (NAMIRS). The research teams approached this problem in two ways. The first was to reassess the ESI in a scientific way by identifying geomorphological coastal types using the EMODnet Geology Portal and assigning them a corresponding ESI value. The other method of assessing coastal vulnerability was done to obtain subjective opinions of professional stakeholders involved in either environmental protection activities or other oil spill response-related tasks. For this purpose, workshops were organised in each of the three countries. The values that determine the level of coastal clean-up difficulty, obtained in both ways, were then compared, and inserted into an electronic map available to first team responders who can prioritise coastal protection in the case of an oil spill using oil spill response assets and equipment such as oil booms, etc. However, the applicability of ESI indices proved to be difficult due to the different types of coasts around the world, insufficient data in EMODnet Geology database, and overestimation of vulnerability gathered in workshops. Consequentially, specific measures needed to be taken.

KEY WORDS

Geomorphology, Vulnerability, ESI, NAMIRS, Survey, Northern Adriatic.

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INTRODUCTION

In the Adriatic, the risk of an incident causing massive pollution by oil or other hazardous substances remains high. In the case of the Northern Adriatic, the main sources of marine pollution are rivers polluted by industry, followed by ports, shipping and marinas. Accidents are expected to increase as the region continues to grow. The risk of pollution requires countries to have contingency plans for oil and chemical spills in place to protect sensitive areas. Despite the intensive human activity, there are extensive protected areas of natural and historic sites. Protected natural areas include cliffs, lagoons, underwater habitats, salt marshes and salt pans, reserves of Mediterranean terrestrial flora and fauna, as well as freshwater lakes. Because of its enclosed location and shallowness, the entire Northern Adriatic is a highly fragile ecosystem. The problem is that individual countries cannot rely on their own resources to deal with a probable major marine pollution incident. Regional cooperation and mutual assistance are, therefore, essential. Already in 2004, a first attempt was made to adopt a sub-regional contingency plan between Italy, Croatia and Slovenia for oil spill preparedness and response (Perkovič et al., 2016). One of the main topics was sensitivity mapping, which gives priority to protection. The cumulative sensitivity values of the Slovenian coast according to the data available at the beginning of 2000 are shown in Figure 1.

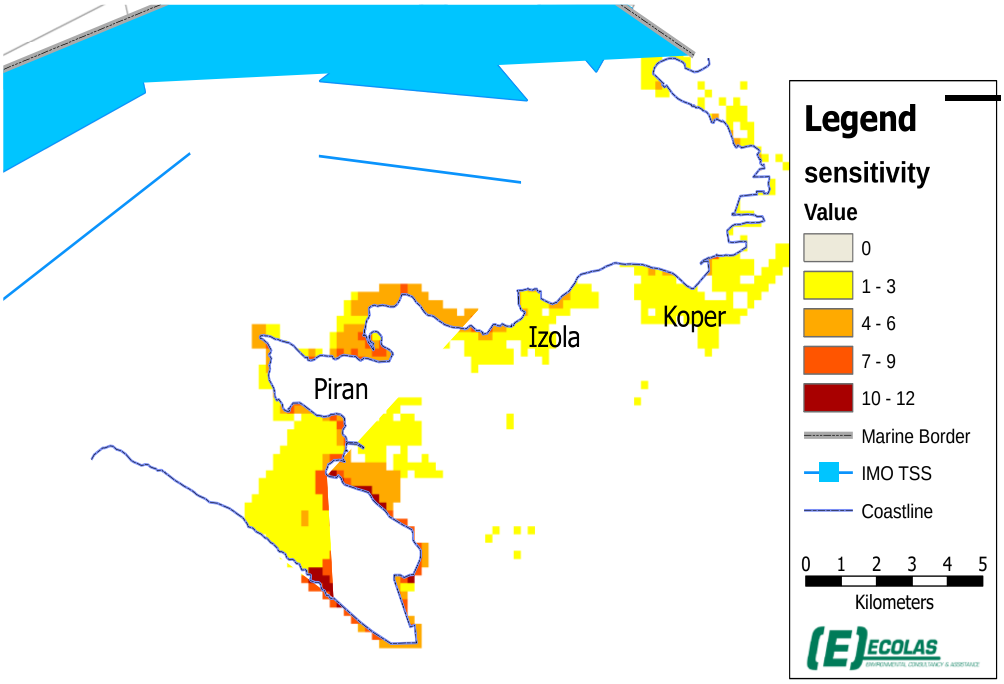

Figure 1. Cumulative sensitivity values of the Slovenian coastal area. Higher scores mean a higher relevance for protection (Source: Perkovič et al).

Twenty years later, the NAMIRS project is continuing its research into the vulnerability of the Northern Adriatic to potential marine pollution, and this time the approach to mapping vulnerability will be different and consistent for all members of the project team.

The geomorphology of coasts is defined as a process triggered by geological evolution that results in the formation of different shapes and compositions of beaches (Bird, 2011). Since the Earth's surface is composed of different types of sediments, which are a result of interactions between pre-existing geological structures, meteorological and oceanographic forces, and, lately, human activities, different types of beaches from all around the globe (Mao, Harris, Xie and Phinn, 2022). Each geomorphological coast type has varying characteristics, such as particle formation, standing (location), absorption (penetration), retention, and persistence (Asif, Chen, An and Dong, 2022). When it comes to oil spill pollution, these characteristics play a crucial role in determining the ability of each geomorphological type to resist the effects of oil, which still remains one of the most adopted energy sources (Grottoli and Ciavola, 2019). Geomorphology is, therefore, one of the three key pillars that determine the vulnerability of coasts to oil, apart from socio-economic and environmental vulnerability factors. The Northern Adriatic area, a territory northward of the imaginary line connecting Ancona to Zadar, is especially susceptible to possible oil pollution because of heavy vessel traffic and its location in an enclosed area. Since oil knows no borders, it can, in the case of spillage in one country, reach the surrounding coastline of another country and affect the local environment and people. The three countries that share the area of Northern Adriatic, Slovenia, Italy, and Croatia, have, therefore, decided on forming a joint oil spill contingency plan in the scope of the North Adriatic Incident Response System project (NAMIRS) to prevent possible spills, or in the case of emergency, join forces in oil spill clean-up operations. So far, the area has not been subjected to coastal sensitivity studies. Thereupon, the research teams from each country have decided to solve this gap.

Vulnerability is, nowadays, a ubiquitous term that describes the susceptibility of the coastline to either natural or human-induced processes. Therefore, the term may either be related to the vulnerability of coasts to any kind of pollution, to artificially made changes or to natural processes such as erosion, floods etc. (Mukhopadhyhay, Dasgupta, Hazra and Mitra, 2012). When it comes to oil spill contingency planning, however, the only point of interest is the aspect of coastline vulnerability related to oil pollution. The reason why this aspect of contingency planning is so essential lies in the high probability of spilt oil reaching the surrounding coastline, especially in enclosed areas such as the Northern Adriatic. If first team responders have vulnerability maps at their disposal, they can decide which stretches of the coast should be prioritised before others because they would be more vulnerable to oil. Of course, the responders would not be able to protect the whole coastline since no one has enough assets and equipment at their disposal to do so.

Vulnerability is determined from three points of view, environmental, socio-economic, and geomorphological. Environmental factors which determine vulnerability are presented by various areas that are protected by law. Should an oil spill occur, these areas would be, at least in countries which enforce such laws, prioritised above everything else. Socio-economic factors are represented by any kind of activity or area that has a social or economic benefit to people, such as tourist or port facilities. Lastly, geomorphological factors are represented by different types of coasts and their susceptibility to oil. To successfully map vulnerability, all three vulnerability factor groups must be either qualified or quantified, compared between themselves to determine which of the three plays the biggest role, and joined together in a unified vulnerability index. In the following chapters, we will focus solely on different ways of determining vulnerability from geomorphological aspects. But how does one qualify or quantify vulnerability? This problem can be approached in many ways

DIFFERENT WAYS OF VULNERABILITY ASSESSMENT

Gundlach and Hayes (1978), and Michel et al. (1978) were the first to classify coastal vulnerability to oil spills. Their efforts were improved by Jensen et al. (1998) and then merged into one of the most efficient tools for coastal vulnerability assessment known to us today, the Environmental Sensitivity Index, or ESI, established by the National Oceanic and Atmospheric Administration, the NOAA (Grottoli and Ciavola, 2019). In Europe, there are no existing tools like ESI, but a few studies were undertaken to form a similar index of coastal vulnerability (Fernandez-Macho, 2016). For the Adriatic Sea, there is only one tool available in the form of an atlas proposed by the SHAPE project that presents their way of oil spill vulnerability assessment. For that very reason, the three countries that share the territory of Northern Adriatic decided to try and form their own index of coastal vulnerability with the goal of developing a tool that would be applicable in other areas of the Adriatic as well.

The research team decided to assess vulnerability in two ways. The first incorporated a scientific assessment made by re-evaluating ESI values and matching them to their appropriate geomorphological type of coast described by the NOAA. The other way of assessing vulnerability was conducting a survey on the value of different geomorphological coastal type and their cleaning difficulty. Values obtained by both ways of vulnerability assessment were then compared and, after deciding on their relevance and applicability, inserted into the coastal vulnerability chart for the Northern Adriatic region.

ESI and the meaning behind them

Environmental Sensitivity Index is the most widely used approach to undertake coastal vulnerability mapping worldwide. ESI maps include geomorphological classification of types of coasts and information on how each of them reacts to oil (Finkl, 2009). However, since geomorphological types identified by the ESI are the ones that can be found in the USA and Canada in The Great Lakes, the list is limited to types which solely consist of materials that can be found there. Therefore, a problem arises when researchers try to apply them to coastlines located in a foreign country, which may, because of worldwide geomorphological diversity, be vastly different to the types listed by NOAA and thus cannot be sufficiently assessed.

NOAA lists 10 foremost ESI ranks and 24 sub-ranks. Each rank is assigned to its geomorphological type of coast, which can either be estuarine (sea shoreline, brackish water, or river mouths), lacustrine (lake shoreline), or riverine (river shoreline). Lower ranks showcase coastline that is less vulnerable to oil pollution, while higher ranks represent shorelines with higher vulnerability (NOAA, 2023). Since vulnerability studies of the Northern Adriatic coastline concerned sea shoreline only, the research team of NAMIRS solely focused on estuarine beaches.

Vulnerability assessment in NAMIRS

Since there are currently no definitive coastal vulnerability indices available for the Northern Adriatic region, the researchers from Slovenia, Croatia and Italy undertook coastal vulnerability studies with the goal of forming such a tool. For the geomorphological aspect of vulnerability assessment, the researchers decided on, firstly, re-assessing ESIs and, secondly, gathering subjective opinions from stakeholders who engage in environmental protection, socio-economic, and oil spill prevention and clean-up activities. Values obtained in both ways were then compared and, upon deciding which of them would be more fitting to use, assigned to each identified geomorphological type of coast.

For the identification of coast types, the team consulted the European Marine Observation and Data Network portal (EMODnet Geology), a database that incorporates seabed geology, seabed substrates, rates of coastline mitigation, geological events, and other data of similar nature. The decision to use this database was made because it represented the easiest and fastest way of identifying coast types. The process could also be done by analysing satellite images, or even Google Street view pictures, or by visiting the actual sites. However, the deadlines of the NAMIRS project and lack of resources did not allow such methods, and thus EMODnet Geology coast types were used.

The following geomorphological types were found in the NA region (note that the extended beaches category from EMODnet pertains to sand beaches and small beaches category to mixed sand and gravel beaches):

- erodible rock with sediments at the base,
- extended beaches (> 1 km),
- small beaches (< 1 km)
- artificial coastline
- muddy coastline
- non-erodible rock without sediments at the base and
- harbour area.

After all coast types were successfully identified, the researchers tried to find matching types in the NOAA ESI table of ranks. Where doubtful, the team consulted NOAA's example ranking list and results obtained from the coastal vulnerability assessment survey.

The survey, with which the team wanted to obtain subjective opinions of experts on the value and cleaning difficulty of different types of coasts, was to be filled out by important stakeholders from each county. Stakeholder mapping was undertaken by means of identifying all governmental and non-governmental, public, and private services and societies that either engage in environmental protection activities, run a business with a social or economic value, or otherwise deal with oil spill prevention and clean-up tasks. To identify important stakeholders, the research team first defined four important classes of tasks related to oil spill detection and clean-up. First-class belonged to Prevention, Preparedness and Monitoring activities (PPM) second class to Detection and Alerting tasks (DA), the third to Cleaning and Cleaning-Related Activities (CCRA), and the fourth to Post Cleaning Operations (PCO). Any service that engages in any of the tasks which belong to one of the four classes, was confirmed to be suitable for participation in coastal vulnerability assessment workshops. Other stakeholders were chosen based on an assumption that they had a high level of knowledge in environmental protection and activities with social and economic value to coastal regions.

Each stakeholder was presented with a questionnaire form on which they were asked to assess the value of each geomorphological type of coast with a grade ranging from 1 to 9, the former representing the lowest level of vulnerability and latter, the highest.

VULNERABILITY ASSESSMENT RESULTS

Re-assessed Environmental Sensitivity Indices

Each type of shoreline that was found in the Northern Adriatic, with the help of the EMODnet Geology database, was compared with coast types in the database of NOAA, with the goal of finding a matching ESI. While this process turned out to be simple for some types of coasts, like sand beaches or mixed sand and gravel beaches, this cannot be said for the whole set. Finding a proper match for erodible rock or cliff with sediments at its base proved to be very problematic since such type of beach is not very common around the globe but is, on the other hand, very common in the Adriatic because of its location in karst region were limestone and flysch form erodible cliffs or gravel beaches. (Juračić, Benac, Pikelj and Ilić, 2009). Since this type of coast can mostly be found in sheltered areas like bays and has gravel or rocks at its base, the team decided to match this coast type to sheltered rocky rubble shores, based on the assumption that, should an oil spill reach the coast, it would primarily affect the base of a cliff and not the cliff itself due to low difference in the tide. The results of coast type matching are highlighted in the table below.

EMODnet Geology beach type	NOAA beach type	ESI
Erosion-resistant rock and/or cliff, without loose eroded material in the fronting sea	Exposed rocky shores	1
Harbour area	Exposed, solid man-made structures	1
Extended beaches (> 1 km)	Fine to medium-grained sand beaches	3
Small beaches (< 1 km)	Mixed sand and gravel beaches	5
Artificial beach	Riprap	6
Erodible rock and/or cliff, with rock waste and sediments (sand or pebbles) at its base	Sheltered rocky rubble shores	8
Muddy coastline laguna	Exposed tidal flats; Sheltered tidal flats; Vegetated low banks; Salt- and brackish-water marshes	10

Table 1. Table of coast type matching from EMODnet Geology and NOAA databases (Source: NAMIRS)

After coast type matching was complete, a reassessment of ESI values followed. There was not much work needed to be done to complete this step since the team of researchers only needed to assign a new value of 9 to the muddy coastline of laguna. This was done to make a comparable scale with results obtained from coastal vulnerability workshops, which were on an interval from 1 to 9. The decision to introduce such a scale was made because hypersaline tidal flats, which fall under rank 9 on the NOAA ESI scale, are not found in the area.

Coastal Vulnerability Assessment survey results

In total, 104 people participated in vulnerability assessment workshops, either in situ or online, via provided links to the digital versions of the questionnaire. Results of workshops, organised in each of the participating countries, were statistically processed by calculating measures of central tendency, e. g. mean, mode and median values, and standard deviation, to see the level of dispersion of gathered data. The pooled results of the three workshops are showcased in the table below, where each geomorphological type of coast is listed under its own question number from the questionnaire:

- Q1 – erodible rock with sediments at the base,
- Q2 – extended beaches (> 1 km),
- Q3 – small beaches (< 1 km),

- Q4 – artificial coastline,
- Q5 – muddy coastline,
- Q6 – non-erodible rock without sediments at the base, and
- Q7 – harbour area.

Question number	μ	Mode	Median	σ
Q1	7.2	9	8	1.815664
Q2	7.5	9	8	1.825759
Q3	7.2	7	8	2.004033
Q4	5.1	6	5	2.127477
Q5	6.7	9	7	2.005687
Q6	6.4	7	7	2.216954
Q7	5.2	5	6	2.465675

Table 2. Table of assessed values of the vulnerability of each of the identified geomorphological types of coast in the Northern Adriatic (Source: NAMIRS)

Apart from showcasing the total average, mode and median values in the upper table, the participant's input was also exported to the charts below, which highlight grade distribution for each question, and their average, mode, and median values. The charts also indicate large data dispersion which is indicated by standard deviation values for each question in the table.

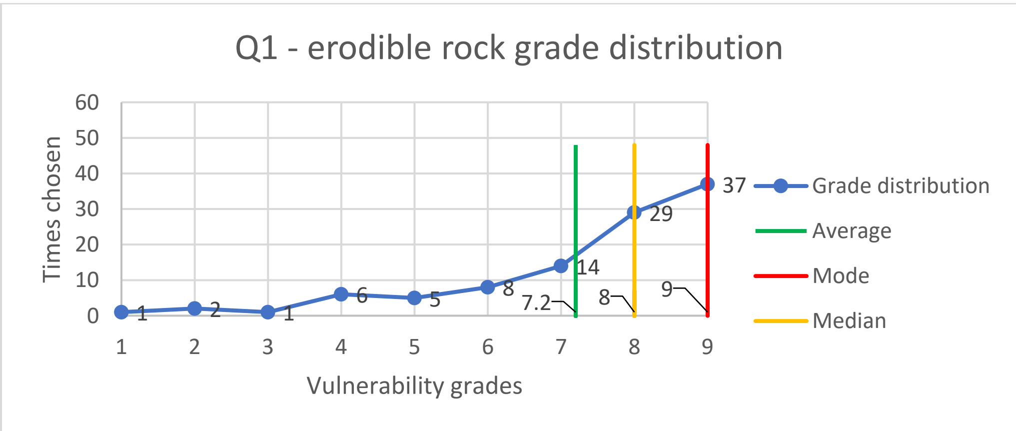

Figure 2. Erodible rock with sediments at the base beach type vulnerability grade distribution (Source: NAMIRS).

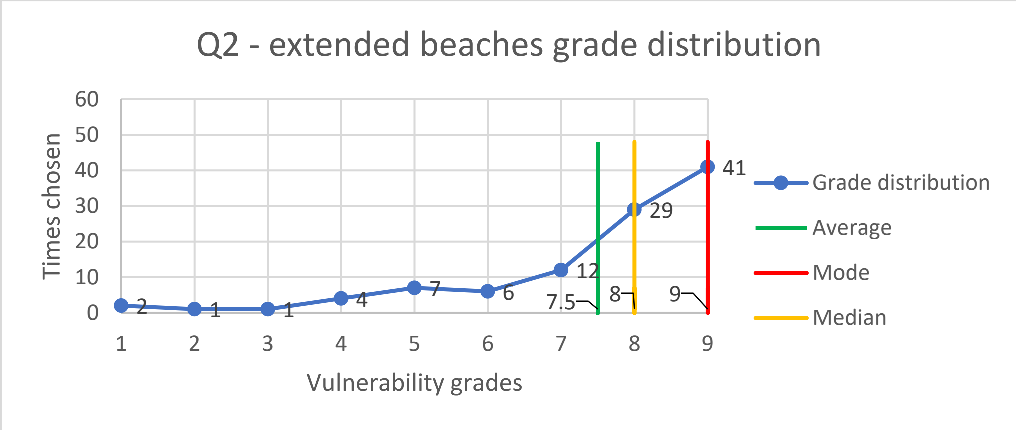

Figure 3. Extended beaches vulnerability grade distribution (Source: NAMIRS).

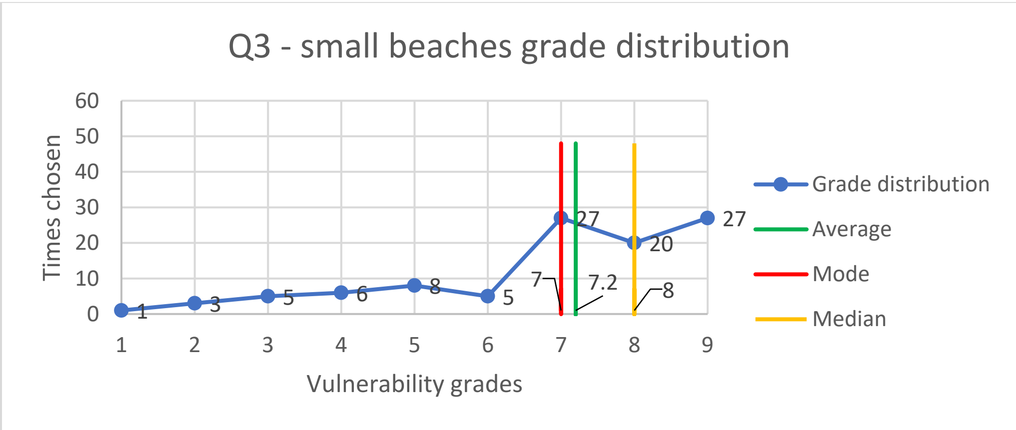

Figure 4. Small beaches type vulnerability grade distribution (Source: NAMIRS).

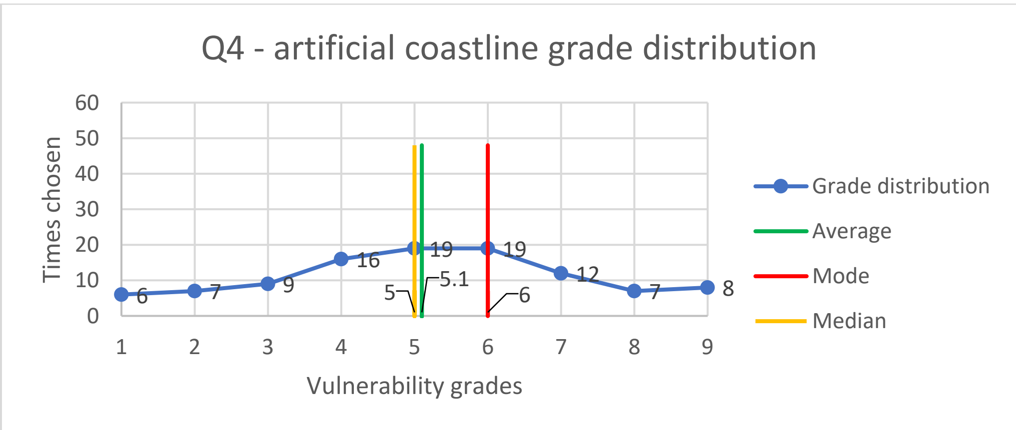

Figure 5. Artificial coastline vulnerability grade distribution (Source: NAMIRS).

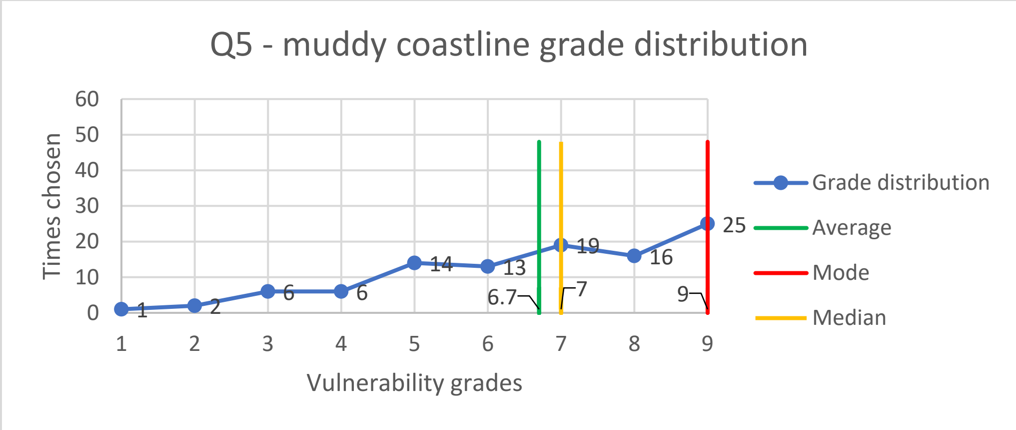

Figure 6. Muddy coastline vulnerability grade distribution (Source: NAMIRS).

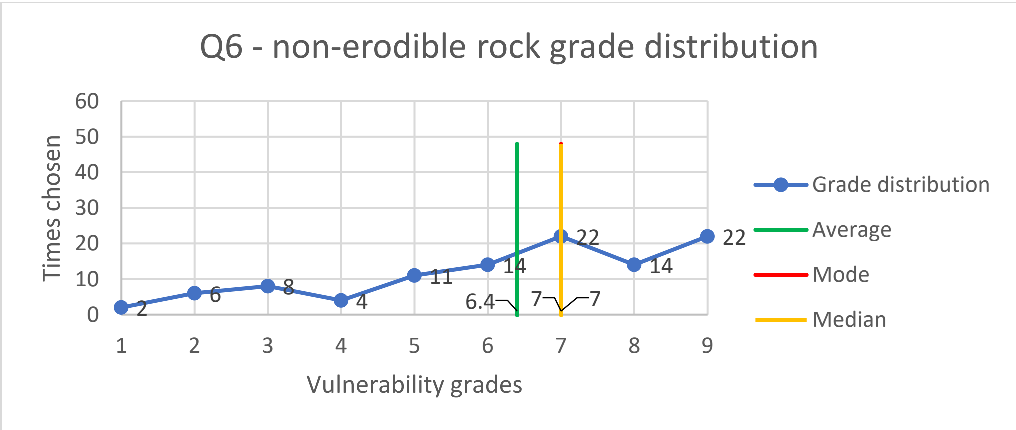

Figure 7. Non-erodible rock beach type vulnerability grade distribution (Source: NAMIRS).

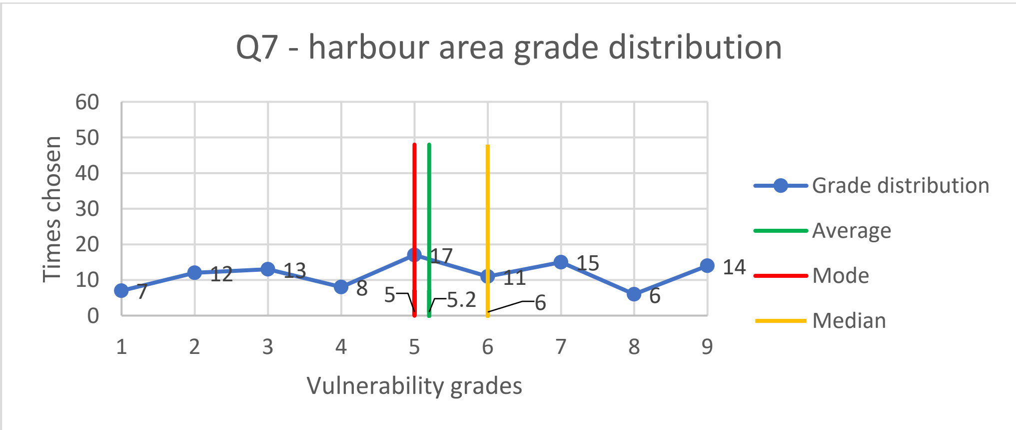

Figure 8. Harbour area vulnerability grade distribution (Source: NAMIRS).

The cumulative grade distribution graphs of each geomorphological type of coast highlight how most participants refrained from using grades from the whole available spectre ranging from the lowest grade of 1, to the highest grade of 9, but rather pertaining to use grades from the spectre's upper half, which can be interpreted in two ways. The first assumption based on the results would be that participants simply deem all the coast types to be very important and consequentially would not neglect any of them should an oil spill occur. But we can also assume, that participants simply lacked proper knowledge on some of the vulnerability factors, which resulted in overestimation. Possibilities of workshop execution somehow influencing participant's input is also high.

FINAL VULNERABILITY INDEX FORMULATION

After analysing coastal vulnerability assessment workshop results and comparing them with ESI values, the researchers made the final decision on which of the obtained values should be used to showcase coastal vulnerability from geomorphological point of view and be exported to a coastal vulnerability map of the Northern Adriatic. The decision was to use modified ESI values since they are scientifically backed up by observations and experience from many oil pollutions from previous years, even though some of the coast types from EMODnet Geology database proved difficult to fully match with their counterparts identified in the USA by NOAA. The final results are showcased in the table below.

Beach type	ESI	NAMIRS	FINAL
Erodible rock and/or cliff, with rock waste and sediments (sand or pebbles) at its base	8	7	8
Extended beaches (> 1 km)	3	8	3
Small beaches (< 1 km)	5	7	5
Artificial beach	6	5	6
Muddy coastline laguna	10	7	9
Erosion-resistant rock and/or cliff, without loose eroded material in the fronting sea	1	6	1
Harbour area	1	5	1

Table 3. Table of final coastal vulnerability grades from geomorphological point of view (Source: NAMIRS)

CONCLUSIONS

The research group decided on using scientifically derived values of coastal vulnerability instead of the ones obtained from the coastal vulnerability assessment workshops, because of big differences among them. The workshop results can be, however, merged with socio-economic factors since they highlight how each coast type is subjectively valuable to people from a social point of view. The final geomorphological vulnerability grades were thus derived from NOAA Environmental Sensitivity

Indices, which give a value on a scale from 1 to 10 according to how difficult each coast type is to clean. Upon assigning each coast type with its respective ESI and re-assigning its value to the 1 to 9 range, the research team faced a problem in the form of different beach classifications in each country. While it was obvious that some of the beaches were the same in their geomorphological type, they were entered into EMODnet Geology under a different name. Some of them, especially those in Croatia were wrongly classified as well. The team successfully solved the problem with beaches classified under different names, but only partially solved the problem with the wrong classification of coast in some areas, because full reclassification would be too extensive. The team, therefore, suggested that each country conduct individual studies and update beach types in their territory in the following years.

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A Comparative Evaluation of Cleanup Methods for the Mucilage Outbreak in the Sea of Marmara

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Mucilage is a white slimy structure that results from the uncontrolled growth of marine microorganisms. The structure has accumulated in the Sea of Marmara, Türkiye, causing a severe environmental pollution problem. Today, the issue has spread throughout the entire sea, posing significant challenges for environmental conservation efforts. The large-scale spread of the mucilage in the Sea of Marmara started in mid-2021, and the government including municipalities immediately took drastic measures to address this serious problem threatening the marine ecosystem. The recent scientific studies and prevention efforts of public authorities to prevent the mucilage outbreak have resulted in several findings that provide more information about the appearance of mucilage in the Sea of Marmara. These initiatives have also shown that this environmental problem should not be taken lightly. Although the problem of mucilage has attracted public attention lately, it was first seen in the Marmara Sea well before mid-2021 and was reported in mid-2007. Research studies have been accelerated to analyze this environmental problem and suggestions have been made to public authorities to support prevention efforts. These efforts yielded rapid results and the surface of the Sea of Marmara became much cleaner than at the beginning of the mucilage outbreak. However, the mucilage has begun to sink towards the bottom of the sea. Today, as of 2023, it continues to pose a serious environmental problem, spreading widely on the seabed and threatening the marine ecosystem.

KEY WORDS

Marine mucilage, Marine pollution prevention, Marine microorganisms, Marine snow, Marine engineering, Dirty sea

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INTRODUCTION

Seas are the home of numerous animal species and provide people with food supplies. Considering their significance for the environment and economy, it is of utmost importance to wisely use and ensure the sustainability of marine resources. A large segment of Türkiye's population lives in the big cities around the Marmara Sea which constitutes the Turkish Straits System (TBS) together with the Dardanelles and the Bosphorus. This brings the fact that a considerable number of industrial activities take place in this region. Black Sea countries also use the Marmara Sea in maritime transport. Some cruise ships visit for tourism activities and are bound in ports particularly In Istanbul. These facts highlight the substantial socio-economic value of the Marmara Sea. Nonetheless, at the same time, it brings some risks that endanger marine life (Acarli et al., 2021). Presently, the Sea of Marmara is under the pressure of wastes originating from domestic, industrial, and maritime endeavors. This pressure is augmented further by pollutants stemming from ship transportation (Dogan and Burak, 2007; Kodak, 2022). At the same time, global warming has been adversely affecting the marine ecology of the Sea of Marmara for almost a decade. Temperatures are increasing sharply in the upper and lower layers of the sea. As a result, the adverse environmental conditions placed on marine ecological system leads to extreme natural events such as mucilage production.

With the effect of global warming, mucilage started to be seen in world's oceans and seas (Giuliani et al., 2005; Precali et al., 2005; Danovaro et al., 2009; Bianchi et al., 2019). The formation of mucilage poses serious detriments to fisheries and marine ecology and has incredibly adverse effects on the marine food system (Karadurmuş and Sari, 2022). The mucilage is a white slimy structure caused by the uncontrolled growth of marine microorganisms accumulated in the sea that has spread to the entire Sea of Marmara, as shown in Fig. 1 as a severe environmental pollution problem today. A mixture of various phytoplankton species gets to the central stage in mucilage formation, which has been observed in the Sea of Marmara in recent years (Tüfekçi et al., 2010). Although the problem of mucilage has attracted public attention lately, mucilage was first seen in the Sea of Marmara long before today and observed in 2007.

The large-scale spread of the mucilage in the Marmara Sea started in mid-2021 (Medvedeva and Stanichny, 2022), and the public and local authorities immediately took drastic measures to address this serious problem threatening the marine ecosystem. These initiatives have also shown that this environmental problem should not be taken lightly. Sea water was taken from the Sea of Marmara to analyze mucilage's physical, organic matter, and element concentration and experiments were conducted to understand the reasons for the formation of mucilage, and preliminary suggestions were made on its elimination (Yümün and Kam, 2021).

Figure 1. Mucilage spread in costal waters of the Sea of Marmara.

Figure 2. The geography of the Sea of Marmara positioned between the Black Sea and the Aegean Sea (Source: "Location map of Türkiye" by Uwe Dedering is licensed under CC BY-SA 3.0).

This study aims to compare and evaluate different cleanup methods for the recent mucilage outbreak in the Sea of Marmara. Section II gives a brief explanation and geographical setting of the Marmara Sea. In Section III, factors and likely consequences of the presence of mucilage are presented. Section IV presents and discusses the results of mucilage-cleaning activities in the Sea of Marmara. In the last section, concluding remarks were given.

THE SEA OF MARMARA

The Marmara Sea (Fig. 2) is an inland sea positioned between the Black Sea and the Aegean Sea. The sea was known by the title "Propontis" in ancient times (Bean, 2015). A constant water exchange between the Mediterranean Sea (deep layer) and the Black Sea (surface layer) is taking place in the Marmara Sea, and the Sea of Marmara acts as a passageway between them across the Dardanelles and the Bosphorus Straits (Beşiktepe et al., 1994). As being serves as a passageway, the sea ecosystem is very specific and involves ecological components of the two seas (İşinibilir-Okyar et al., 2015). The average salinity of water varies from 20‰ (surface layer) to 40‰ (deep layer). A significant characteristic of the Sea of Marmara is the enduring lack of oxygen found beneath the halocline. This special feature of the sea greatly affects marine biodiversity (Gross, 2012), pollutant load (Yümün, 2017; Şirin et al., 2022), and fisheries (Harlioğlu, 2011).

FACTORS AND LIKELY CONSEQUENCES OF THE PRESENCE OF MUCILAGE

The mucilage structure is ubiquitously present in seas all over the world and have been intensively noticed in the Marmara Sea since 2007 (Tüfekçi et al., 2010). A variety of factors and likely consequences could be attributed to the presence of mucilage in the Sea of Marmara (Savun-Hekimoğlu and Gazioğlu, 2021). The pycnocline, or the vertical structure of the water column, has a major role in the formation of mucilage (Misic et al., 2011). The climate and marine environment have an evident influence on the formation, spread and aggregation of the event (Philippart; 2011). Moreover, in the case of high sea water temperatures, the rate of mucilage formation rises steadily (İşinibilir-Okyar et al., 2015; Savun-Hekimoğlu and Gazioğlu, 2021).

Figure 3. Sea cleaning activities in the Sea of Marmara. a) Vehicle Vacuum Truck b) Sea Surface Cleanup c) Coastal Cleanup.

As for the Marmara Sea, there are various factors that attribute to the presence of mucilage. Firstly, the Sea of Marmara is an interior sea connected with straits and has a limited water exchange with surrounding seas. Secondly, the population density in the area is on the rise, and the sea is constantly exposed to domestic and industrial wastes. Inadequately handling procedure of waste disposal is a serious issue in this matter. Thirdly, there is habitat loss due to marine dredging, unloading activities, and coastal fill areas (Yılmaz et al., 2019). Moreover, overfishing drastically affects biodiversity loss. Lastly, there has been an increase in sea water temperature due to climate change (Danovaro et al., 2009; Turan and Gürlek, 2016; Savun-Hekimoğlu and Gazioğlu, 2021). The release of wastewater into the sea, particularly in an inland sea such as the Marmara Sea, increases the amount of pollutants present and can trigger eutrophication (Danovaro et al., 2003; Öztürk et al., 2021). Especially nitrogen and the phosphorus-rich excessive amount of nutrients, together with stationary weather conditions and temperature increase, excessively increase the intracellular secretion of sea organisms that leads to mucilage (Balkıs-Özdelice et al., 2021). When it sinks to the seafloor, mucilage interacts with benthic fauna and flora, which refers to the community of living sea organisms on the seabed. There are both negative and positive effects of mucilage residing on the seabed. The positive impact is that mucilage might be a food source for sea organisms living in the seabed (Savun-Hekimoğlu and Gazioğlu, 2021). The negative impact is that mucilage, as there is a significant amount of heavy metals found in the mucilage mass formed, rich with various pollutants, disrupts the structure of benthic fauna and flora (Mecozzi et al., 2008). Moreover, deep layer of the Marmara Sea suffers from an extreme lack of oxygen causing hypoxic conditions (Savun-Hekimoğlu and Gazioğlu, 2021). Therefore, the abundance of organic matter in the mucilage will result in a further reduction of oxygen caused by bacterial consumption. The disruption of the natural structure of the food web caused some species to migrate from the Marmara Sea for seeking new environments as breeding and sheltering places (Karadurmuş and Sari, 2022).

RESULTS AND DISCUSSION

Mucilage cleaning activity is a procedure for removing and reducing the mucilage present in marine environments. The Sea of Marmara experienced widespread mucilage in 2021. Subsequently, the government and municipalities implemented intense precautions to tackle this serious issue that menaced seawater life. Mucilage cleaning activities were initiated under the coordination of the Ministry of Environment, Urbanization, and Climate Change in mid-2021. Herein, the results of mucilage cleaning activities for one month (between 08 June 2021 and 06 July 2021) performed by the Istanbul Metropolitan Municipality (IMM) are presented. All areas with mucilage density are intervened by cleaning teams and vehicles. These cleaning activities have included vehicle vacuum trucks, sea surface cleaning, and coastal cleanup, as shown in Fig. 3. IMM conducted coastal cleanup activities with thirteen mobile shore cleaning teams of seventy people and sea surface cleanup activities with seven sea surface cleaning boats. Moreover, these cleanup works are supported by eleven vacuum vehicles. Fig. 4 displays the amount of mucilage collected during coastal cleanup operations in kilograms (kg) and carrier bags over a month. On average, 13318 kg and 1532 bags of mucilage were collected daily. The total amount of mucilage collected as a result of three types of mucilage cleaning activities (vacuum vehicles, sea surface cleaning, and coastal cleanup) are given in Fig 5. On average, 118101 kg and 138 m^3 of mucilage were collected daily.

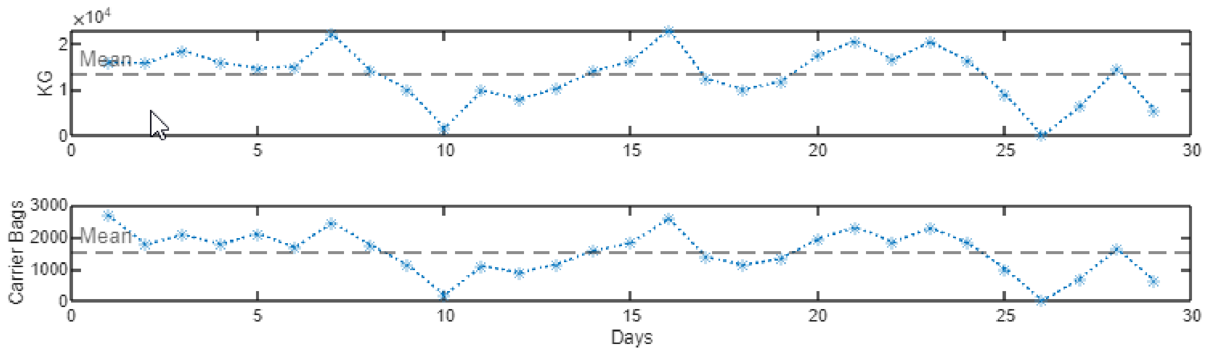

Figure 4. Amount of mucilage collected during the mucilage coastal cleanup activities. (a) in kg/d. (b) in carrier bags/d.

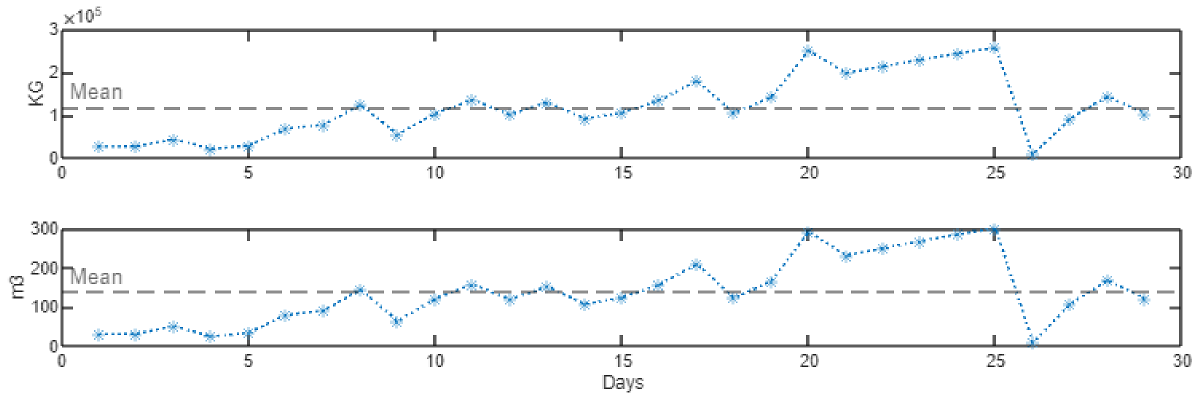

Figure 5. Total amount of mucilage collected during three types (sea surface cleaning, coastal cleanup and vacuum vehicles) of mucilage cleaning activities. (a) in kg/d. (b) in m^3/d.

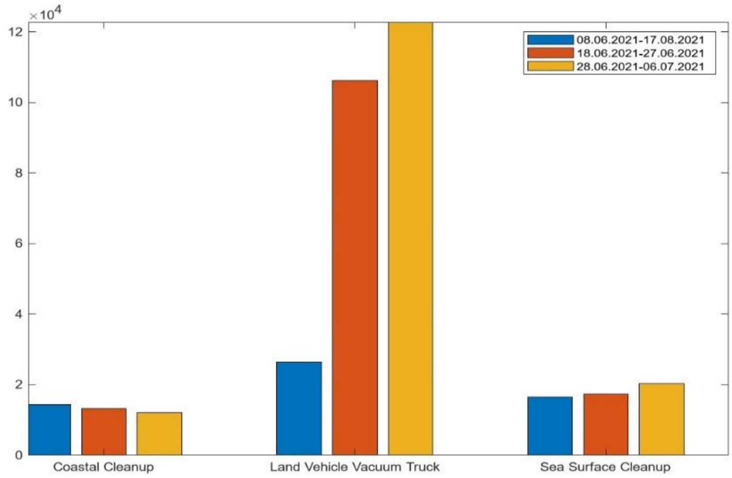

Figure 6. Average sea cleanup operations over a month at ten-day intervals.

Within the scope of mucilage cleaning works carried out under the coordination of the Ministry, a total of 6440 m^3 of mucilage was collected throughout Istanbul. While 4027 m^3 of this amount was collected by the IMM, 2412 m^3 was collected by companies assigned by the Ministry. The main part of the cleaning activities took place during the middle phase of the cleaning period. In Fig. 6 average sea cleanup operations over a month at ten day intervals were given. As seen in this figure, the average amount of mucilage collected in the first ten days with the sea surface cleaning and coastal cleaning activities is approximately 1.5-2.0 x 10^4 kg/d. The average mucilage collected by the land vehicle vacuum truck is approximately twice this value. By the second and third ten days, however, the average amount of mucilage collected by the land vehicle vacuum trucks was quite large, approximately five and six times the coastal and sea surface cleanup operations, respectively. In this way, the average amount of mucilage collected daily in the second and third ten days reached approximately 120,000 kg (120 tons). Even though at the beginning of cleaning activities land vehicle vacuum trucks weren’t used, later on, as clearly seen in Fig. 7, they became the primary mucilage collection activity as compared to coastal cleanup and sea surface cleanup operations.

We conducted this research to explore the technical and practical measures that have been taken and can be taken further to avoid mucilage issues in the Marmara Sea. The health of the marine environment should be the primary objective when devising plans for activities to take place in the Sea of Marmara as it is closely related to economic resources, pollution and ecosystem issues. In particular, events that will affect the Marmara Sea in terms of water and substance exchange, biodiversity and habitat change should not be implemented without considering the consequences. Many steps should be taken to protect the Marmara Sea. As the Black Sea is the main water source (60%) for the Sea of Marmara, the amount of pollution flowing from this sea should be observed on a regular basis, with appropriate technological and practical steps taken to keep it to the lowest amount possible. It is vital to start monitoring activities promptly by initiating measurement stations, particularly in areas with polluting sources. Discharge of wastewater from households and industry should be kept under control, and the "deep sea discharge" method should be abandoned immediately to decrease the input of nutrients such as nitrogen and phosphorus, as well as additional pollutants into an inland sea such as the Sea of Marmara. All maritime operations such as fishing, dredging, transportation activities and discharge of contaminated ballast water must be kept under control in line with the current regulations. Each participant taking part in such maritime operations should be controlled and inspected vigilantly. To maintain the stability of the food web and the marine environment, coastal locations that most living creatures prefer to feed, shelter, and breed should be protected. Measures should be taken to prevent damage to the coastal areas.

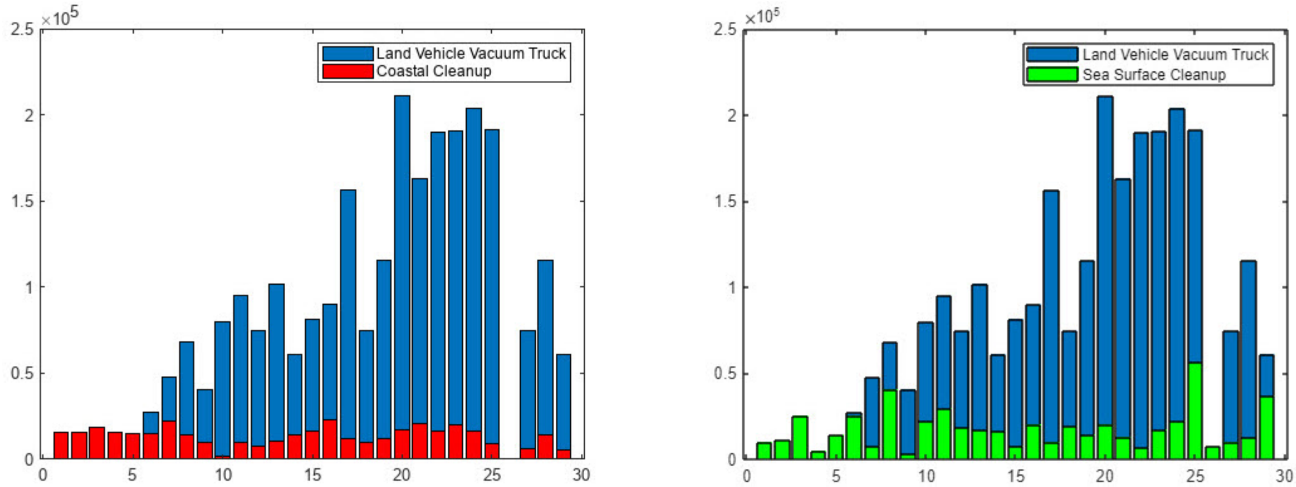

Figure 7. Amount of mucilage collected during the mucilage cleaning activities. a) Coastal Cleanup with respect to Land Vehicle Vacuum Truck. b) Sea Surface Cleanup with respect to Land Vehicle Vacuum Truck.

Additionally, concrete structures that harm the ecology of the coastal environment should be demolished if possible. Controlled and sustainable fishing should be done. Unfortunately, there is an increasing rate of population in the area, and this dense population puts immense pressure on the sea. Green spaces, especially water basins, should be protected effectively. Another main source of pressure on the sea is coming from global warming. Therefore, government policies related to global warming be strictly enforced in the area. Limiting the introduction of heavy metals into the sea is also essential since it is known that the organisms that cause mucilage release organic matter as a response to the presence of toxic metals such as lead and copper.

In summary, public awareness on this issue should be increased by using communication tools such as the press, publications and billboards, where the Marmara Sea adds value to the Marmara Region and the disappearing sea will cause great harm to the economy, tourism and fisheries. Research studies on the analysis of this environmental problem have been accelerated, and as a result of these studies, suggestions have been made to public authorities to support mucilage prevention efforts. These efforts already yielded rapid results and the surface of the Sea of Marmara became much cleaner than at the beginning of the mucilage outbreak. However, the mucilage has begun to sink towards the bottom of the sea. Today, as of 2023, it continues to pose a serious environmental problem, spreading widely on the seabed and threatening the marine ecosystem.

CONCLUSION

It is possible to conclude that one of the most effective cleanup methods for the collection of mucilage in the Sea of Marmara during the mucilage outbreak was the use of Land Vehicle Vacuum Truck. Therefore, we think that these trucks should be brought into service once the outbreak is noticed in the sea. Although the mucilage was cleaned from the surface effectively, there are still mucilage masses under the sea. Further research and analysis are necessary to improve the cleanup efforts to address the mucilage outbreak. Therefore, new methods and technologies are needed and have to be applied for the cleaning and prevention activities of the mucilage to protect the undersea environment.

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Mixed Reality and Autonomous Technology in Port Environmental Monitoring Based on PASSport Project

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It is becoming more crucial to offer a solution for managing the current mission and status of autonomous and semi-autonomous vehicles operating on site in big and complicated port areas. Digital twin systems, which offer a complete 3D reconstruction of the port with real-time data on all objects and operations going place, are being used by more ports. It is difficult to present all the data that is available in a way that will improve situational awareness and decision-making, leading to better management and a faster, more effective response during an emergency. This is because port areas are larger and drones operate in the air, on the water's surface, and underwater. A novel solution based on Mixed Reality (MR) technology is being developed by the PASSport initiative, a project funded by the European Agency for the Space Programme (EUSPA), to address this problem. The solution integrates real-time geo-tagged and Earth Observation data and will give end users access to an advanced 3D visualization of the port area through a dedicated Head Mounted Display (HMD) that tracks user location and movement.

KEY WORDS

Autonomous systems in ports, Pollution monitoring in ports, Quality of air in ports, Mixed reality

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INTRODUCTION

Ships' substantial environmental impact is felt in seaport locations.

Ports serve as the entry points for international marine trade, however despite the sector's considerable economic and social benefits, there are several instances where it negatively affects the environment and the health of EU citizens [Passerini et al 2019]:

- Ports and shipping can produce greenhouse gas emissions that contribute to global warming.
- 40% of Europeans live within 50 kilometres of the sea, which means that air pollution from ships can impair both the marine ecosystem and human health.
- Pollution incidents, including oil spills, can have severe repercussions for the impacted areas' marine life and inhabitants.
- According to research, underwater noise from ships traveling through the ocean can induce hearing loss, higher levels of stress, and alterations in behaviour among marine species.
- Untreated ballast water contributes to the introduction of species from one maritime environment to another, changing ecosystems and endangering native marine life.

For ships to function properly, ballast water is required. The International Maritime Organization (IMO) has made significant efforts to eliminate accidental and intentional ship pollution. One of the key initiatives in this direction has been the implementation of MARPOL, one of the most significant international accords for the maritime environment (International Convention for the Prevention of Pollution from Ships, 1973, as revised by the Protocol of 1978). The International Maritime Organization (IMO) created it to reduce pollution of the seas and oceans, including marine environment and surrounding air pollutant that are covered in Annex I, II, III, IV, V and VI. Pollution from ships in ports can be divided into the following:

- Air pollutants, such as PM, SOx (sulphur oxides), NOx (nitrogen oxides), and greenhouse gases (particulate matter).
- Ship-related spills, such as (accidental and operational) oil, chemical, and dry-bulk leaks during loading and unloading procedures.
- Water pollution from waste.
- Bilge water contamination of the gray and black water types (e.g., sanitary facilities) (sinks, showers, kitchens and laundries).
- Water used for cargo hold cleaning contamination.
- Pollution from solid waste (litter).
- Invasive species, other biological stuff, such as bacteria or viruses, contaminating ballast water.
- Airborne and undersea noise.

In actuality, multiple studies came to the conclusion that more international laws are required to evaluate vessel-related air pollution caused by ship traffic emissions (Lindgren, 2021).

PASSPORT SOLUTION

The PASSport program's goal is to develop and validate a method for expanding situational awareness using fixed-wing, rotary-wing, and underwater drones in port environments.

In order to greatly increase security and safety for daily operations ensconced in the port area, the EU Directive 2005/65/CE on Enhancing Port Security requests the addition of surveillance systems throughout the whole port area. The directive is applicable to over 1000 ports in Europe. By using a fleet of drones to extend the surveillance perimeter, the suggested solution aims to supplement currently in use platforms. It offers innovation and operational support for the identification, management, and analysis of safety and security aspects of daily operations, paying particular attention to:

- Pollution monitoring (environmental protection).
- Support to e-navigation (safety).
- Critical buildings/ Infrastructures protection (security).
- Protection against non-cooperative small craft approaching the port areas (security).
- Underwater threats monitoring (security).

The unique aspect of the project is the use of a fleet of partially automated drones that integrates Galileo services (and other sensors) for safe and effective guidance, navigation, and control (GNC) even in the presence of obstacles like buildings and other ground assets as well as potentially unfavourable weather conditions. The PASSport system design is shown in Figure 1, which lists the segments shown below:

- PASSport Aerial Segment (PAS)
- PASSport Ground Segment (PGS), composed by mission (PMS) and Control (PCS) elements

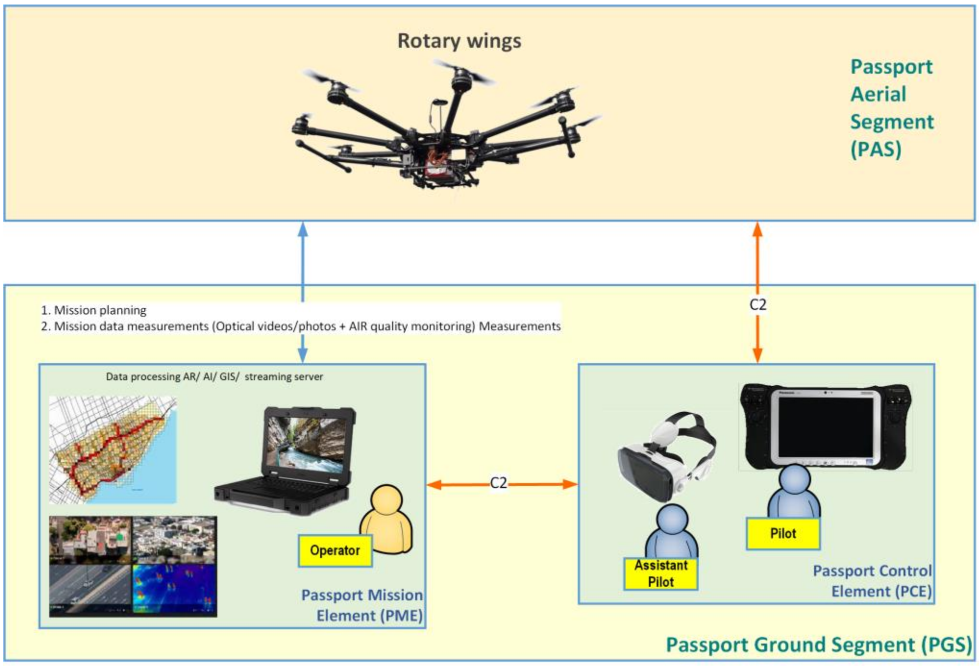

Figure 13. PASSport architecture for the pollution monitoring (source: own work)

The purpose of PASSport is to ensure the following key features

- Measuring player awareness of dangers and increasing player awareness (security). The PASSport platform suggests the design and implementation of suitable procedures that can be used to fight threats after the assets and infrastructure which need to be secured against the threats and risks of purposeful illegal activity facing port activities are recognized. This is accomplished after determining the risk level (normal, increased, or high), and it is done so by following specified methods and utilizing technical tools designed with ports in mind. This enables the proper response to be given to infrastructure's potential vulnerability.
- Control and oversight of port areas (security and safety). The PASSport platform offers a suitable HMI to apply pertinent procedures and monitor port security and safety on a regular basis.

Data possessed by the RPAS are analysed at the PGS level in real time by a local computer. In order to provide proper positioning, RPASs are outfitted with high accuracy GNSS receivers that leverage Galileo differentiators such as OSNMA (for position reliability and security), HAS/PPP (for positioning accuracy), and multi-frequency (for robustness and accuracy). These technologies are combined with contemporary robotics (vision-based navigation, AI, and Deep Learning algorithms) to ensure automated, secure, and continuous operations.

THE VALIDATION CAMPAIGN IN KOLOBRZEG

All ports and harbours face the challenge of maintaining air and water quality. Mitigating against problems means taking care of the whole marine ecosystem and surrounding land. Ports and harbours are very highly concentrated industrial areas next to the water. Many activities such as boat repair, transportation, terminal operations, cargo handling and storage all have potential impacts on air/water quality above all if an incident were to occur. On this purpose, PASSPort team conducted tests in the Port of Kolobrzeg (Figure 2) to validate the water and air pollution monitoring system and the augmented reality system interface as a situational awareness solution. The Kołobrzeg Port is located on the Baltic Sea, at the mouth of the Parsęta River. It performs a merchant ship loading/discharging, fishing and passenger function. The port has a several loading quay, two shipyards, fishing harbour and two marinas. Hence the port of Kołobrzeg identified problem of pollution monitoring and considers PASSport as a possible solution for:

- Air quality surveillance mission.
- Water pollution surveillance mission

A 3D point map is generated with each data point describing air and water quality as measured with all installed sensors. Colour coding and simple alert system should be implemented. The mission assumes the surveillance flight aerial and marine complemented with additional EO data from satellite.

Figure 14. Port of Kołobrzeg. Layout. (1) – cargo handling and administration area, (2) – fishing port and shipyard area, (3) – yacht marina

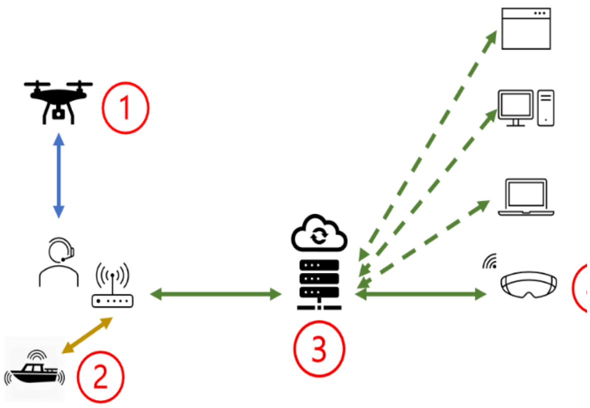

Figure 15. Architecture of the PASSport solution (1- flying drone with operator, 2 - floating drone with operator, 3 - server, 4 - decision-making part with interface in mixed reality technology)

The aim of the validation is to show the solution to the end user - in this case the Kolobrzeg Sea Port Authority. The system consists of the following modules (Figure 3):

- A drone module consisting of flying drones (UAVs) and floating drones (USVs) with operators controlling their operation.
- Communication system based on the Internet and GSM communication (4G/5G).
- A server responsible for processing data including also data from Copernicus and presenting it to end users and decision-makers.
- A mixed reality system, which is an operator decision support system enabling two-way communication between decision makers and drone operators.

PASSPORT PLATFORM RESULTS OF VALIDATION IN KOŁOBRZEG PORT

During the validation campaign, the following equipment and services have been used.

1) A rotary wings drone, i.e. DJI Matrice 300 RTK (Figure 4). It provides a 30-minute flight with a maximum load of 3kg and the ability to operate three sensors. Hot-swapping the battery, i.e. without turning the drone off, allows all intended tasks to be practically accomplished. The drone is able to defy wind speeds of up to 15 m/s. Its speed during flight is approximately 20 m/s. The drone is equipped with an RTK system to achieve in-flight positioning accuracy of up to 10 cm. A Sniffer 4D was used [Kim et al. 2021] as the main air pollution sensor on the drone, allowing the detection of particulate matter with different particle diameters, sulphur oxides, nitrogen oxides and ozone (Figure 6):

- Particulate matter:
    - PM1 (0.3 - 10 μm),
    - PM2.5 (0.3 - 10 μm),
    - PM10 (0.3 - 10 μm),
- O_3 + NO_2 (0-10 ppm),
- SO_2 (0- 10 ppm).

The drone was additionally equipped with a specialised Zenmuse H20t camera, which is an integrated vision and thermal imaging camera that also has a laser rangefinder. No UV cameras (PCO-UV in the 190nm - 1100nm band) or the Mica Sense multispectral camera (supporting as many as 10 bands) were used in the study due to the inability to simulate spillage.

2) A double-hulled USV 'Sharky' (Figure 5) designed for hydrographic surveys in sheltered waters (rivers, lakes, harbour basins, lagoons) was used during the validation. The 1 m x 0.85 m vehicle has a laminated hull design allowing it to operate in water temperatures in the full encountered range of 1-30° C. The freeboard height is 0.6 m and the minimum draught of 0.3 m allows it to be used in the shallowest areas. The displacement of max. 25 kg allows up to 10 kg of apparatus to be fitted. The electric propulsion motor (BLDC) allows infinitely variable speed control from 0 to 6 knots. The drone is supplied with a single-beam probe and water sampling kit.

Figure 16. DJI Matrice 300 RTK drone with Sniffer 4D air pollution sensor and thermal imaging camera installed

Figure 17. The USV "Sharky" floating drone in preparation for testing during the validation campaign

3) EO data from Copernicus. The scope of the activities carried out within the PASSport project was to evaluate and assess the usability and applicability of Copernicus services to the PASSport scenarios and to deduce attainable performances applicable to PASSport-related applications. The great advantage of the Copernicus program is represented by the synergic use of different satellite platforms (ESA's families of dedicated Sentinel and Contributing Missions), hosting either active or passive sensors, and observing different portions of the electromagnetic spectrum. Each region of the electromagnetic spectrum has its unique applicability for observations. In particular, quality parameters assessment and monitoring using Sentinel-5P have been analysed for the campaign n Kolobrzeg.

4) A dedicated application was created for the first-generation Microsoft HoloLens device, which is one of the most advanced mixed reality technology devices available on the market, allowing for full 3D holographic projection. Through its use, it is possible to present a three-dimensional map of the area with clean air measurement points, the current position of the drone along with its parameters. Configurable values for standards and alerts allow quick and accurate identification of areas where there is a risk of increased emissions.

Finally, a Mixed Reality solution 0 has been proposed as an experimental solution where data from multiple drones as well as any external data source like AIS or Copernicus, can be integrated and visualized together. For the purpose of the campaign, a Microsoft HoloLens gen. 1 device has been used. The application has been developed using following software and SDK:

- Unity Engine 2019.4,
- Microsoft Mixed Reality Toolkit,
- Microsoft Maps SDK for Unity.

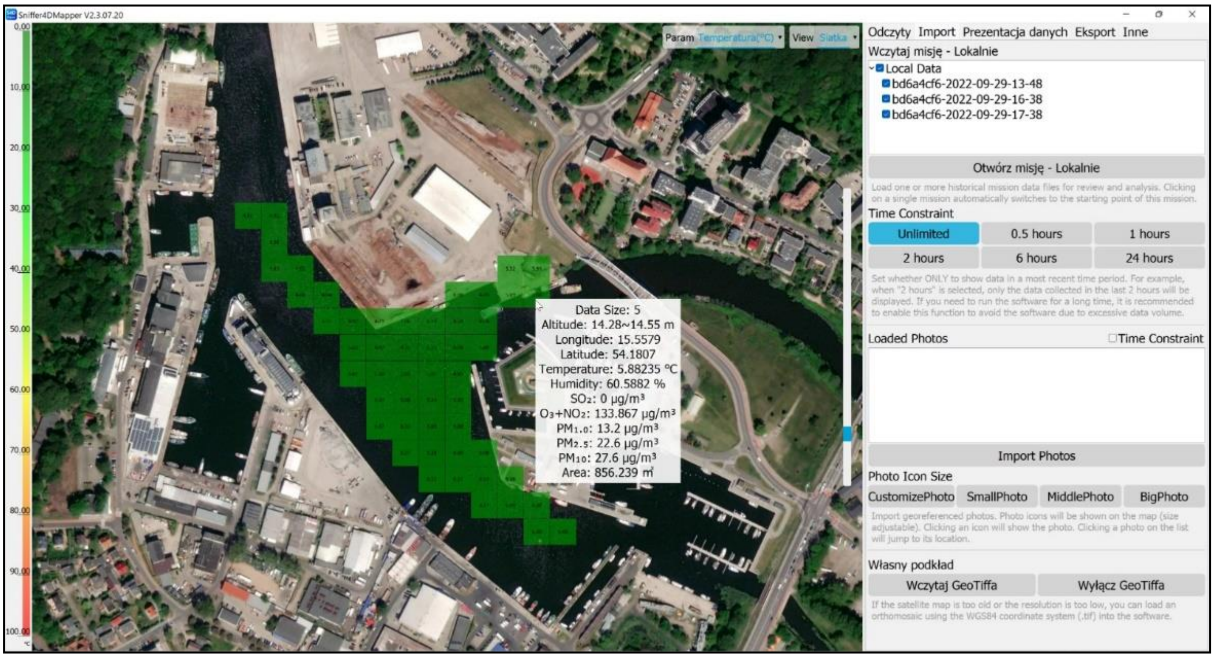

Figure 18. Visualization of data from Kołobrzeg campaign using Sniffer4D Mapper™ Analytic Software

This particular set of tools makes it possible to develop a solution that can be build for range of hardware platforms in both AR and VR technology, including Microsoft Hololens gen. 1 and 2, Meta Quest and SteamVR devices. Since the data is taken directly from the server it is possible to feed processed and historical data in real-time (Figure 7).

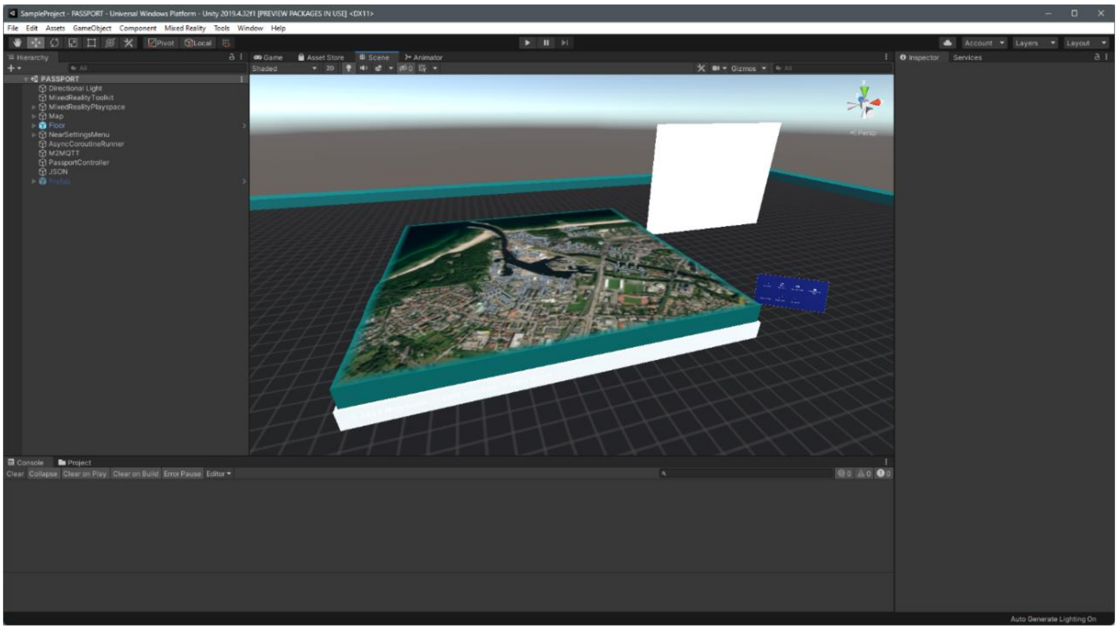

Figure 19. Dedicated MR application. View from the Unity Engine Editor

The presented architecture makes it possible to present the data with a 1Hz sampling rate in real time, in 3D environment to any end-used with an authenticated access to the server (Figure 8).

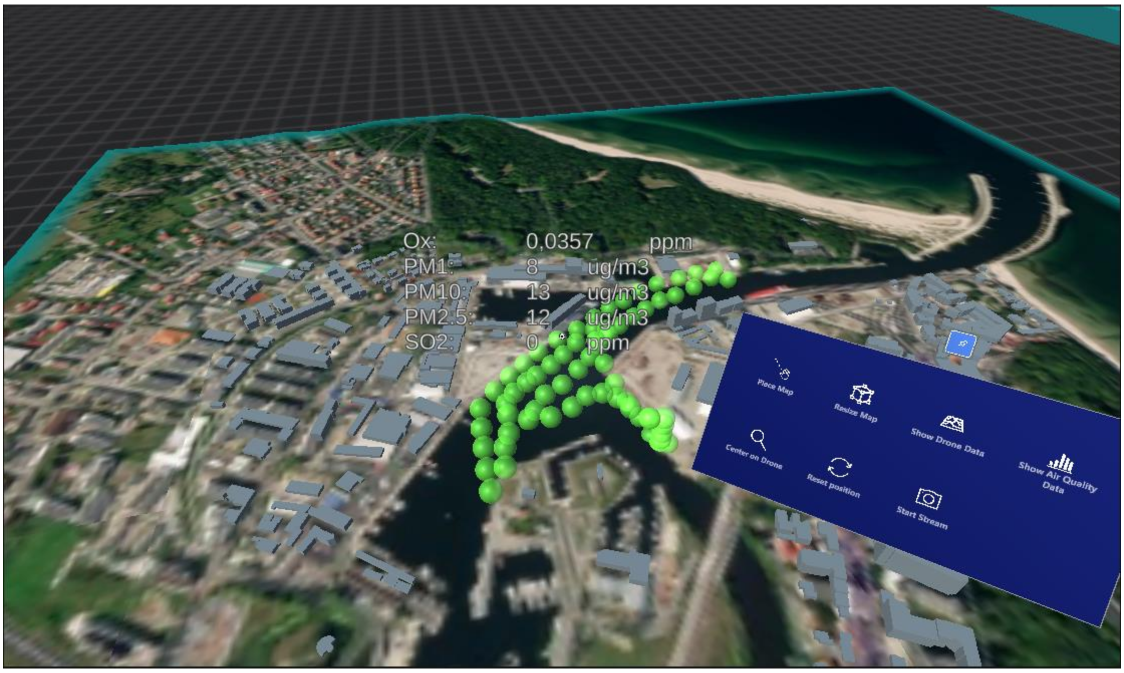

Figure 20. Data as presented in the MR app. Screenshot taked from desktop version of the app (source: own work)

Due to the massive traffic involving the coastal area of Kołobrzeg, the monitoring of air pollution is a paramount task in order to reduce the risk of environmental health problems. Data has been acquired locally using the drones fleet equipped with the Sniffer 4D sensors (Figure 9).

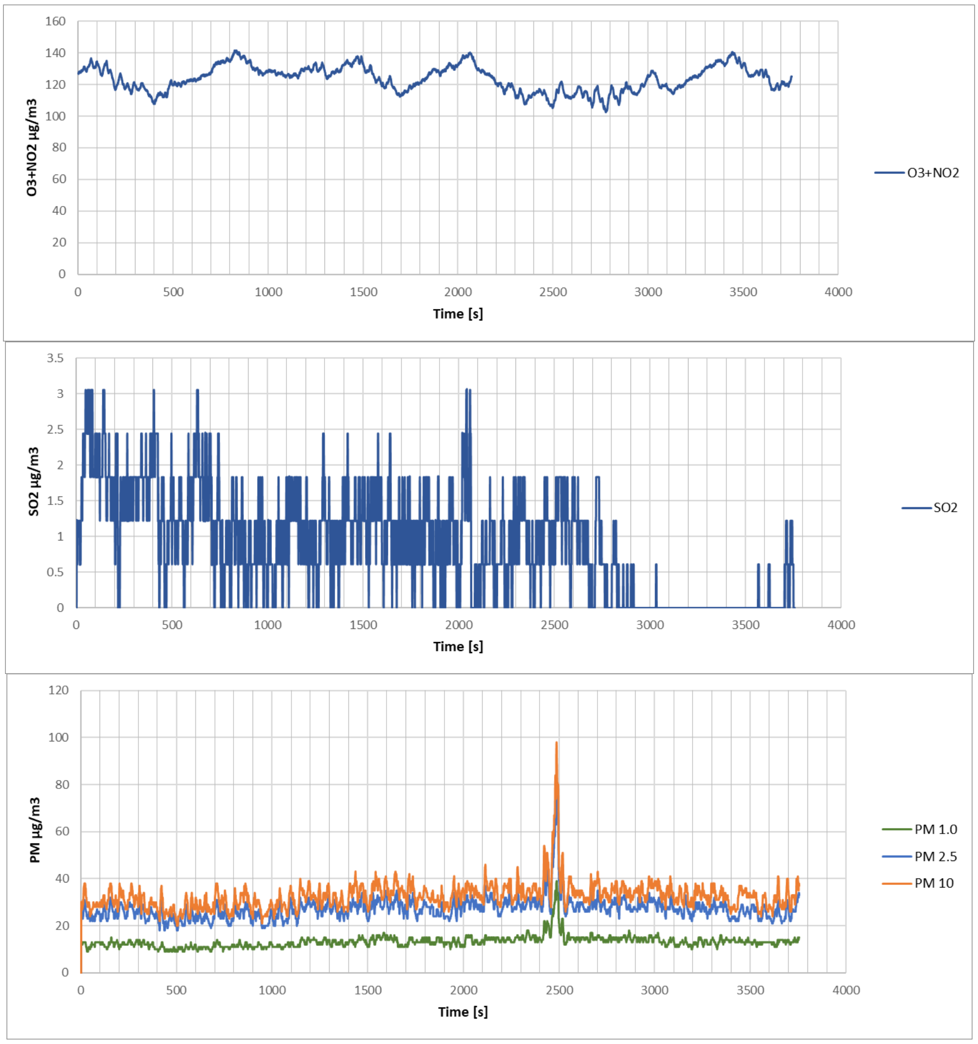

Figure 21. In situ data using the fleet of drones equipped with Sniffer 4D sensors.

CONCLUSIONS AND FUTURE WORK

In order to assess the water and air pollution monitoring system and the augmented reality system interface as a situational awareness solution, PASSport's validation campaign in the port of Kolobrzeg was presented in this article. For the PASSport project, this was the first in a series of validation initiatives. The next validation campaigns will be held in places including Hamburg (for essential infrastructure), Valencia (for e-Navigation), Le Havre (for small, uncooperative vessels), and Ravenna (for underwater hazards).

In-situ data from numerous drones that are GPS-referenced as well as any external data sources, such as AIS or Copernicus, are combined and presented in a Mixed Reality application, which has been offered as an experimental solution.

Future work will address a number of other research, operational, and engineering problems in order to fully utilize and apply the created system and fully utilize drones for monitoring and pollution control in port environments. These problems include::

- Automated monitoring - Drones are capable of carrying out monitoring chores on their own, but safety is paramount in this situation, so drones must fly over water while keeping a safe distance from ships and other objects to avoid endangering occupants of nearby buildings.
- Creation of a multi-sensor head for port environmental contamination scanning (combination of optics and other sensor heads).
- OEM components can be used to create such a multi sensor platform.
- The creation of a multi sensor platform with integrated optics, laser fluorescence, and thermal imaging camera is proposed oil spill tracking and forecast program for tracking already-spilled oil.
- Operator-induced monitoring. Performing certain tasks that are called by the operator. Coursing the drone around an object, stationary suspension, etc.
- Physical water sampling. Landing and take-off from the water.
- Supporting firefighting operations and combating chemical and oil spills. Provision of oil spill information. Online monitoring of oil stains or fires.
- Providing evidence in court cases involving air and water pollution.
- Drone approach to a moving vessel using AIS information and visual observation by the operator for exhaust samples. It is a very high demand also in terms of safety.
- Monitor the vessel's approach to the quay for evidence of excessive mooring energy and damage to the fenders and quay.

ACKNOWLEDGEMENTS

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Preserving Natural Resources of the Croatian Adriatic through Maritime Spatial Planning

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The aim is to evaluate the importance of developing and adopting the maritime spatial plan in a present situation characterized by competing uses of the marine environment and its resources. The authors applied qualitative research method based on direct observations, authors' previous experiences and research, official documents, literature surveys and current research reports on the subject. The drafting and adoption of a maritime spatial plan with its accompanying strategic environmental assessment requires the involvement of experts, scientists, economic sectors representatives, and the public. The principles for good practice maritime spatial planning aimed at achieving environmental targets are presented, whereby focus is placed on land-sea interactions. Global coverage of the marine area by maritime spatial plans is constantly increasing, but the Republic of Croatia is lagging behind, it having as yet not adopted the maritime spatial plan for its sea. Analysis is made of the pressures on the Adriatic Sea and its eastern coasts, pointing to significant aspects to be contemplated holistically in drafting the maritime spatial plan which should be a prerequisite preceding any planning of economic activities along the coast, on sea surface, its column, sea bottom, and subsoil. In conclusion, maritime spatial planning should be seen as a mean for supporting healthy, productive, and rich biological resources in the sea, which are themselves vital for true economic well-being and that of the coastal communities.

KEY WORDS
Maritime spatial planning, Preservation of natural resources, Marine environment, Public participation, Blue economy, Adriatic Sea.

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INTRODUCTION

There is a mounting pressure on the resources and potentials of the Adriatic Sea and its Croatian coast by different sectors ranging from non-renewable and renewable energy production, maritime transport, nautical tourism, and tourism in general, aquaculture, fisheries, environmental protection, health, and those preferred by local communities and their inhabitants. An important vehicle for resolving timely the potential user or use conflicts is a national Maritime spatial plan, the drafting whereof has not even initiated, not to mention its adoption or implementation. Nine years ago had the authors at this very conference presented the paper dealing with the challenges of maritime spatial planning (MSP) in Eastern Adriatic (Runko Luttenberger and Luttenberger, 2014). At the time the Directive 2014/89/EU establishing a framework for MSP had not yet been in force. It is also to be noted that prescribed deadline for the adoption of the national Maritime spatial plan for Croatia as a Member State of the EU expired two years ago.

Countries worldwide have started or implemented their marine spatial planning and in that process pursued the targets related to renewables, to achieving the 10% marine protected areas (MPAs) coverage by 2020 as per Aichi Biodiversity Target of the Convention on Biological Diversity (CBD), along with those related to blue economy, transboundary MSP, climate change, and the United Nations Sustainable Development Goals (SDGs) (UNESCO-IOC/European Commission, 2021). The processes that regulate the stability and resilience of the Earth system and their safe operating limits within which humanity can continue to develop and thrive for generations to come identified by Rockström et al. (2009) are closely related to the oceans, seas, and coastal areas. Safe operating space has already been crossed for biodiversity loss and extinction, climate change, land system change, nitrogen and phosphorus flows to the biosphere, plus chemical pollution and the release of novel entities (Persson, 2022).

Flannery et al. (2020) urge the development of research that not only critically engages with MSP but that also imagines how MSP can be made better, considering the interaction of MSP practice and thought with the likely post-COVID 19 return to the fore of the ever more serious climate emergency, and how politically attuned and spatially agile forms of MSP might be vehicles for wider social adaptation in response to the far-reaching changes in the seas and oceans.

The paper starts with the origins of MSP and its definitions followed by its relationship with natural resources. The focus is placed on land-sea interactions. The review of the status of MSP process worldwide is completed with the analysis of Croatian case, as the country has not yet embarked on its adoption in spite of its exceptional resources that are subject to constantly emerging pressures from different sectors, many of which have the potential to dominate individually the Croatian coastal and marine area.

ORIGINS AND DEFINITIONS

It is considered that MSP concept or spatial planning in the marine environment emerged within the context of marine conservation planning and the original zoning plan of the large ecosystem of Great Barrier Reef Marine Part in Australia and the integrated coastal zone management (Frazão Santos et al., 2019; Flannery, 2020) . As MSP spread worldwide, it seems that its conservation foundation has in some instances become diluted.

MSP is a multiobjective, multiuse planning process that seeks to integrate and balance economic, social, and environmental objectives for all uses of the ocean space and is a tool for managing conflicting maritime uses (use-use conflicts) and the conflicts between these uses and marine ecosystems goods and services (use-environment conflicts), prior to having any activities in place (Frazão Santos et al., 2019). MSP is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process. For instance, the desire to increase revenues from a particular sector, tourism for instance, may severely compromise other objectives or exceed the carrying capacity of the marine area (Ehler and Douvere, 2009).

MSP is defined by the Intergovernmental Oceanographic Commission (IOC) of UNESCO (2009) as a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that have been specified through a political process. The National Ocean Council of the United States of America (2013) defines it as a science- and information-based tool that can help advance local and regional interests, such as management challenges associated with the multiple uses of the ocean, economic and energy development priorities, and conservation objectives. The European Union (EU) Directive 2014/89/EU establishing a framework for MSP (EULEX, 2014) defines MSP as a process by which the relevant Member State's authorities analyze and organize human activities in marine areas to achieve ecological, economic, and social objectives. Through their maritime spatial plans, Member States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, Member States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw materials. MSP Directive laws down that MSPs should be subject to review every 10 years.

MSP is related to ocean governance, meaning that the governing of ocean affairs should besides governments also undertaken by a whole range of stakeholders ranging from local communities and industries, whereby national and international law, both public and private, along with customary law, tradition, and culture should be adhered to (Borgese, 2001).

An ocean economy can generally be defined as unsustainable, or 'brown', or as one characterized by sustainable growth, or 'blue' (Patil et al., 2018), although blue economy in itself poses significant threats not only to the ecosystem services, but also with regard to governance and sectoral issues (UNESCO-IOC, 2021). MSP can support healthy, productive, and biologically diverse seas, instead of being simply an instrument for Blue Growth (Dom et al., 2019). Sustainable ocean plan should therefore apart from economic benefits also deliver social and environmental benefits. Social benefits involve improved and equitable livelihoods, income-generating opportunities and human well-being – especially for coastal communities and Indigenous Peoples, enhance food and nutrition security, improved health from clean air, clean water, clean beaches, safe seafood and opportunities to spend time in nature, sustained opportunities for recreation, education, exploration and inspiration, as well as the acquisition of knowledge and practical skills (e.g. fishing, swimming, navigation). Environmental benefits entail enhanced climate change mitigation (e.g. via carbon sequestration by mangroves, seagrass meadows and tidal marshes), improved resilience and adaptation to climate change, increased conservation of critical ecosystems, restoration of natural ecosystems, their productivity and biomass, reduced ocean pollution (e.g. plastics, effluents, runoff) (Ocean Panel, 2020), and reduced energy pollution or underwater noise (Runko Luttenberger et al., 2022). There exists a number of instructive step-by-step approaches to developing a maritime spatial plan (The Nature Conservancy, 2009; UNESCO-IOC/European Commission, 2021; Dom et al., 2019; Ehler and Douvere, 2009).

Basic constraints of MSP activities are set in the UNCLOS which provides the legal basis for sea exploitation, the right to allocate activities, and the obligation to conserve the marine environment (Schubert, 2018).

MSP AND NATURAL RESOURCES

Guiding principles for good practice maritime spatial planning involve 1. sustainable management; 2. ecosystem-based planning and not sectoral silos-type planning; 3. long-term perspective and objectives; 4. precautionary principle; 5. MPAs, MSFD targets and sensitivity zoning as a prerequisite to MSP; 6. strategic environmental assessment (SEA); 7. participation and transparency; 8. high-quality data and effective monitoring; 9. transnational coordination and consultation; 10. coherence in terrestrial and maritime spatial planning considering land-sea interactions; and 11. continuous planning (Dom et al., 2019).

With regard to the precautionary principle, the EEA developed a list of the following 12 rules for its application: 1. acknowledge and respond to ignorance, as well as uncertainty and risk, in technology appraisal and public policy-making; 2. provide adequate long-term environmental and health monitoring and research into early warnings; 3. identify and work to reduce ‘blind spots’ and gaps in scientific knowledge; 4. identify and reduce interdisciplinary obstacles to learning; 5. ensure that real world conditions are adequately accounted for in regulatory appraisal; 6. systematically scrutinize the claimed justifications and benefits alongside the potential risks; 7. evaluate a range of alternative options for meeting needs alongside the option under appraisal, and promote more robust, diverse and adaptable technologies so as to minimize the costs of surprises and maximise the benefits of innovation; 8. ensure use of 'lay' local knowledge as well as relevant specialist expertise in the appraisal; 9. take full account of the assumptions and values of different social groups; 10. maintain the regulatory independence of interested parties while retaining an inclusive approach to information and opinion gathering; 11. identify and reduce institutional obstacles to learning and action; and 12. avoid 'paralysis by analysis' by acting to reduce potential harm when there are reasonable grounds for concern (EEA, 2001).

The environmental targets in practice often unfortunately become secondary to sectoral ones (Dom et al., 2019), particularly those promoted by the 'blue growth'. In fact, the MSP Directive itself profiles the MSP process as an enabler of blue growth, see also (EC, 2018). MSP should instead comply with environmental limits stemming from MSFD and the MPAs designation. Namely, it is precisely the ecosystem-based approach (EBA) to management and planning that is common to and legally required by the MSFD and MSP Directive. Preamble 15 of the MSP Directive states that ‘MSP has to contribute to achieving the objectives of, inter alia, MSFD, Habitats and Birds Directives, the Water Framework Directive as well as the Common Fisheries Policy'. The principles of an ecosystem-based approach according to the Convention on Biological Diversity are specified by CBD Secretariat (2007).

Marine spatial plans do have an impact on marine environment, whereby do-nothing alternatives should also be evaluated in order to establish the baseline state of the environment subject to the impact of current activities. The environmental assessment represents an important tool for integrating environmental aspects when preparing and adopting plans, programmes, and strategies, as is established by SEA Directive (2001/42/EC). Early, participatory, and iterative strategic environmental assessment (SEA) of the plan may identify incompatibilities of sectoral plans and spatial elements with each other, with marine protected areas (MPA), and biodiversity. SEA should assess the plan and its alternatives and the results should be used for refining the policies and organizing the space (Dom et al., 2019). Obviously not all impacts for MSPs can be assessed at plan level. The impacts of specific projects are then assessed separately through the environmental impact assessment (EIA) procedure, and also the appropriate assessment (AA) in protected areas.

LAND-SEA INTERACTIONS

A properly designed and effectively implemented plan may improve coastal and ocean governance, particularly since problems in marine area related to the environment are frequently the consequence of activities taking place onshore, and the same applies other way around. Veto was applied by some countries to incorporating the integrated coastal zone management (ICZM) in the original draft proposal of the EU MSP Directive. The argument was that land planning falls within the competence of MSs only (Dom et al., 2019). The Directive does set out that 'land-sea' interactions have to be addressed (Article 1, Article 4, Article 6 MSP Directive), but MSs may interpret that freely. Anyhow, according to Barcelona Convention the Mediterranean countries have the obligation with regard to ICZM. MSP has many similarities with ICZM, as they are both integrated, strategic, participatory, aiming to maximize compatibilities among human activities and reduce conflicts both among human uses and between human uses and nature. When coastal zone management was first conceived about half a century ago, one definition of the 'coastal zone' was the 'area of land affected by the sea and the area of the sea affected by the land'. That definition was interpreted to cover the coastal plain to the edge of the continental shelf (Ehler and Douvere, 2009).

According to a study commissioned by DG Environment (Shipman, 2018), land-sea interaction planning and management may require wider landward coverage and transnational involvement rather than its confining to the coastal strip only. Such land-sea interactions (LSI) involve environmental, socio-economic, and technical aspects. The study deals with eight of the most typical marine development sectors: aquaculture, desalination, fisheries, marine cables & pipelines, minerals & mining, ports & shipping, tourism & coastal recreation, and offshore energy.

The White House Council on Environmental Quality considers coastal and maritime spatial planning (CMSP) to be a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analysing current and anticipated uses of ocean, coastal, and Great Lakes areas. CMSP should provide a public policy process to better manage a range of social, economic, and cultural use, including aquaculture, commerce and transportation, commercial fishing, environmental conservation, maritime heritage and archaeology, mining, oil and gas exploration and development, ports and harbours, recreational fishing, renewable energy, other recreation, scientific research and exploration, security, emergence response, and military readiness activities, tourism, and also traditional hunting, fishing, and gathering (Council on Environmental Quality, 2009).

Although coastal and marine aspects may be said to be generally articulated, their interface with land planning is still uncommon. The reasons could be its complexity, the distribution of administrative competences among institutions, and scarce precedence in maritime planning (UNESCO-IOC/European Commission, 2021).

CURRENT STATUS OF MSP GLOBALLY

According to IOC-UNESCO (2022) twenty countries covering 22% of the world exclusive economic zones (EEZs) have plans approved and under implementation for their maritime jurisdiction, with further twenty-six countries covering 25% of the world EEZ being in the process of approving plans (that group includes EU countries mandated to have MSP plans by 2021 and countries in Africa, America, Asia, and Oceania). Further eighty-two countries covering 47% of the world EEZ have committed to progress with the development of MSP.

In practice, in many marine and coastal management initiatives, 'policy cycles', that is the sequence of actions that characterize MSP development are never fully completed. Also, many of the current MSP processes are more about the growth of blue economy rather than really balancing conservation and development objectives. In these cases, marine conservation is often perceived as just ‘another’ spatial use of the ocean and is being treated at the same level as fisheries, shipping, renewable energy, etc., with the balance heavily weighted toward economic development. Further problem is that MSP processes do not usually create new authorities and responsibilities for the conservation realm, leaving them instead to the already legislatively created entities that govern each of the sectors which unfortunately are usually not well integrated with each other in the development of conservation approaches (Frazão Santos et al., 2019).

In Europe, for example, the EU legal framework on MSP opted for a ‘maritime’ approach to spatial planning, viewing its MSP primarily as an opportunity for economic growth, framed within EU’s blue growth strategy (Frazão Santos et al., 2019). Drawing on the analysis of four MSP efforts around Europe, Jones et al. (2016) highlight that the ‘current blue gold rush is undermining idealistic theoretical concepts underpinning discussions in the academic literature. It is arguably more about political expedience than it is about conceptual ideals of proactive, consensual, and ecosystem-based approaches. Nevertheless, in some MSP initiatives ensuring ecosystems health is the priority, with ecosystem goods and services being the foundation, of the planning process (Frazão Santos et al., 2019). In some places however, the only concession to ecosystems is to create small unconnected networks of marine reserves (Merrie and Olsson, 2014).

THE REPUBLIC OF CROATIA AND THE MSP PROCESS

The Adriatic Sea is one of the Mediterranean Sea areas most worth of protection due to its biodiversity and richness in endemic flora and fauna. It is an intensely fished area in relation to its size. Also, due to its physical and geographical characteristics the Adriatic Sea hosts busy shipping routes and is all the more subject to the pressure of nautical tourism and intense development along its eastern karst coasts. Blue economy adds its various new challenges, such as energy from renewables produced at the sea and from fossil fuels, fish farming, and commodification of its other marine resources, while climate change effects further deteriorate the situation.

The siting of such competing and sometimes environmentally harmful but profitable private activities should be regulated through a properly adopted maritime spatial plan, which in Croatia has by now not been even proposed, let alone adopted, in spite of the obligations and expired deadlines. Croatia has only implemented a legally binding integrated sea use management plan focused on a particular sector, aquaculture, for the Zadar county, but no single MSP for the entire Croatian marine area. There are very few Member States with no national MSPs currently adopted, those being Bulgaria, Italy, Romania, and Spain.

The backbone of the legislation on physical planning in Croatia is the Physical Planning Act (OG, 2013), as amended. The amendment to this Act which came into force in July 2017 is considered as complete transposition of the EU MSP Directive into the legislation of the Republic of Croatia. Its Article 49a among others states that marine area is planned by physical plans of the counties that encompass marine area and zoning of the cities or municipalities. Article 49b lays down that on the occasion of drafting and adoption of physical plans encompassing marine area, proper attention should be given to specific features of the marine area, important existing and future activities, the use and modes of use of the marine area as well as their impacts on the environment and navigation safety, as well as on natural resources, considering the interaction between the land and marine area as well as long-turn variations caused by climate change.

The ministry in charge of physical planning is the Ministry of Physical Planning, Construction and State Assets. In authors' opinion the Maritime Spatial Plan as a document of indisputable national importance should be drafted in-house and that undertaking requires certain capacities and specific knowledge that could possibly be found in the ministries whose portfolios involve maritime affairs or marine environment protection. Two problems arise consequently: 1. maritime affairs portfolio would result in preference for economic aspects, and 2. marine environment portfolio has for years not been accorded respective attention within the ministry that is currently also responsible for the economy and energy.

The problem of nonexistence of maritime spatial plan comes to the fore in the process of drafting and adoption of certain legislative documents related to the sea and coastal area, as is currently happening with the Law on Maritime Demesne and Marine Ports that is particularly focused on granting long-term concessions on maritime domain. Without the valid maritime spatial plan agreed among different sectors and stakeholders, which had undergone mandatory public consultation and strategic environmental assessment, it is highly risky and inappropriate to allocate certain maritime demesne area for a particular use such as energy production, mariculture, tourism, and recreation in short term, let alone long term. The maritime spatial plan is important for resilience of communities in coastal areas (Runko Luttenberger and Mandić, 2022), the resilience of ecosystems (Runko Luttenberger et al., 2021), as well as the vital ecosystem services they provide, as well as coastal management in general (Runko Luttenberger and Gudelj, 2019).

CONCLUSION

Given that the seas and oceans and their sensitive and exceptionally important ecosystems as well as coastal populations are subject to an ever-increasing pressure originating from various industrial sectors, it is indispensable to use an ex-ante instrument of maritime spatial planning to ensure that its use does not disrupt natural processes, biodiversity and the well-being of local communities. Its development and application to date shows that there is still much space for improvement, particularly in respect of nature protection, but it is also certainly a proof that conflicting interests are considered and the stakeholders and public consulted. Maritime spatial plan development involves also the strategic environmental assessment which should guide the planning process in the direction that demonstrates sufficient consideration of the environment and local communities.

The Republic of Croatia should urgently initiate the process of developing its national maritime spatial plan for the Eastern Adriatic and its coasts. The process itself is important as it requires the integration of various areas of knowledge and the discussion among diverse stakeholders. Adriatic Sea is in many ways unique for its biodiversity, geology, influx of rivers, oxygen supply and indentation deeply in the European continent. Blue economy brings about serious challenges for the Adriatic torn between the interests of onshore wind energy production despite unsteady winds, big nautical marina projects, oil and gas drilling, aquaculture, coastal area land use changes, all combined with the risks of granting inappropriately long-term concessions on maritime domain, or commons, for various uses, resort industry included. Undertaking or further expanding of any of the mentioned or unmentioned activities on the sea surface, in water column, at seabed or subsoil, and along the coastal strip should be preceded by the adoption of the maritime spatial plan of the Republic of Croatia.

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Using a Bubble Barrier System to Tackle Marine Litter in the Port of Split

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Due to increased environmental awareness and the global increase in maritime traffic, the appropriate technical solutions to tackle marine litter are a high priority to protect the marine and coastal environment. It is especially significant in port cities where a port often located in a densely populated area affects the urban population environment. This study aims to analyze the possibility of improving waste removal from the sea basin at the northern cargo terminals of the Port of Split by introducing a bubble barrier system. Regarding the cargo terminals' physical conditions in the semi-enclosed port basin, an increasing waste accumulation in the rear part of the port is noted. Hydro-meteorological, oceanographic, microclimatic, and other environmental influences are primarily responsible for these effects. For this purpose, an overview of the site, operational, environmental, safety, and other conditions was provided, considering both the proposed waste disposal technology and technical features of the port. The potential use of hydrogen as a renewable energy source to operate the waste containment system would support sustainability. Hypothetically, the selected innovative technologies and interventions in the cargo terminal space would reduce the amount of waste on the sea surface. Technical and operational challenges of the bubble barrier system and its suitability at sea will play a principal role in the future decision-making process on potential installation at the seabed.

KEY WORDS

Marine litter, Bubble barrier, Port of Split, Environmental protection

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INTRODUCTION

The issue of marine litter is a global challenge. Its importance has been emphasized by the most established entities concerning environmental protection on various scales, such as United Nations (UN), European Commission (EC, 2022), International Maritime Organization (IMO), and other relevant parties, a fact that contributes to the significance of the global concern. They have all emphasized the pursuit of limitation and final disposal suppression of the material in the marine environment as a strategic objective labeled with the highest priority. Besides the well-known causes of marine garbage, the principal pollution sources are related to land-based activities (UNEP, 2022). While these activities contribute to almost 80% of marine garbage, an increasing trend of sea-based environmental pollution has been noted, damaging marine life and influencing the overall economy (EC, 2022). Generally, marine litter can be classified based on the criteria of the material used for its production and in terms of size, having diverse implications in the marine environment (Fleet et al., 2021). The most common type of marine litter is plastic. It is suggested that every year more than 8 million tonnes end up in the oceans (Gallo et al., 2018), while the total ocean contamination is estimated at around 150 million tonnes (Mckinsey, 2015). Additionally, the estimations point to an increase of 10% in additional plastic debris produced and disposed of in the sea (Thompson, 2006), with the projections that by 2050, the plastic could outweigh the fish in the ocean (World Economic Forum, 2016). It is interesting to note that microplastics have been nominated as "PM 2.5" in the ocean and defined as pieces and particles with a diameter of <5 mm (Thompson et al., 2004). They have damaged the marine environment physically (Gorokhova et al., 2020) and, through bioaccumulation, have entered the aquatic food chain (Schwabl et al., 2019). There is evidence of microplastics behaving as a vehicle for biofilm, and they can also carry waterborne diseases (Mughini-Gras, 2021). While only 1% of plastic marine litter floats on the sea surface (Piccardo et al., 2021), these effects are more significant in ports considering both the environmental and public standpoints. Floating garbage damage can be found in its harmfulness to the environment, marine life, human health, and the overall economy (Battawi et al., 2022). It is mainly an implication of the port location historically set in the center of metropolitan space. Ports as entities are heavily affected by marine litter (BLUEMED, 2021), a consequence related to the position of the port basin with respect to the terrestrial space and various commercial, logistical and industrial activities located in the vicinity of the port as an effect of location economics (Rodrigue, 2020). This unfavorable geographical setting is also supported by the climate impacts (wind, sea currents, tides, etc.), which contribute to the extension of plastic pollution in the observed space while creating negative port publicity. Despite the obligation to support the efficient and sustainable reception of ship-generated waste in port reception facilities, there is an increasing plastic waste issue and general waste disposal suppression when entering the port basin space.

This work discusses the possibility of a bubble barrier system implementation as a viable option to tackle waste pollution in the sea basin of the northern cargo terminals under the jurisdiction of the port of Split. This technology, already proven on rivers, provides an energy-efficient and environmentally friendly solution for plastic waste retaining without obstructing regular marine traffic. This simple system, based on the curtain of air bubbles, thus upward current generated by compressed air, has the objective to limit and direct the plastic towards the waste removal system while also contributing to the removal of microplastic, especially particles as small as 1 millimeter up to 1 meter (The Great Bubble Barrier, 2022). Due to the specific terminal design and setting, there is an increasing trend of plastic marine litter accumulation in the bottom enclosed space of the terminal, which under the specific climatic impacts, disperses throughout the open sea. It is mainly an implication of accompanying commercial, industrial, and other land-based activities located in the port surrounding, under the influence of natural impacts, thus location-specific wind, current, and wave effects. Introducing an efficient waste retaining and removal system is necessary to improve marine and coastal environment protection and increase the environmental awareness of all stakeholders in the area. The aim is to prevent the dispersion of plastic waste and additional pollution into the surrounding area. Additionally, by investing in waste removal technologies, the supporting objective is to improve the public perception of a local community, at this moment impaired by the low environmental and marine plastic removal standards.

THE BUBBLE BARRIER TECHNOLOGY AND ALTERNATIVES

According to the pollution location, there are two known methods to tackle macro-floating litter. (1) one related to the waste from oceans commonly handled by the available collection vessels and different tools, and (2) another related to the litter found in coastal streams and rivers, which are removed by using collection traps (Duan et al., 2021a; Duan et al., 2021b; Duan et al., 2021c; Duan et al., 2020). The bubble curtain technology is one of the several systems of marine litter booms (pneumatic), with the primary objective of containing floating waste and preventing further dispersion into the open sea. Booms are a passive technique usually applied in the open sea and streams, in combination with catchment equipment to collect the floating litter (Battawi et al., 2022). Also, they are only effective as a control measure under specific site conditions (Mohd Shah et al., 2021). Booms are commonly listed under the floating debris trap category, among remaining techniques as in-pit devices, trash racks, litter control devices, sediment traps with sedimentation reservoirs, and fixed trash racks (SBTR Trap), nominated as trash traps. The principal function of the trash trap is to remove water from litter and other waste forms (Department of Irrigation and Drainage, 2017). The available marine litter removal techniques differ based on the type of operation performed, which can be addressed as (1) direct prevention of the inflow of plastic into the waterway or (2) collection of the existing plastic pollution. The overview of a comprehensive database on the type of technology provided and targeted plastic can be further seen in Schmaltz et al., 2020, while a brief overview of floating plastic clean-up technologies is listed in Falk-Andersson et al., 2020.

The use of bubble curtain technology in the marine environment is multifold as retaining oil spills (McClimans et al., 2013), attenuating and reducing the sound propagation of different media (Gao, Ma, and Ding, 2021); mitigating the effects of the saltwater intrusion (Oldeman et al., 2020), controlling the movement of fish species (Zielinski and Sorensen, 2016), and numerous other purposes. However, promising bubble curtains as an anti-plastic barrier has emerged along with the growing importance of sustainable development as a novel paradigm focusing on environmental protection, including plastic pollution prevention of the environment. It primarily applies to retaining, directing, and controlling the flow of marine plastic litter. In order to physically remove plastic waste from the marine environment, this method is combined with an adequate waste collection system and disposed into port waste reception facilities at the end of a process. The bubble curtain technology (or bubble barrier) operates on the basics of compressed air, which is pumped from the perforated tube submerged at the seabed, creating an upward current (Mansa, 2022), while the circular sea current prevents waste from flowing downstream (Suprith et al., 2020). In order to exploit the natural flow of the water, the tube is placed diagonally across the port basin to push the debris to the side of the quay wall and direct the plastic toward the collection system (The Great Bubble Barrier, 2019). It is important to note that setting a bubble barrier in a waterway does not involve a physical barrier. There are positive side-effects of bubble barrier device. Compared to other barrier-type waste collecting systems (such as booms), it enables the ships to navigate throughout the port basin without obstruction, increases the dissolved oxygen, and provides safe fish passage (Zhang et al., 2022). This marine litter remediation process was first invented by a Dutch start-up, nominated as “The Great Bubble Barrier.” The visualization of the bubble barrier technology is provided in Figure 1.

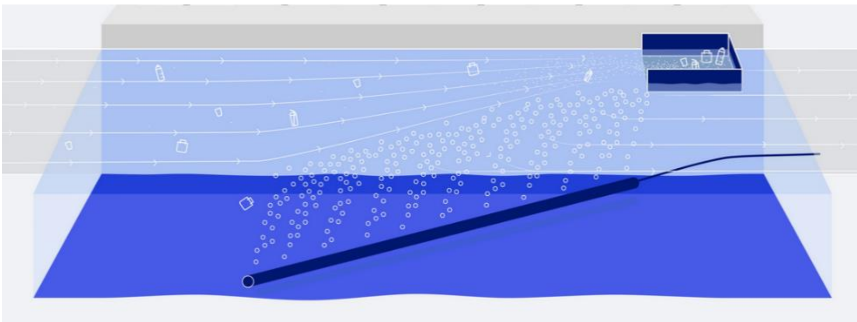

Figure 1. Schematic view of a bubble barrier technology based on prevention (bubble curtain) and collection functions (catchment system) (The Great Bubble Barrier, 2019)

The previous studies confirmed the effectiveness of a bubble curtain in blocking buoyant plastic particles (> 1mm) from the surface of the flowing water (KWR, 2021). It also refers to marine litter single size of up to one meter while considering the plastic under the water surface (The Great Bubble Barrier, 2019). The movement of these particles floating on a free water surface is affected by endogenous factors such as plastic size, shape, and density, thus its physicochemical characteristics (De Leo et al., 2021; Chubarenko et al., 2016). There are also several exogenous ones mainly related to the water flow and hydrodynamic conditions, such as the velocity and direction of the flow and others. Two physical properties affect the formation of air bubbles in the water, namely buoyancy and surface tension. The first relates to the force driving the bubbles toward the surface, and the latter keeps the bubbles attached mutually around the opening of the perforated tube. Depending on the increase in air bubble size, the buoyancy force overcomes the surface tension and provides a rising effect. That rising effect contributes to the merging of air bubbles while the thickness of the bubble curtain increases. The side-effects of rising air from the seabed are the creation of sound pressure waves throughout the liquid (Suprith et al., 2020). Depending on the pressure airflow variations in the perforated tube and its size and the sizes of the openings, the system application is different among water bodies according to their depth, width, and flow rate. Other factors also influence air bubble formation, such as the airflow rate, the distance between the seabed and the surface, the velocity of the liquid, the type of current flow, and others (Vanjari et al., 2021). Despite its advantages declared and data gathered from the small sample of implemented systems, there are still limited experimental data on bubble curtain effectiveness as a separation barrier (Oldeman et al., 2020), as well as on the optimum parameters for operating the bubble barrier (Bacot, Frank and Linden, 2022). These uncertainties and multi-factor dependences in the practical use of bubble curtains were the primary incentives for the research of Bacot, Frank, and Linden (2022). They studied the effectiveness of a bubble curtain as a separation barrier according to the different densities, air fluxes, and water depths based on quantitative measurements and theoretical considerations. However, despite its indisputable comparative advantages, at this moment, the waste-removal device has been designed and tested solely for fluvial pathways.

Current experience with diffusion of bubble barrier technology as a remediation method for marine plastic debris removal includes implementation at multiple sites, exclusively on rivers, considering the varying conditions and challenges in a specific environment. The first system was installed in Amsterdam to prevent the flowing of plastic from the Amsterdam canal into the North Sea. Before the bubble barrier installation, the city used water boats to collect and remove plastic from inland waters amounted to 42 tons annually. The manual cleanup limitation was reflected in the fact that the plastic remained below the water surface and was cleaned only periodically throughout the day, contributing to a large discharge of plastic waste into the open seas. With the application of a novel technology based on compressed air, the floating and sub-surface plastic waste cleaning at a size up to 1 millimeter were achieved. It was a significant advance, especially considering the performance of current cleaning methods, which were limited to collecting plastic pieces larger than 2 cm. The installation of a bubble curtain in Katwijk (Netherlands) aimed to prevent plastic from drifting upstream before reaching the North Sea. It was the first installation of a bubble barrier at the mouth of a river leading to a significant reduction in plastic pollution in the region. The next application was a pilot project conducted at a wastewater treatment plant in Wervershoof (North Holland) to determine if the bubble barrier could reduce the number of microplastics in the treated wastewater discharge and, ultimately, prevent them from entering the environment. This experimental project examined the amounts of microplastics upstream and downstream of the bubble curtain. Since the results were the same, it was concluded that the factors affecting the presence of plastic in the water remained to study in more detail. The project MAELSTROM (MArine Litter SusTainable remOval and Management) in the Porto region (Portugal) was undertaken to mitigate the impact of marine litter on coastal ecosystems. As this project started recently, the results will be available upon completion (The Great Bubble Barrier, 2022).

In recent years, influenced by the environmental protection paradigm, several innovations for plastic pollution reduction in the marine environment have been introduced. One of the most interesting for its setting and productivity in seas is the Seabin, a marine litter skimmer. Seabin is an effective tool to tackle marine plastic pollution, as it intercepts floating debris and plastic by skimming the water surface and pumping the water into the bin (Oceans Plastic Cleanup, 2022). Besides its principal function of waste collection, it continuously filters seawater. It has already been installed in numerous ports, marinas, and other water areas, where conditions of a calm environment and available services are satisfied. The general difference between Seabin and Bubble barrier technologies lies in the diverse type of operation, thus their fundamental function. While Seabin acts as a collection device that absorbs the plastic debris from the water surface, the bubble barrier is primarily a prevention tool that pushes the waste to the surface and directs it toward the collection system. The operating scheme of a Seabin device is shown in Figure 2.

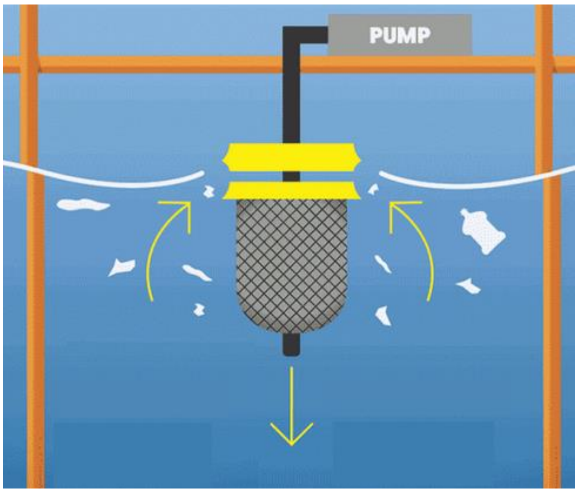

Figure 2. Operating functions of a Seabin device (SeaBin, 2022)

TECHNICAL AND LOCATIONAL CHARACTERISTICS OF THE NORTHERN CARGO TERMINALS INFLUENCING THE MARINE LITTER ACCUMULATION

Cargo terminals of the port of Split are situated in the northern part of the city, and according to the municipal setting of its location into port areas, namely Vranjic-Solin basin and Kaštela basins (B and

C). The area of the Vranjic-Solin basin is nominated as the North port (Vukić, Ukić-Boljat, Slišković, 2018), which represents the largest infrastructural surface for cargo transport, transshipment, and storage in the port of Split (Vukić et al., 2019). Cargo-handling activities occur on both sides of a semi-enclosed and narrow port basin (Vukić et al., 2022), which has a specific, elongated shape and extends approximately in the ESE direction. The width of the waterway decreases from about 200 m at the entrance to the Vranjic-Solin basin to about 80 m at the rear eastern part of the terminal (berth equipped with a ro-ro ramp) (Vidan et al., 2022). Figure 3 is the real-time and cartographic view of the Vranjic-Solin basin, along with the data on distances between selected points across the waterway.

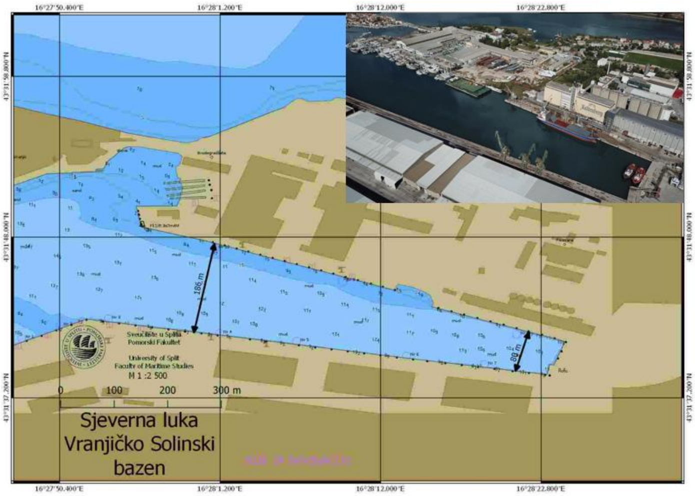

Figure 3. Cartographic and real-time view of the North port (Vidan et al., 2022)

The port location is in complex geography, surrounded by residential buildings in the southern part and the inhabited peninsula in the northwest, accompanied by numerous industrial entities operating in the free trade zone. More than 4,000 inhabitants are estimated to be exposed to harmful effects of port activities (cargo terminals), especially noise (Vukić et al., 2022). Considering the presence of industrial and manufacturing facilities, such as shipbuilding and sailboats maintenance areas, along with the regular port activities, free trade zone, and other operations in the closer surrounding, there is a growing issue of plastic litter presence in the marine environment. It implies the disposal of plastic material and other waste in the water due to the climate effects usually displaced throughout the waterway of the North port basin. Generally, the lost plastic in the surrounding environment is commonly transported to the oceans by waves, currents, winds, and tides due to disposal and improper waste management (Law, 2017; Ritchie & Roser, 2018). The port basin's semi-closed shape and meteorological and oceanographic conditions contribute to waste accumulation. It should be emphasized that waste movement in the Kaštela bay is under the impact of sea density (salinity and temperature), the change of sea levels (tides), local forces as wind and impact of Coriolis force, whose action occurs the circulation of the sea. This circulation can be divided into two types, anticyclonic circulation in the clockwise direction and cyclonic circulation in the counterclockwise direction, where the latter can be applied for the situational analysis presented in this paper. However, the selection of situational analysis in this paper does not neglect the effects of anticyclonic circulation and accompanied impacts, as the analysis of the current state can be applied to both situations differing in the direction of bubble barrier setting. Additionally, the effects of Jadro river and other fluvial masses contribute to these effects. Marine litter pollution in the port becomes visible when the waste through the waterway reaches the rear eastern part of the port basin and accumulates in the northeast angle. The pile-up effect of marine litter in the east end of the Vranjic-Solin basin is shown in Figure 4.

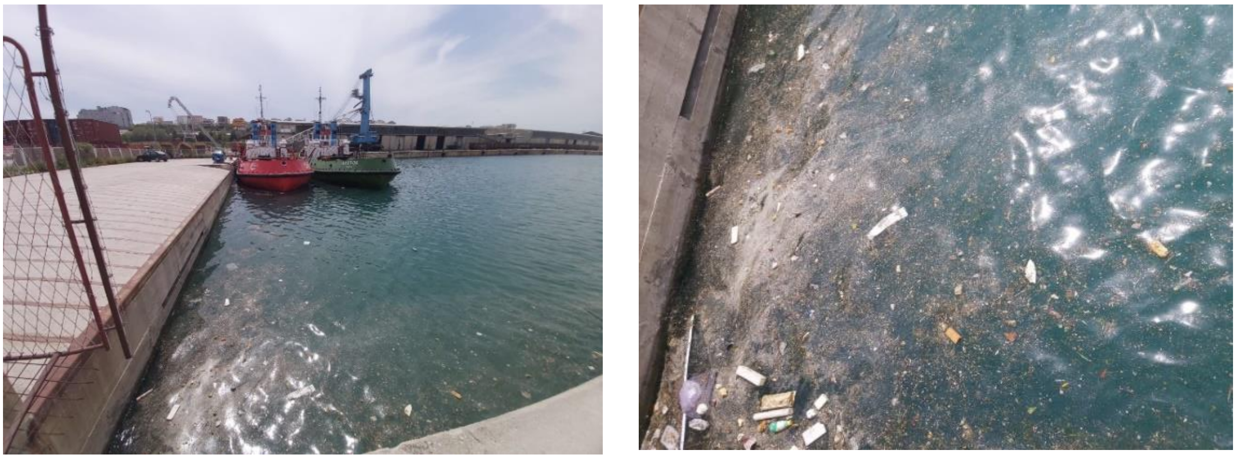

Figure 4. Waste accumulations in the Vranjic-Solin basin (private collection)

This pollution is later displaced during the day/night towards the inhabited peninsula (in the northwestern part of the port basin area) due to the circulation of sea currents. The implications of improper waste management result in the contamination of the marine environment and a negative public perception of the North port, which is often groundless and unjustified. It is due to the accumulated waste also originating from the other dislocated land-based activities but floats towards the Vranjic-Solin basin. Furthermore, depths in the Vranjic-Solin basin are around 11 meters (Vukić et al., 2019), so there is an obligation to utilize a technology that enables the unhindered progress of port traffic. Figure 5 provides the overview of cargo basins in the port of Split, along with the definition of the main infrastructural functions. Additionally, in the adjacent Kaštela bay (further north), the mouth of river Jadro is located. All of the mentioned specifics of the port site and location imply the improvement of waste management in the port area and a rise in awareness of the harmful effects of plastic waste on the marine environment.

Figure 5. Location and overview of main functions of cargo terminals in the Port of Split (Vukić et al., 2022)

APPLICATION OF BUBBLE BARRIER SYSTEM IN THE PORT OF SPLIT – ASSUMPTIONS

Due to the port's specific location and physical features, vicinity of a densely populated area, increased industrial activities in the port surrounding, and other climatic effects, there is a necessity to improve marine litter remediation in the Vranjic-Solin basin, especially plastic, from and under the water surface. The fundamental objectives of the implementation of the bubble barrier system are:

- to direct the waste entered the waterway towards the rear end,
- prevent further displacement of the marine litter and retain the accumulated waste at a single point,
- the final collection of marine debris by setting an adequate catchment system and continuous removal by a device without obstructing the port traffic.

A bubble barrier implementation in the North port assumes the system based on the flow of compressed air through a perforated tube lying on the seabed. The primary device components are a perforated rubber tube, electric compressor, and catchment system at the process end for waste clean-up. A pipe should be placed diagonally across the waterway, from the southern quay wall to the northeast corner of the basin, to catch as much plastic pollution as possible running downstream towards the end of the semi-enclosed port. The barrier angle should be determined according to the calculation for the maximum capture of plastics. It should enable the guidance of the marine litter in reaching the catchment system at the end of the terminal by using the energy of the wind and sea currents. The added value of bubble barrier technology gets the tube laid on the seabed allowing the continuation of the regular port traffic activities in the water area of the port basin and fish migration. Considering the reliable sunny weather all year long in the city of Split, which can be expressed through more than 2,700 sunny hours per year (TBS, 2022), and the availability of water, the use of hydrogen as a fuel for powering the electric compressor becomes a viable option. Generally, the use of hydrogen and fuel cell system represents the alternative of conventional internal combustion systems. When hydrogen is used as a fuel in fuel cells, it does not generate emissions during operation (Aydin and Dincer, 2022). The concessionaires in the Vranjic-Solin basin (on both sides) have already invested in photovoltaic cells at the rooftops of their warehouses for electricity production, useful as a first step in green hydrogen utilization. In addition, there is enough space at the bottom of the terminal on the east for planning and setting up the hydrogen production and storage facilities.

The installation of waste removal technology in the North port using the bubble curtain method also entails meeting technical, operational, ecological, climatic, and other requirements specific to the examined location. It should be noted that the cyclonal circulation of sea currents under the impact of other forces and effects, as wind, tides, density, fluvial masses, is considered as situational assumption in this paper. The data on sea currents, wind, and waves are predictors that directly impact the movement of the debris throughout the port basin and its entering. Based on the data indicated by Vidan et al. (2022), the sea currents in the observed area are, on average, up to 0,5 knots, with waves up to 1 m. Slightly larger waves are possible from the west, but rarely. On an annual level in the Split area, the prevailing wind is NE, followed by SE wind (CMHS, 2015), while NW wind causes choppy sea in the Vranjic-Solin basin. The depth decreases under the quay walls to around 8 to 9 m (CHI, 2018). This data is essential in determining the operative parameters of the bubble curtain system as air pressure rate, size of the tube and its openings, bubble curtain flow, and others considering the distance between the seabed and waterline level. The bathymetric measurement in the Vranjic-Solin basin is provided in Figure 6.

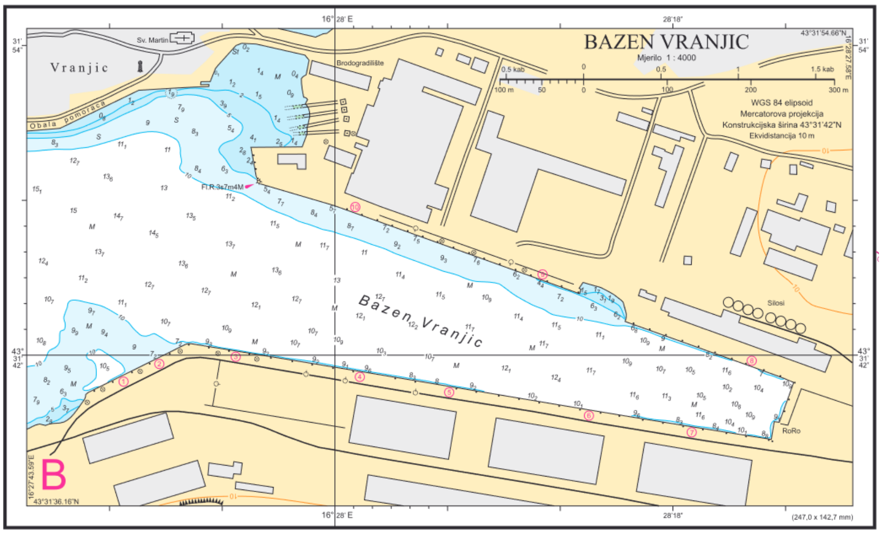

Figure 6. Bathymetric data of depths in the Vranjic-Solin basin (CHI, 2018)

Collecting waste, planned by setting the suitable catchment system, should retain the accumulated waste at the rear part of the basin and remove it from the marine environment into the land-based reception facility. The circular economy principles fulfillment can be reached by recycling the collected plastics in their further life-cycle phases. The biggest challenge of bubble barrier implementation will be its suitability in seas, as this technology is until now only tested in rivers. Figure 7 provides the setting of the bubble barrier in the Vranjic-Solin basin according to the described conditions.

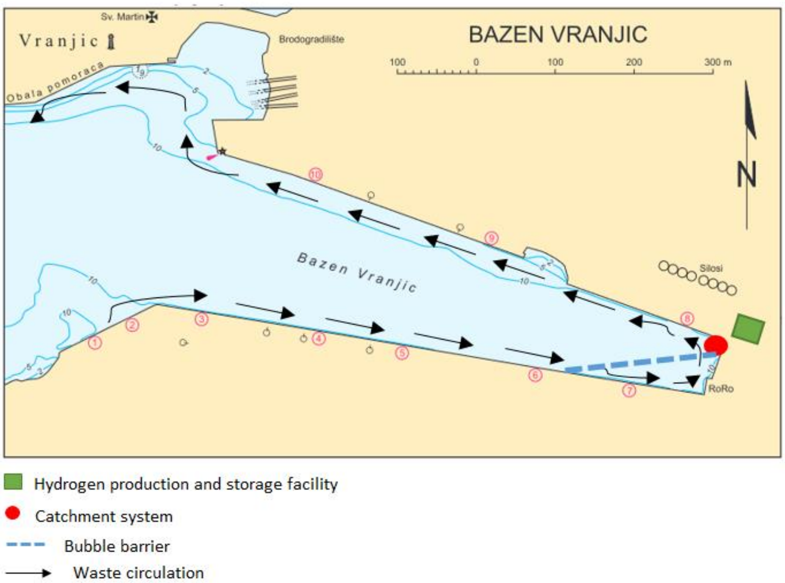

Figure 7. Setting of the bubble barrier system in the Vranjic-Solin basin

DISCUSSION AND CONCLUSION

The objective of this paper was to provide an overview of the main predictors required for the bubble barrier technology implementation in the Vranjic-Solin basin, where the largest cargo terminals are situated. The fundamental motive was the gradual accumulation of marine plastic litter in the northeastern corner of the semi-enclosed port basin throughout the years, a consequence of waste migration from the surrounding industrial areas by sea currents, wind, and waves. After reaching the port basin end, influenced by oceanographic and meteorological conditions, the waste spread to a northwest densely populated area, increasing the necessity for a proper waste remediation system. From the environmental and social standpoint, the implications of waste disposal in the examined area rise. Marine plastic litter contributes to marine environment pollution affecting marine life and biodiversity, creating adverse public perceptions, and questioning the port authority's environmental care and activities. The port site challenge, located in the vicinity of the inhabited area, additionally imposes a higher sensibility level and importance of improving waste management in the complex marine space. Despite the proven effects of bubble barrier technology on fluvial pathways, it represents a promising method to eliminate surface and below-surface plastic litter from seas so port basins as a complex and dynamic environment. This simple clean-up method supports the economic justification of investment. Using hydrogen for powering the compressor should also be taken into consideration. Bubble barrier powered with hydrogen could be tested in the location within the pilot project aiming for an extensive introduction of the hydrogen drive in traffic and industry activities. The permanent installation and continuous performance of the bubble curtain method clearly contribute to the viability of the marine debris suppression from the port area. However, its effectiveness will surely be challenged as for the lack of natural flow of the sea, greater depths, and unproven operational factors.

Considering the predominantly positive results and the experience gained in the application of this technology at different sites, the application of the bubble barrier system requires a thorough analysis of the site and all the accompanying conditions specific to the individual location to achieve maximum performance in the removal of marine litter.

The selection of appropriate marine litter removal technology in the Vranjic-Solin basin and its permanent installation will depend on the comprehensive and systematic analysis of indicated endogenous and exogenous factors specific to this site and the requirements for efficient plastic remediation technology. This work presented the conceptual solution and analyzed the prerequisites for the bubble curtain technology potential installation in the Port of Split cargo terminal area. Future research should aim to determine the necessary parameters needed for launching an experimental phase of the bubble barrier suitability in the sea. Most importantly, the first step in the planning phase of the bubble barrier implementation would be modelling the meteorological and oceanographic conditions in the Kaštela bay, by defining combined impact of sea density, fluctuations of wind direction, tides and both cyclonic and anticyclonic circulation.

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Comparative Analysis and Trends of Environmental Incidents in the Gulf of Mexico Offshore Oil Fields

Zlatko Boko, Zaloa Sanchez-Varela, Ivica Skoko, Merica Slišković

Marine oil pollution is a severe threat to the ocean environment. The Gulf of Mexico, with reserves of 26.77 billion barrels of oil and 197 trillion cubic feet of gas from 1325 oil fields, has an enormous potential impact on the world's energy supply and marine ecological balance. It has been the scene of marine pollution from the different offshore activities in the area. Offshore oil fields are maritime areas where hydrocarbon exploration, drilling and production are undertaken at or under the sea in association with oil or natural gas under the seabed. This paper presents an analysis and trends of environmental incidents in the Gulf of Mexico from 1964 to 2012, focusing on various data significant in the offshore oil industry. The objective is to analyse spill incidents by cause and the number of barrels spilt for the observed period concerning the number of structures. Results will show downtrends in environmental incidents and spilt barrels despite significant enhancement in the numbers of offshore structures and increased productivity.

KEY WORDS

Offshore, Environmental, Incident, Oil spill.

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INTRODUCTION

Environment refers to the interaction between the physical, chemical and biological components. The environmental problems include pollution, deforestation, global warming, and other broader issues.

Environmental science seeks to protect humans and ecological systems from harmful pollution by focusing on human impact. Technological and industrial progression significantly impact many ecosystems, affecting the global environment (Kte'pi, 2022).

The search for affordable, potent and ecologically friendly energy sources has been constant throughout the history of humankind. In 2011 crude oil was estimated to provide 52.8% of world energy, with oil accounting for 31.5% and gas 21.3% respectively (Bora et al., 2018).

The term "offshore" means "off the coast". In oil and gas extraction, "offshore" refers to the oil and natural gas deposits under the seabed.

Modern exploration, drilling and production technologies evolved from 1890s California oil piers. In 1896, as enterprising business people pursued California's prolific Summerland oilfield to the beach, the lure of offshore production enticed Henry L. Williams and his associates to build a pier 91.4 metres out into the Pacific — and mount a standard cable-tool rig on it. By 1897 this first offshore well-produced oil and 22 companies soon joined, constructing 14 more piers and over 400 wells within the next five years ("Offshore Drilling Exploration History - American Oil & Gas Historical Society," n.d.).

This Kerr-McGee drilling platform, known as Kermac Rig No. 16, was the first offshore rig in the Gulf of Mexico that was out of sight of land in 1947.

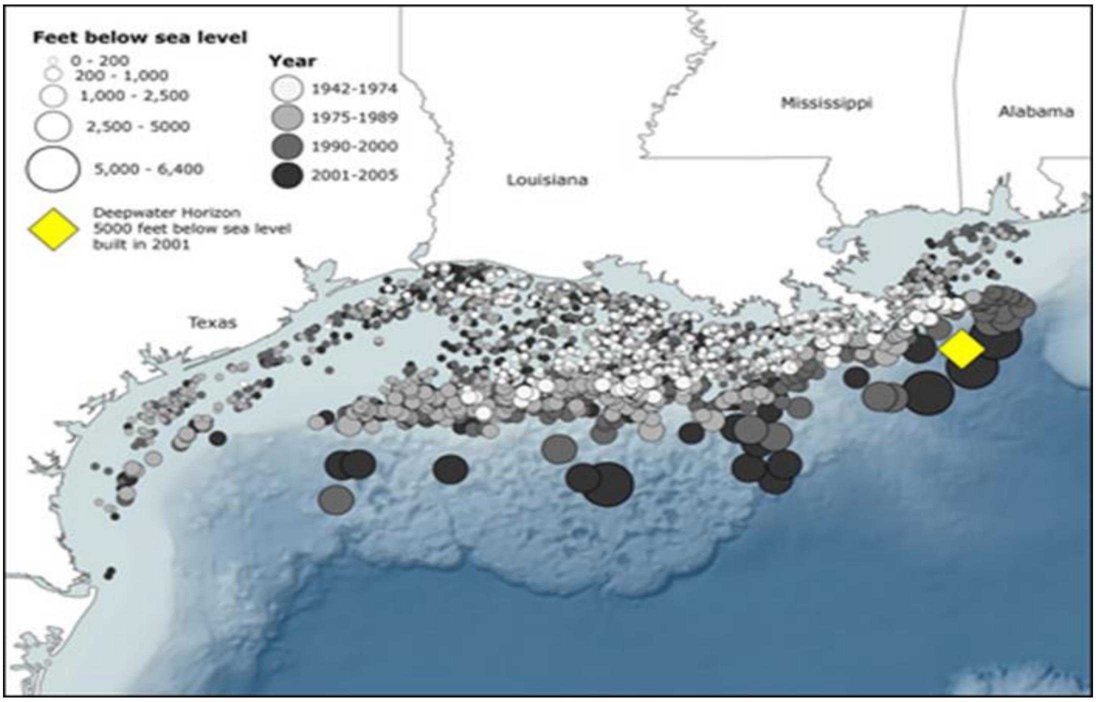

Figure 1. Depths and locations of the oil platforms in the Gulf of Mexico. Source: (McClain Craig, 2023)

Strategic planning of offshore oil and gas fields involves capital-intensive decisions about the installation of exploration and production facilities, subsea structures, pipeline connections, well drilling, etc., taken at the project's early stages (Gupta and Grossmann, 2012).

In early offshore oil and gas development, drilling wastes were discharged directly to the ocean from the platforms. However, during the 1970s and 1980s, evidence showed that some of these discharges could damage local ecology, particularly in shallow water (Dismukes, 2010).

This paper analyses spill incidents and their environmental impacts. Regular waste from drilling operations and ecological repercussions are not highlighted.

Since the early 1980s, the Gulf of Mexico offshore oil search, production and exploration experienced a shift from shallow to deep waters; the amount of extracted oil and gas increased simultaneously, opening new possibilities and dramatically enlarging the number of new installations.

This deepwater expansion has only sometimes been matched by legislation that reflects modern environmental conservation practices (Cordes et al., 2016).

Renewable energy must still be at the level required to replace fossil fuels as a primary energy source component.

Years of offshore drilling are still in front, and high-tech rigs and installations with diminished environmental impact will be crucial in permanent marine and coastal ecology care.

Determining the "decision time" to secure safety should start with the potential of an extreme weather event. The decision to continue well operations should depend on a forecast track to the asset location.

Oil and gas reserves in the Gulf of Mexico, Outer Continental Shelf, found as of December 31, 2019, were estimated as follows: the Original reserves are 26.77 billion barrels of oil and 5.58197.0 trillion cubic meters of gas from 1,325 fields. Original reserves are the total of the Cumulative production and the reserves. These reserves are recoverable from 414 active fields (Cross and Kellie, 2019).

Blowouts are the sudden and uncontrolled release of hydrocarbons from their natural reservoirs and are the most significant risk to the marine environment.

The Deepwater Horizon (DWH) or Gulf of Mexico oil spill is the largest marine oil spill in history, caused by an explosion on the DWH oil rig in 2010.

Risk modelling data suggests that major adverse events like DWH Macondo well blowout and severe ecological disasters as a direct consequence may be predicted to occur on an interval of a rough average of once every 17 years (Cordes et al., 2016).

Maritime oil spills result in the accumulation of genotoxic substances in the air, soil, and water. The direct impact of marine oil pollution is ecological and social harm. Pollutant as oil should be cleaned fast and effectively, or they will disturb the photosynthesis of plankton and jeopardise sea organisms dependent on plankton as a primary food source, subsequently reducing all marine life. Social harm is easy to observe, polluted beaches or coastal entertainment venues, increased cost of fishing equipment damaged by oil floating in the ocean or obstacles when using contaminated seawater for salt drying or desalination plants (Yang et al., 2021).

Centralising environmental maps and data of interest in oil and gas drilling and exploration fields in the form of an archive available to all parties concerned would create safer and easier-to-operate working areas, lessening the probability of human errors.

High pollution is associated with a higher production level, and improving technologies have beneficiary effects on oil barrels gained but are harmful to pollution.

Adequate environmental regulations are essential to balance production and pollution discharge appropriately.

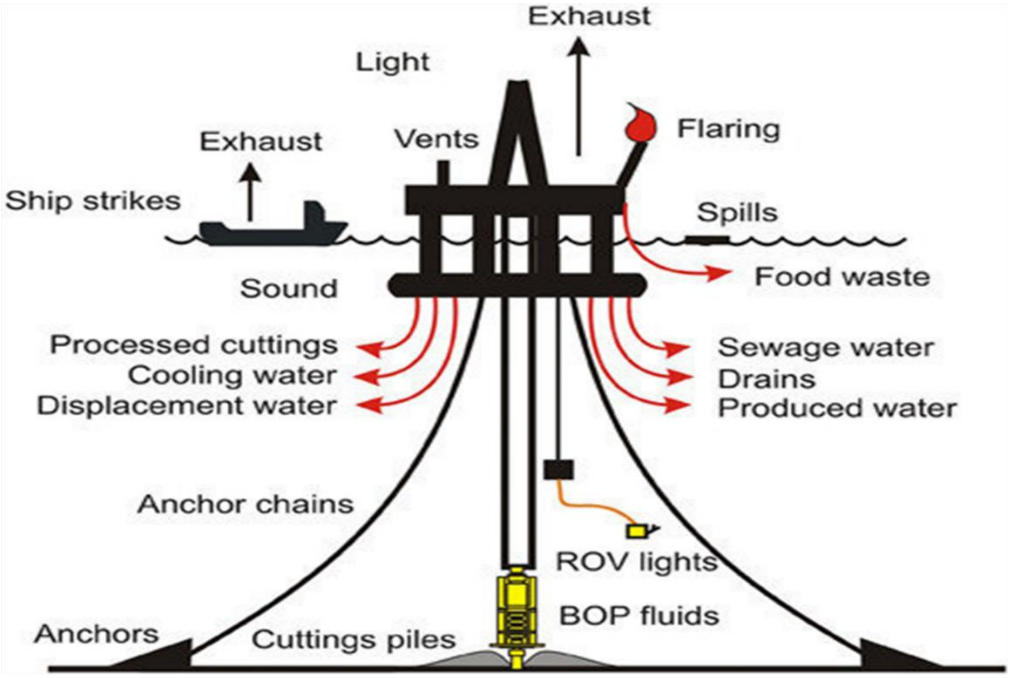

Figure 2. Diagram of environmental impacts from typical deep-sea drilling activity. Source: (Cordes et al., 2016)

Routine oil and gas activities can have detrimental environmental effects during the primary exploration, production, and decommissioning phases. During exploration, impacts can result from indirect (sound and traffic) and direct physical (anchor chains, drill cuttings, and drilling fluids) disturbances. As pipelines are laid, other direct physical effects occur in the production phase, increasing the volume of discharged produced water. Lastly, decommissioning can result in a series of direct impacts on the sea floor and can re-introduce contaminants to the environment (Cordes et al., 2016).

There are inevitable environmental issues surrounding each of the activities included in offshore oil searches, starting with the surveys to locate oil reserves and then drilling and exploration of extracted oil or gas (Seddiki Safia, 2012).

Technology progress should be crucial in ecological protection, with particular attention to environmental policies design and implementation.

The danger of out-of-control accidents like well-blowouts or incidents caused by extreme weather remains persistent and practically unavoidable.

Risk-based operational planning and preparation will minimise harmful consequences when addressing extreme weather events.

Oil and gas companies evolve and implement an Environment Management System that aligns with international rules and regulations and should prevent and minimise environmental hazards and incident consequences.

ANALYSIS AND TRENDS OF ENVIRONMENTAL INCIDENTS IN THE GULF OF MEXICO

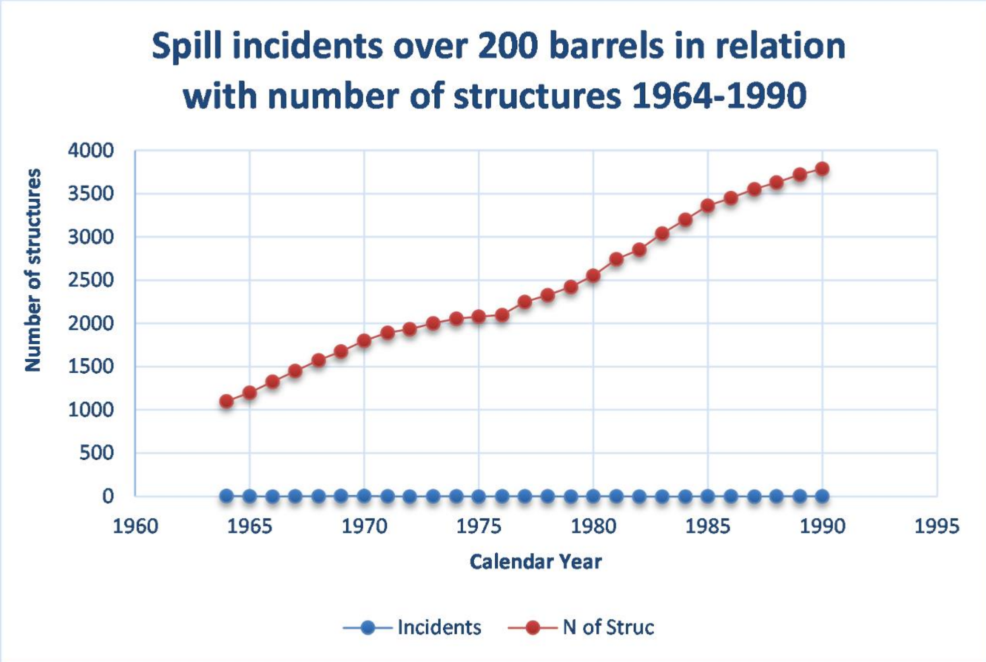

Figure 3: Spill incidents over 200 barrels concerning a number of structures 1964-1990; made by authors. Source: (The Bureau of Safety and Environmental Enforcement, 2022)

According to the USCG, the classification of spill sizes are MINOR for spills less than 238 barrels, MAJOR for 2381 barrels and more, and MEDIUM covering values in between.

One barrel of crude oil is 158,987 litres.

Figure 3. Data compares the number of offshore installations with spill incidents, stating a permanent increase in structure digits for the observed period, with rapid growth from the early 80ies caused by industry movement into deep waters. This graph contends all oil spills related to installations, minor included, and there is a flat line describing no augmentation in the number of incidents.

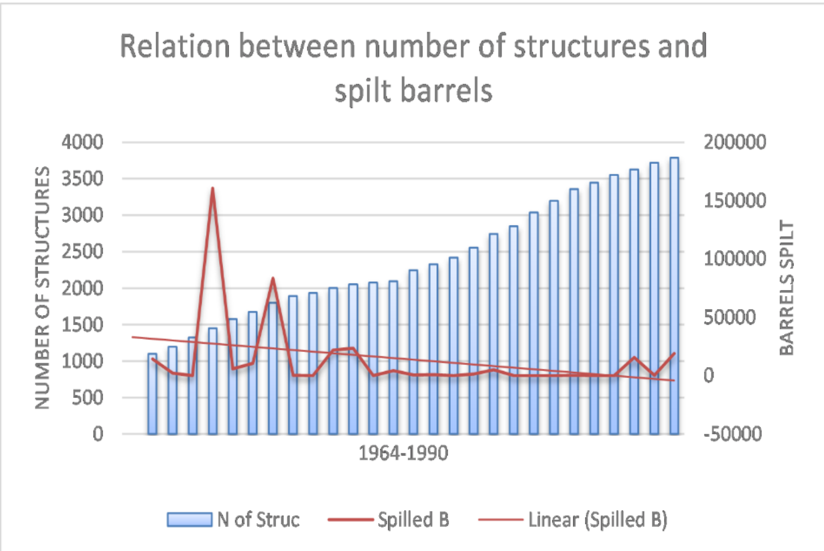

Figure 4: Relation between the number of structures and spilt barrels; made by authors. Source: (The Bureau of Safety and Environmental Enforcement, 2022)

Figure 4 shows an upsurge in offshore structures followed by the downsizing of barrels spilt due to newly introduced regulations, safety acts and advanced technology used.

Spikes in spilt barrels in 1967 and 1970 are due to external forces.

A robust decreasing trend in barrels spilt since 1973 became negative in 1986 before USCG implemented adequate environmental protection regulations in 1990.

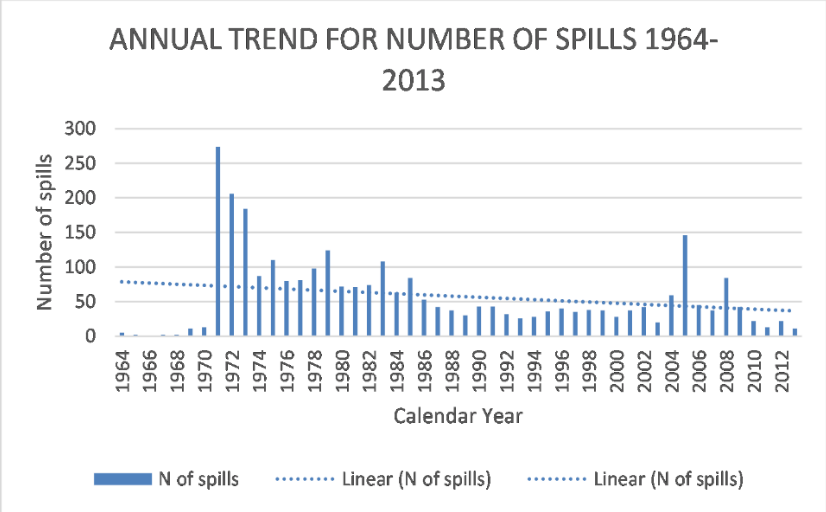

Figure 5: Annual trend for the number of spills 1964-2013; made by authors. Source: (The Bureau of Safety and Environmental Enforcement, 2022)

Data from Figure 5 shows that in the 1970s, the industry reported an average of 110 spills a year. Since then, this figure has fallen by a significant 43.18%, averaging 47.5 spills annually in 1980-2013, despite a noteworthy increase in the number of offshore oil installations and vessels supporting them.

As seen in Figure 4, the data downtrend of spilt barrels initiated in early 1973 mirrors the decreasing annual trend for spills until 2013.

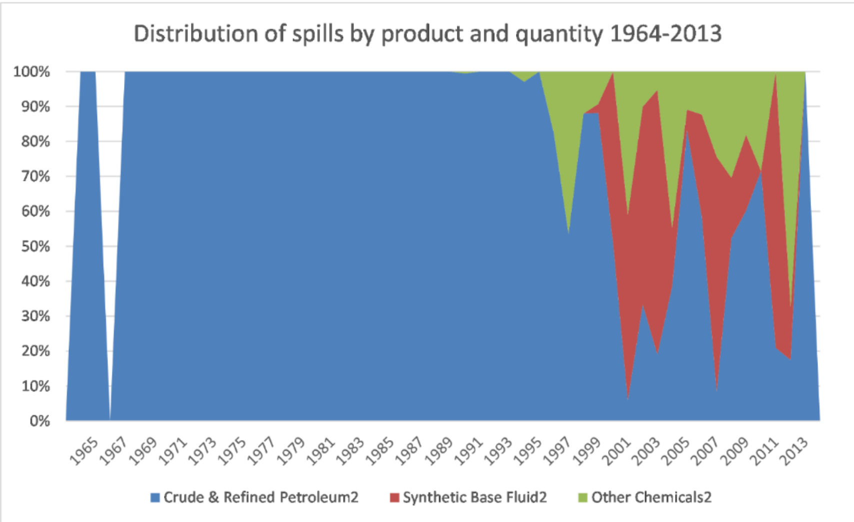

Figure 6: Distribution of spills by product and quantity 1964-2013; made by authors. Source: (The Bureau of Safety and Environmental Enforcement, 2022)

Figure 6 data shows the distribution of spills by product and quantity, and it is obvious that till the early 90ies, only spilt product was crude and refined petroleum. During the mid-1990s, mud companies developed and promoted synthetic-based fluids (SBFs) that offered strong drilling performance but were much more environmentally friendly than oil-based liquids(National Academies of Sciences, 2020).

SBF has been shown on the above graph since 2000, when they became standard in the industry.

Figure 6 refers to dispersants as 'other chemicals', showing up after the incident to diminish adverse effects. Dispersants have been used since 1967(Adofo et al., 2022), with constant reformulations allowing widespread use.

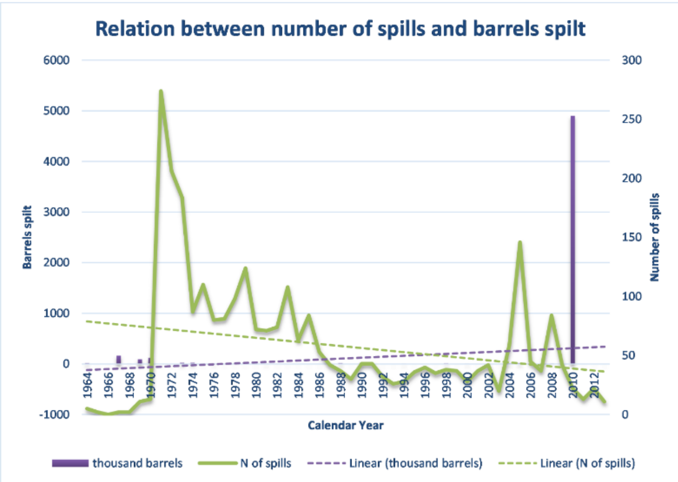

Figure 7: Relation between the number of spills and barrels spilt; made by authors. Source: (The Bureau of Safety and Environmental Enforcement, 2022)

The number of spills is constantly decreasing through the observed period.

Figure 7 data presents spilt barrels opposing that trend due to rare but significant spills, affecting statistics.

The 2010 DWH oil spill as a repercussion of the Macondo well blowout in the Gulf of Mexico is the most significant environmental disaster and remediation effort in United States history. Approximately 4 million barrels of crude oil were spilt. About 7 million litres of chemical dispersant were applied along the northern Gulf of Mexico, resulting in over 1600 km of the shoreline contaminated with weathered oil (Singleton et al., 2016). The closing of almost 202 342.8 square kilometres to fishing, hunting, and tourism, the displacement of residents, and the arrival of workers recruited to participate in mitigation efforts all contributed to the overall impact of the spill (Barron, 2012).

Environmental rules and regulations introduced after 2010 and the Deepwater Horizon installation accident harm oil and gas production and continuously mitigate the pollution.

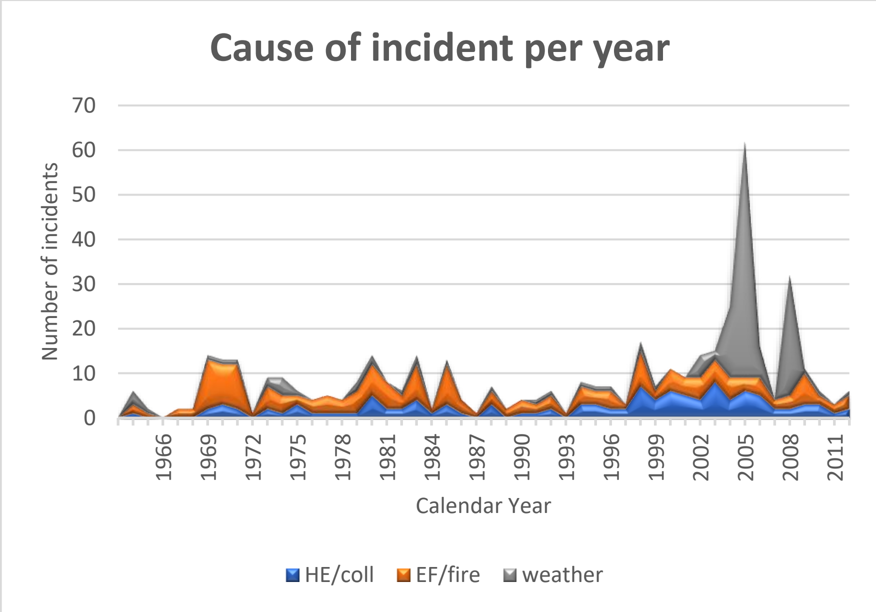

Figure 8: Cause of incident per year; made by authors. Source: (The Bureau of Safety and Environmental Enforcement, 2022)

A combination of factors is a common cause of safety issues in oil fields; for example, weather causes a human error which leads to a collision between a boat and an installation then an explosion or fire happens on the offshore structure. In such cases, incidents will be counted in more than one category. Furthermore, they can be expected during regular operations.

Figure 8 data points to an increase in human errors causing collisions, fires and explosions from 2001 following the rise in extreme weather incidents as the root cause.

The graph indicates explosions, fires, human errors, and weather to be permanent incident causes since 1965, and that is expected due to the nature of offshore oil and gas exploitation.

DISCUSSION AND CONCLUSIONS

In 1989, as a result of the tanker vessel 'Exxon Valdez catastrophe in Prince William Sound, Alaska, and the ensuing oil spill, was a passage of the Oil Pollution Act of 1990, which had a tremendous impact on positioning the maritime community to better prepare for marine oil spill response (United States Coast Guard, n.d.). United States Coast Guard (USCG) published a Final Rule on September 30, 2009, entitled Vessel and Facility Response Plans for Oil Removal Requirements and Alternative Technology Revisions. This Final Rule clarified requirements for response capabilities, including daily application capacity for dispersants, using a planning calculator, Dispersant Mission Planner 2(Government Printing Office, 2009).

Detected values from Figures 3, 4 and 5 clearly show that the spills decrease over time, and average spilt barrels follow that trend. Still, the frequency at which enormous blowouts occur indicates they can be expected.

Figure 6 graph shows the use of unprecedented amounts of dispersants at the origin of the DWH oil spill in 2010, which remains controversial because the natural behaviour of deep oil spills is to stay deep below the surface (Singleton et al., 2016). However, dispersants have already disrupted this natural process.

Figure 7 data confirms that environmental regulation can reduce pollution in two ways: first, through its impact on production, and second, by provoking technological improvement, which positively affects the environment.

Figure 8 shows that human reaction to extreme weather may be a key to enhancing all safety aspects, including environmental protection.

The increased number of incidents seen in Figure 8 caused by weather since 2001 is primarily due to an improved and more demanding report system requested by USCG and BSEE.

Reducing human errors will diminish fires, explosions and collisions.

It can be achieved by constantly reviewing approved Bridging Documents and Extreme Weather Plans on all installations before hurricane season to verify which plan takes precedence and reflects actual operations and practices.

Research results present downtrends in spills and spilt barrels during the researched period despite significant enhancement in the numbers of offshore structures and increased productivity. Decreasing trends starting before the implementation of clear and precise regulations.

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Particularly Sensitive Sea Area and the Eastern Adriatic Sea

Josip Dorigatti[1], Tina Perić[1], Mihaela Bukljaš[2], Gorana Jelić Mrčelić[1]

This paper analyses IMO Resolution A.982(24) - Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas - (adopted 1 December 2005) and attempts to identify arguments for designating the Adriatic as a PSSA area, taking into account cruise industry trends, cruise ship routing practices, and the newly created high-risk areas in the Eastern Adriatic region. As PSSA areas require special protection through IMO measures due to their environmental, socio-economic or scientific importance, as they may be vulnerable to damage from marine and coastal activities, the paper identifies the characteristics of the Adriatic Sea that may be an important argument for the designation of the Adriatic Sea as a PSSA. The aim of this paper is to review cruise traffic trends in the Eastern Adriatic and to test the PSSA criteria for the Adriatic region in order to assess the need for designating the Adriatic as a PSSA. One of the objectives is to raise awareness of current navigation practices in the central and southern parts of the Eastern Adriatic, which result in high-risk zones and pose safety and environmental risks. However, the implementation of additional regulations in the region has become necessary due to the large expansion of cruise ship traffic in this diverse and environmentally vulnerable region that previously lacked dense maritime traffic.

KEY WORDS

Cruise industry, Sustainability, Navigational safety, Marine environment, PSSA, Eastern Adriatic sea.

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INTRODUCTION

A Particularly Sensitive Sea Area (PSSA) is an area that needs special protection through action by International Maritime Organization (IMO) because of its significance for recognized ecological, socio-economic, or scientific attributes where such attributes may be vulnerable to damage by international shipping activities (IMO, 2023). Environmental threats related to shipping involve: operative discharges, non-intentional or deliberate contamination and damage to natural marine environment or marine life (MEPC, 2022).

To date, the IMO has designated 18 Particularly Sensitive Sea Areas worldwide. The first was the Great Barrier Reef in Australia (which was declared a PSSA in 1990), the second seven years later was the Sabana - Camagüey Archipelago in Cuba. The European seas designated as PSSAs are: Western European Waters (2004), Canary Islands, Spain (2005), the Baltic Sea Area (2005), the Strait of Boniface, France and Italy (2011), and the Northwestern Mediterranean Sea (2022) (MEPC, 2022). The most recent designation of a PSSA was in December 2022 for the Northwestern Mediterranean Sea, and the request was made by Italy, Monaco, France, and Spain to avoid risks of ship-source pollution and to raise awareness of an area of critical importance for fin whales and sperm whales (IMO, 2023). Many discussions, workshops and seminars have been organized on the designation of the Adriatic Sea as PSSA. In December 2019, a workshop and seminar on PSSAs focusing on the Adriatic and Mediterranean Sea was held in Tirana, Albania, to build a solid knowledge base and explore the possibility of making requests to the IMO for the designation of PSSAs in the Adriatic Sea. One of the conclusions of the workshop was the need to collect all the necessary data and information required to prepare such a proposal, not only those proving the values of the area, but also those related to maritime traffic, risk of incidents and potential dam-ages. It was agreed that full cooperation of all countries concerned was needed in the preparation and development of the proposal and that all countries should decide jointly on the key elements related to the designation of the Adriatic Sea as a PSSA (INFO RAC, 2019).

Particularly sensitive sea areas: the need for regional cooperation in the Adriatic Sea (Vidas, 2006) dis-cusses the need for designation of the Adriatic Sea as a Particularly Sensitive Areas. In his paper, he reviews PSSA concept, European Union emerging policies towards PSSA and asses current status of IMO designations. The paper elaborates the key features of the Adriatic as corresponding to the IMO criteria for designation of PSSA and cover basic characteristics of the area, determines status and trends of international navigation and defines present and suggests potential associated protective measures. The research mentions oil industry, European and global oil transport trends and its effect on development of tanker shipping in the region. Side effects such as potential safety accidents, pollution, ballast management and hull fouling is one of the key arguments for implementation of PSSA in the Adriatic. His consultation states that PSSA proposal in the semi-enclosed Adriatic Sea with several states is a complex affair if compared to those PSSAs proposed by single country only. Successful application should be formulated in cooperation where two or more countries have a common interest in a particular area. Such regional cooperation towards PSSA needs to have impact on international navigation and has to be approved at the global IMO level. In order to achieve successful application the Adriatic Sea as a region needs to make balance between national regulations and regional cooperation. The effort should be based on commonality and be oriented towards cooperation in approaching issues of joint concern (Vidas, 2006).

The paper analyses IMO Resolution A.982 (24) - Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas - (adopted 1 December 2005) and attempts to identify arguments for designating the Adriatic as a PSSA area, taking into account cruise industry trends, cruise ship routing practices, and the newly created high-risk areas in the Adriatic region. As PSSA areas re-quire special protection through IMO measures due to their environmental, socio-economic or scientific importance, as they may be vulnerable to damage from marine and coastal activities, the paper identifies the characteristics of the Adriatic Sea that may be an important argument for the designation of the Adriatic Sea as a PSSA.

The aim of this paper is to review cruise traffic trends in the Eastern Adriatic and to test the PSSA criteria for the Adriatic region in order to assess the need for designating the Adriatic as a PSSA. One of the objectives is to raise awareness of current navigation practices in the central and southern parts of the Eastern Adriatic, which result in high-risk zones and pose safety and environmental risks

PARTICULARLY SENSITIVE SEA AREA

A PSSA is a comprehensive management tool, available at the international level, for reviewing the characteristics within an area that is vulnerable to damage from international maritime traffic and determining the most appropriate protective measures available within the IMO to address that vulnerability (IMO, 2023).

The Marine Environment Protection Committee (MEPC) of the IMO commenced researching PSSAs in regards to the 1978 Resolution of the International Conference on Tanker Safety and Pollution Prevention. Discourse on this idea from 1986 to 1991 resulted in the acceptance of Guidelines for the designation of Special Areas and the recognition of Particularly Sensitive Sea Areas by Assembly Resolution A.720 (17) in 1991. This document was created with intention to define the steps in for the nomination and recognition of PSSAs and the acceptance of adequate protective measures. The Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas IMO Resolution A.982 (24) was adopted on 1 December 2005.

The IMO is the only international body responsible for designating areas as PSSAs and adopting appropriate protective measures. A Member Government may only submit a request to IMO to designate a PSSA and accept analogous measures for protection. The Member Government should provide to the MEPC information on the vulnerability of that area to damage from international shipping, and indicate the proposed protective measures to prevent, reduce, or eliminate the identified vulnerability.

Procedure for the designation of PSSA and the adoption of associated protective measures

According to MEPC (2022), the application for PSSA designation should first include a summary of the objectives of the proposed PSSA designation, the location of the area, the need for protection, and associated protection measures, and how the identified vulnerability will be prevented by existing or proposed associated protective measures. The application shall state the potential impact of the proposed measures on the safety and efficiency of navigation, taking into account the area in which the proposed measures are to be implemented (IMO, 2023).

The application should have two parts:

- Part I – in this part the area should be described and the importance and the sensitivity of the area to the activities related to the maritime transport) and
- Part II –this part consists of adequate protective measures and IMO’s competence to approve or adopt such measures.

These measures may include ships' routing measures, reporting requirements, discharge restrictions; operational criteria, and prohibited activities, and should be specifically tailored to the needs of the area to prevent, reduce, or eliminate the identified vulnerability of the area from international shipping activities. The application should clearly identify the category or categories of vessels to which the proposed protective measures would apply. The application should indicate the potential impact of the proposed measures on the safety and efficiency of navigation, taking into account the maritime area in which the proposed measures would be implemented.

The application should include, inter alia, the following information:

- Uniformity with the legal instrument under which the related protective measure is being suggested
- Impact on ship safety; and
- Impact on ship operations, including existing traffic patterns or use of the proposed area (MEPC, 2022).

Associated protective measures for PSSAs are limited to actions that are to be or have already been approved by the IMO and include the following options:

- Designation of an area as a Special Area under MARPOL Annexes I, II, or V, or as a SO_x Emission Control Area under MARPOL Annex VI, or application of special discharge restrictions to ships operating in a PSSA.
- Implement ships' routing and reporting systems in the vicinity or area in accordance with the International Convention for the Safety of Life at Sea (SOLAS) and in accordance with the General Provisions on Ships' Routing and the Guidelines and Criteria for Ship Reporting Systems.
- Develop and adopt other measures to protect specific sea areas from environmental damage by ships, where there is a legal basis for doing so (MEPC, 2022).

Ecological, socioeconomic or scientific criteria for the identification of a PSSA

For purpose of recognition a PSSA, the region should comply with at least one of the principles listed below, and supporting documentation should be presented in order to clarify that at least one of the principles applies to the entire proposed area. These principles can be divided into three categories: ecological criteria; social, cultural, and economic criteria; and scientific and educational criteria (MEPC, 2022). Chapter four of the Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas (IMO Resolution A.982 (24)) lists ecological, socioeconomic, or scientific criteria for identifying a PSSA.

Ecological criteria (MEPC, 2022):

- Uniqueness or rarity
- Critical habitat
- Dependency
- Representativeness
- Diversity
- Productivity
- Spawning or breeding grounds

- Naturalness
- Integrity
- Fragility
- Bio-geographic importance

Social, cultural and economic criteria (MEPC, 2022):

- Social or economic dependency
- Human dependency
- Cultural heritage

Scientific and educational criteria (MEPC, 2022):

- Research
- Baseline for monitoring studies
- Education

The area should not only meet at least one of the above criteria, but also be at risk from international shipping activities. The factors for vulnerability to impact from international shipping are listed in chapter five of the Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas (IMO Resolution A.982 (24)).

Vulnerability to impact from international shipping

Vulnerability to impact from international shipping includes vessel traffic characteristics and natural factors. Natural factors include hydrographical, meteorological and oceanographic factors while vessel traffic characteristics include (MEPC, 2022):

- Operational factors – Variety of maritime actions by variety of maritime dynamic and stationary objects in the designated area that might have impact on the navigational safety
- Vessel types – Categories of vessels operating through or in vicinity of the area
- Traffic characteristics – Traffic density, ships interaction, distance from which ships pass from the shore or other dangers to navigation that can contribute to higher risk of collision and grounding
- Harmful substances carried – any type of cargo or item in any form that by discharging to the sea can create harmful impact

Information that might be helpful in recommending an area as a PSSA includes (MEPC, 2022):

- Any evidence that international shipping activities are causing or may cause damage to the characteristics of the proposed area
- Groundings, collisions, or spills in the past in the region and the effects of such events
- Any negative environmental side effect outside the recommended PSSA that can result from alterations in international shipping practice as a result of the PSSA designation;
- Any measures already in use and their present or foreseeable positive impact.

CRUISE INDUSTRY AND RELATED NAVIGATIONAL AND ENVIRONMENTAL RISKS IN THE EASTERN ADRIATIC

In the Mediterranean, the Adriatic region is developing the fastest in terms of cruise calls and total passenger movements in the period from 2015 to 2019 (Cruise Industry News, 2021). Development of cruising industry in the Adriatic region follows the expansion of cruise ships ports; currently approximately 30 ports are able to accommodate cruise ships (Dorigatti et al., 2022c). The tendency of passenger movements goes along with increment of cruise ship calls. In the central and south part of the Croatian coast, the passenger movements grew to almost 50 % in the period from 2015 to 2019, compared to about 20 % in the Adriatic and only 15 % in the Mediterranean (Dorigatti et al., 2022c). The above data justify the fact that the central and southern part of the Croatian coast is the region with the strongest cruise development trends in both the Adriatic and the Mediterranean.

The expansion of cruise industry in the Eastern Adriatic has made impact on navigational routing in the region. The routes are adjusted according to development of new destinations and have become standard navigational practice and the alternative to the Central Adriatic Separation Scheme. Maritime traffic in the northern Adriatic is regulated by Northern Adriatic Separation Scheme, which directs traffic on steady route without oscillation. Traffic flow in central and southern part of the Adriatic east coast does not have steady pattern. Limited size of the Central Adriatic Separation scheme offer more navigational options to cruise ships. The Central Adriatic Separation scheme is in use only on direct south-easterly and north-westerly routes from the Northern Adriatic to the Otranto Strait and from Otranto Strait to the Northern Adriatic ports. Traffic monitoring has shown that cruise ships on north-westerly or south-easterly curses, heading from Northern Adriatic to the south Adriatic east coast destination and vice versa, stay out of the Central Adriatic Separation Scheme. They chose coastal navigation among the islands until they reach final destination (Dorigatti et al., 2022b). Increment in cruise ships traffic and newly implemented cruise ships routes in the central and southern Adriatic east coast have created high-risk zones. Selected high-risk zones are four Marine Protected Areas: Kornati National Park, Mljet National Park, Lastovo Nature Park and Sušac Island Nature Park. Cruise traffic monitoring has shown newly implemented navigational practices for cruise ships in coastal navigation. Navigational area often in use are: the islands of Svetac, Biševo, Sušac and Lastovo, as well as the Svetac-Biševo passage, the Hvar Channel and the Sušac-Lastovo and Lastovo-Mljet passages. Acquired data on cruise ships movement has shown that cruise ships often pass through areas of high navigational and environmental risk, which are geographically restricted, navigationally challenging and environmentally delicate areas. Coastal navigation in immediate vicinity of the outer island shores and between the islands have become standard operational procedure for cruise ships. Mutual interaction on longitudinal and transversal cruise ships routes in coastal navigation place cruise ships in crossing, head-on, and overtaking situations that increase the risk of collisions, groundings, and pollution, especially in areas of high navigational risk (Dorigatti et al., 2022b).

PSSA AND THE ADRIATIC SEA

The identification and designation of a PSSA and the adoption of related protective measures require consideration of three essential components: the particular characteristics of the proposed area, the vulnerability of such an area to damage from international shipping activities, and the availability of appropriate protective measures within IMO's jurisdiction to prevent, reduce, or eliminate risks from such shipping activities. The Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas (IMO Resolution A.982 (24)) lists ecological, socioeconomic, or scientific criteria for identifying a PSSA. The area should not only meet at least one of those criteria, but also be at risk from international shipping activities. The factors for vulnerability to impact from international shipping listed in IMO Resolution A.982(24) includes natural factors as well as vessel traffic characteristics such as: operational factors, vessel types, traffic characteristics and harmful substances carried. Information that might be helpful in proposing an area as a PSSA includes any evidence that international shipping activities are causing or may cause damage to the attributes of the proposed area, including the significance or risk of the potential damage. It also includes groundings, collisions, or spills in the past in the area and the consequences of such incident and any adverse environmental impacts outside the pro-posed PSSA that are expected to result from changes in international shipping activities as a result of the PSSA designation.

The expansion of traffic in the Adriatic region especially cruise traffic and cruise destinations in recent decades and related studies on cruise industry trends, cruise ship routing and navigation practices in the Adriatic have demonstrated the need for further study of the environmental sustainability of the cruise industry in the Adriatic. In the period from 2015 to 2019, cruise industry trends have shown that the central and southern part of the Adriatic east coast has the fastest growth in cruise ship calls and passenger movements in the Adriatic and throughout the Mediterranean. The development of new cruise destinations in the Adriatic has led cruise ships to choose new routes in a coastal region of high natural value, where there was previously no dense maritime traffic. (Dorigatti et al., 2022b) Cruise ship routing monitoring has shown that operational demand for attractive cruise routes and a rich passenger experience brings cruise ships too close to shore, resulting in various challenging navigation situations that endanger ship safety as well as the marine environment (Dorigatti et al., 2022c). In order to meet operational demand, cruise ships plan routes in less defined navigation regions that pose a threat to navigation, safety, and the environment. Cruise ships deliberately select high-risk routes, and selected routes have become a repetitive practice and standard navigation routine (Dorigatti et al., 2022b). However, the adoption of additional protective measures in the Adriatic region must be considered.

Criteria for identification of a PSSA applicable to the East Adriatic coast.

Strong development of cruising industry and cruise ships traffic in the East Adriatic coast and its unique natural environment has put the region in position to comply with following criteria for identification of a PSSA.

Ecological criteria:

The region is famous worldwide for its unique nature, cultural tradition and particular, well-preserved environment. The uniqueness of the area is justified by two National Parks, two Nature Parks and one Special Nature Reserve (Dorigatti et al., 2022b).

The great diversity of land and marine habitats has resulted in a wealth of species and subspaces, including a significant number of endemics. There are 6 endemic fish species in the Adriatic. Mammals have their habitat too, among threatened mammals bottlenose dolphin (*Tursiops truncatus*) is a resident species in addition variety of creations have been registered in the eastern Adriatic (State Institute for Nature Protection, 2006).

When considering the threat status of Adriatic ichthyofauna, 124 fish species have been included in threatened representative list (Red List) of Marine Fish of Croatia in 2005. The main causes of threat to Adriatic fish are uncontrolled fishery, degradation of important habitats (like Posidonia beds), estuaries, coastal areas and channels, as well as pollution (State Institute for Nature Protection, 2006).

Above mentioned status of the East Adriatic region justifies compliance with ecological criteria such as: Uniqueness or rarity, Critical habitat, Representativeness, Diversity, Naturalness and Fragility.

Impact of marine traffic, in particular cruise ships traffic on coastal areas and possible realization of safety risks such as grounding, collision and pollution would have tremendous ecological effect.

Social, cultural and economic criteria:

The Adriatic coast region is a very popular tourist destination due to its uncommon natural beauty, historical heritage and general appeal. Natural beauty and cultural–historical diversity are the key factors that attract tourists and represent the main advantage towards competitors. (Dorigatti et al., 2022b) Croatian and Montenegrin economies depend on tourism, as it is their key source of GDP growth. Tourism accounts for some 20% of Croatian GDP (Europa Economy and Finance Forecast, 2020) and almost 25% of Montenegrin. (Orsini and Ostojić, 2018)

Being the region whose economies heavily depend on tourism, any possible realization of safety and environmental risks in coastal region such as collision, grounding or pollution would have serious social and economic impact. Pollution as a result of marine accident would have noticeable environmental influence that would impact human dependency of the region. Implementation of PSSA zone in the Adriatic region would have positive impact on social and economic aspect because it will certainly enhance economic and social cooperation among involved countries.

Vulnerability to impact from International shipping:

Strong development of cruise ships traffic in the east Adriatic region and newly accepted navigational practices in the area that have not had considerable maritime traffic before, have created high risk zones from the aspect of navigational safety environmental protection. High risk zones are designated in coastal areas with dense cruise ships traffic and which have become intersection of maritime corridors in coastal region. In addition, in these areas dense touristic and pleasure boat traffic elevate risk of collision and grounding for international shipping passing close to the coastal region. Taking current maritime status in consideration the region is vulnerable to impact from international shipping from aspect of vessel traffic characteristics, such as: operational factors and vessel types.

The Eastern Adriatic is the area of high natural value. Strong development of cruise industry has changed navigational practices in the area that have not had considerable maritime traffic before.

The strong expansion of the cruise industry and cruise traffic in the Adriatic since 2000 has had an impact on the route planning of cruise ships. New cruise destinations on the Adriatic east coast have created new cruise ship routes in the region that have not had dense maritime traffic before. Cruise industry operational demand for attractive cruising routes and rich passenger experience bring cruise ships too close to the shores on various challenging navigational situations. That practice elevates safety and environmental risks and can compromise ships safety but also marine environment.

CONCLUSION

Development of maritime industry in the Adriatic, in particular cruise industry has created multiple factors for Adriatic region to be taken into consideration. Available results prove that further development of cruising industry in the Adriatic coast has to be well planned and monitored from the aspect of navigational safety and sustainable development. One of the measures that would contribute to navigational safety and sustainable development is implementation of Particularly Sensitive Sea Are-as and additional protective measures in the Adriatic region. Future expansion has to be in line with implementation and development of additional protective measures such as routing systems, implementation of 'no go areas', efficient traffic control and etc. Implementation of PSSA in the Adriatic certainly would accelerate implementation of new protective measures. There are multiple possibilities for application. If the idea is to include entire Adriatic region as PSSA then all Government Members who have access to the Adriatic sea have to make an agreement on protective measures implementation in order to submit jointly application. Another solution is submission of independent application by one of the Government Members for selected PSSA area inside their territorial waters. However, the implementation of additional regulations in the region has become necessary due to the large expansion of cruise ship traffic in this diverse and environmentally vulnerable region that previously lacked dense maritime traffic.

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Public Service Compensation and Prolongation of Public Service Contracts in the Maritime Transport Sector under European Union Law in the Case of COVID-19

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The COVID-19 pandemic minimized the mobility of European Union (hereinafter: EU) citizens and businesses by sea and caused disruptions in the maritime supply chains. Consequently, the EU designed a series of measures to protect mobility and connectivity in Europe. This paper is dedicated to the analysis of the measures concerning the award of public service compensation to the maritime transport operators (shipowners) with whom Member State concluded public service contracts or imposed public service obligations (prior to or after the outbreak of the COVID-19 disease) in order to ensure the regular provision of the maritime transport services. Maritime transport services covered with these measures are freight and passenger transport, provided whether as cabotage or transport between two or more Member States or between EU and third country. The objective of the paper is to discuss and analyse under which conditions these measures do not constitute State aid or can be exempted from the *ex ante* notification to the Commission and a public contract concluded for the provision of the maritime transport services may be prolonged without a new award procedure and whether these terms are applicable also in case of other exceptional occurrences (such as wars, global economic crisis, etc.). In this context, relevant EU Law will be analysed: sector-specific rules on the provision of maritime transport services (Regulation 3577/92 on the provision of maritime cabotage services and Regulation 4055/865 on the provision of international maritime transport services), EU State aid rules (criteria established in the *Altmark* judgement), applicable rules on public procurement (Directive 2014/23/EU and Directive 2014/24/EU) and lastly, Working document issued by the departments of the European Commission for information purposes in response to the COVID-19 crisis.

KEY WORDS

Public service compensation, Public service contract, Public service obligation, Maritime transport services, Prolongation of public contracts, Exceptional occurrences.

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INTRODUCTION

At the time of the COVID-19 outbreak, the Member States needed to ensure the provision of maritime transport services and preserve the continuity of the provision of these services for the future. They created a series of measures to support maritime operators, such as shipping companies and port operators. These aid measures included, among others, aid in the form of grants, loans, public guarantees, tax rebates or deferrals, and rebates or deferrals of concession and land-lease fees (Bulum, 2022).[18] Above that, Member States introduced temporary public service obligations (hereinafter: PSOs) and/or public service contracts (hereinafter: PSCs) to ensure the regular provision of maritime transport services previously provided on a commercial basis that become unavailable or provision of which has become difficult or economically unviable for their providers, due to the COVID-19 related crisis.

According to Article 107/1 State aids on the internal market are, in principle forbidden. Within the meaning of Article 107/1, to be classified as State aid the following conditions relating to the measure in question must be cumulatively fulfilled: (1) the presence of an undertaking/economic activity; (2) the measure must be imputable to the State and financed through State resources; (3) it must confer an advantage on its beneficiary which is selective; and (5) the measure must distort (or threaten to distort) competition and affect trade between Member States.

Pursuant to Article 107/2 b of the Treaty on the Functioning of the European Union (hereinafter: TFEU) State aid granted to make good the damage caused by natural disasters or exceptional occurrences is an exception from the prohibition of State aid under Article 107/1 TFEU. However, the EU legislation does not define the term exceptional occurrence. For that reason, the Commission is making assessments of events case-by-case.

To be qualified as an exceptional occurrence, pursuant to the Commission's decision-making practice the event needs to fulfil the following conditions: 1. It is unforeseeable, or difficult to foresee; 2., It has a significant economic impact, and 3. It is extraordinary, and significantly different from the conditions under which the market is ordinarily functioning.[19]

The Commission first qualified COVID-19 as an exceptional occurrence within the meaning of Article 107/2 TFEU in the case in which it assessed the compensation measures that Denmark awarded to the private legal entities organizing events held in Denmark for the cancellation of these events related to COVID-19 disease.[20]

Consequently, the Commission awarded big amounts of State aid to operators in almost all economic sectors, including transport under the rules prescribed in the Temporary Framework for State aid measures to support the economy in the current COVID-19 outbreak (hereinafter: the TF).[21] In this paper, we analyse the measures that Member States introduced at the time of the COVID-19 pandemic

1. See for example, Odluka o usvajanju programa dodjele državnih potpora sektoru mora, prometa, prometne infrastrukture i povezanim djelatnostima u aktualnoj pandemiji COVID-A 19. Official Gazette of the Republic of Croatia of 3 July 2020 no. 20020(77) - as amended 2020(116), 2021(5), 2021(114), 2021(41), 64/2022(64), 72/2022(72).
2. Commission Decision of 12.3.2020 on the aid scheme State Aid SA.56685 (2020/N) – DK – Compensation scheme for cancellation of events related to COVID-19, Brussels, 12.3.2020 C(2020) 1698 final, paragraph 25.
3. Ibidem, paragraphs 26-30.
4. See, Communication from the Commission, Temporary Framework for State aid measures to support the economy in the current COVID-19 outbreak, adopted on 19 March 2020 (C(2020) 1863) - as amended C(2020) 2215 of 3 April 2020, C(2020) 3156 of 8 May 2020, C(2020) 4509 of 29 June 2020, C(2020) 7127 of 13 October 2020, C(2021) 564 of 28 January 2021, and C(2021) 8442 of 18 November 2021.

concerning the award of public service compensation to the maritime transport operators with whom Member States concluded public service contracts or imposed public service obligations in order to ensure the regular provision of the maritime transport services. Maritime transport services covered by these measures are freight and passenger transport, provided whether as cabotage or transport between two or more Member States or between the EU and a third country. The objective of this paper is to establish under which conditions State aid measures in case of exceptional occurrence, such as COVID-19 do not constitute State aid or can be exempted from the *ex ante* notification to the Commission and a public contract concluded for the provision of the maritime transport services may be prolonged without a new concession award procedure in order to provide regular provision of transport services.

THE PROVISION OF SERVICES OF GENERAL ECONOMIC INTEREST IN THE MARITIME SECTOR

Services provided in the maritime transport sector that the Member States need to protect and support in case of exceptional occurrences in order to provide connectivity across their territories or with other States may be also of economic nature. These are services of general economic interest. In the EU law, the term services of general interest have been used as a European alternative to the term public service which originates from French administrative law. Services of general interest can be economic (services of general economic interest, hereinafter: SGEI), non-economic, and social. Member States have wide discretion when it comes to defining a service as an SGEI and awarding compensation to their provider. The Commission's competence in this regard is limited to assessing whether the Member State has made a manifest error when defining the service as an SGEI and whether State aid is included in the compensation. Where sector-specific EU rules exist, the Member States' discretion is additionally limited by those rules.

As regards maritime transport, sector-specific rules are contained in Regulation 3577/92 on maritime cabotage (Radionov et al, 2011)[22] and in Regulation 4055/86 regulating the provision of international maritime transport services.[23] These Regulations ensure freedom to provide maritime cabotage or international maritime transport services. The imposition of PSO and/or the conclusion of one or several PSCs is allowed by these Regulations but only under the conditions stipulated in these acts. According to Article 4 of Regulation 3577/92 a Member State may conclude PSCs or impose PSOs for the provision of maritime cabotage services, on carriers for the provision of regular transport services to, from, and between islands. When concluding PSCs or imposing PSOs, a Member State should comply with the principle of non-discrimination in respect of all EU shipowners. When it comes to imposing PSOs, Member States are limited only to terms regarding ports to be covered, regularity, continuity, frequency, vessel capacity to provide the service, freight rates to be charged, and manning of the vessel. Compensation for PSOs must be available to all EU shipowners under the same conditions, in the case when it is applicable.

According to Article 6 of Regulation 4055/86, if a Member State's shipping companies are in a situation where they do not have an effective opportunity to ply for trade to and from a third country, the Member State will inform thereof the other Member States and the Commission. The Council on a proposal of the Commission will decide on the necessary measures that may include the

5. Council Regulation (EEC) No 3577/92 of 7 December 1992 applying the principle of freedom to provide sevices to maritime transport within Member States (maritime cabotage), *OJ L 364, 12.12.1992, p. 7–10*.

6. Council Regulation (EEC) No 4055/86 of 22 December 1986 applying the principle of freedom to provide services to maritime transport between Member States and between Member States and third countries, OJ L 378, 31.12.1986.p.1.

negotiation and conclusion of cargo-sharing arrangements. Any measures adopted must be in line with the EU Law and provide for fair, free, and non-discriminatory access to the relevant cargo shares to EU shipping companies**.**

The State aid rules applicable to public service compensation for the provision of SGEI steam from the *Altmark j*udgment,[24] which introduced four cumulative conditions under which the existence of State aid may be excluded because it is presumed that support that fulfills so-called *Altmark* conditions is not selective.

Public service compensation granted for the purpose of performance of SGEI can be classified as: 1. Constituting no State aid, 2. The aid which is exempted from notification to the Commission or 3. Aid that must be notified to the Commission.

In a document titled *Overview of the State aid rules and Public Service rules applicable to the maritime sector during the COVID-19 pandemic* (hereinafter: Working document),[25] prepared by the services of the European Commission for information purposes the Commission gave its guidance on the above-mentioned matters.

This paper is dedicated to the analysis of the application of *Altmark* criteria in the maritime transport sector. When these criteria are fulfilled, there is a legal presumption that the public service compensation awarded for the provision of SGEI includes no aid and, therefore, no formal notification of aid to the Commission is required.

CASES WHEN PUBLIC SERVICE COMPENSATION FOR THE SGEI PROVIDED IN THE MARITIME SECTOR INCLUDES NO STATE AID – APPLICATION OF *ALTMARK* CRITERIA

The distinction is made depending on whether on the line in question, there was PSO for the provision of SGEI imposed, one or more PSCs concluded before the COVID-19 outbreak, or whether a such line was operated on a commercial basis. In the Working document, the Commission gave its interpretation on the application of *Altmark c*riteria to the public service compensation granted for the provision of basic port services and maritime transport services.[26] When these conditions are fulfilled, it is presumed that the advantage for the provider of the SGEI and, consequently State aid may be excluded. For that reason, notification of compensation to the Commission's Directorate General for Competition is not necessary. Member States self-estimate case-by-case whether the future measure is in the line with the *Altmark* conditions.

For new PSCs, under the first *Altmark* criterion which introduces the obligation of the definition of the scope of the public service the Commission in the Working document obliges the Member States to define the essential lines or essential port services that need to be maintained in order to safeguard the provision of transport or port service (not the specific operators of these services). Above that, the Member States need to specify the minimum required frequency and volumes or in the case of port infrastructure, (the quantity and quality of services that need to be protected). Also,

7. See, Judgment of the Court of 24 July 2003, Altmark Trans GmbH and Regierungspräsidium Magdeburg v Nahverkehrsgesellschaft Altmark GmbH, C-280/00, EU:C:2003:415, paragraphs 88 - 93.
8. Overview of the State aid rules and Public Service rules applicable to the maritime sector during the COVID-19 pandemic – Update March 2021, available at: https://competition-policy.ec.europa.eu/system/files/2021-05/maritime_transport_update_March_2021.pdf
9. See, Working document, point 2.3.

the Member States need to demonstrate the necessity of the measure in question by proving that there has been a serious and unpredictable decrease in passenger and/or freight demand and that losses of income make the provision of the service no longer economically viable for the shipper.

In case more than one operator provided transport services on the same line on a commercial basis before COVID-19, Member States should conclude a PSC that does not distort competition. The proportion of the service entrusted to the selected operator could be determined on the basis of the market share of that operator before the beginning of the outbreak. In the Working document is also emphasized that the so-called “exclusive emergency PSO” in favor of a single operator should not be used in situations where there are other operators on the market already, and where the EU public procurement rules applicable in case of emergency contain the rules for the award of a PSC through a competitive procedure. In addition to that, every emergency COVID-19 contract must be limited in time and may be prolonged only once for a period of three months maximum. The Member States must inform the Commission every three months about the emergency PSCs in place and submit data on the traffic volumes. Passenger and/or freight demand increase can be proof that the further prolongation of an emergency PSC is not justified.

The second *Altmark* criterion also introduces the obligation of establishing the parameters on the basis of which the compensation is calculated in advance and in an objective and transparent manner. According to the Commission Working document, if the maritime transport services were operated on a commercial basis before the COVID-19 pandemic, the compensation parameters for each route should be based on profit and loss accounts submitted for the following periods: the last two months before the outbreak of the COVID-19 pandemic (January and February of 2020) and/or corresponding months of 2019 (for example, June to October of 2019 if the PSCs was concluded for the period from June to October of 2020). The eligible costs are determined on the basis of average costs reported for one month in the above-mentioned profit and loss accounts. Consequently, the Commission considers that the public service compensation should not exceed the difference between the average incomes and average costs, during the selected months before the COVID-19 outbreak.

Many Member States didn’t include any profit in the public service compensation awarded during the COVID-19 pandemic. This is in the accordance with EU State aid rules. However, according to the Commissions Working document Member States may decide to award a reasonable profit to the shipping companies providing public services during exceptional occurrences, such as the COVID-19 pandemic.

To avoid overcompensation, the level of profit should correspond to the level of profit of shipping companies commercially active on similar maritime routes in the Member States before the COVID-19 outbreak. This is in the line with the third *Altmark* criterion according to which the compensation must not exceed what is necessary to cover all costs of the public service provision, also including a reasonable profit. Additionally, a so-called “claw-back mechanism” should be established that allows Member States to assess ex post the possible overcompensation and have the return of the surplus.[27]

The fourth *Altmark* criterion prescribes that when the undertaking that performs public service obligations, is not selected under a public procurement procedure that would provide the selection of the tenderer able to provide those services at the least cost to the community. The level of public service compensation must be determined on the basis of the costs that a typical undertaking, well-run and provided with the relevant means, would have made. To comply with the above-mentioned

10. Ibidem.

criterion, Member States are obliged to: (a) select the maritime operator under public procurement procedure rules, or (b) directly award the PSC while granting the compensation on the basis of the costs of the above-mentioned typical undertaking. Member States may self-assess the fulfillment of these criteria, considering the circumstances in the market caused by the exceptional occurrence.

When it comes to the existing PSCs the Member States need to establish that the initially concluded contracts cover the services necessary in the context of the exceptional occurrence, COVID-19 and that there is no overcompensation. A direct award of an emergency PSO to shipping companies or port service provider in difficulties is it is not allowed. The same principle is applicable in the case of the State aid awarded under the TF (Bulum, 2022). Under Article 43/1 of Directive 2014/23/EU[28] and Article 72/1 of Directive 2014/24/EU,[29] existing contracts may be modified without a new procurement procedure when all the conditions prescribed by these Directives are fulfilled.

PROCEDURES AND DEADLINES UNDER THE EU PUBLIC PROCUREMENT RULES IN CASES OF URGENCY

Where the PSC in question has the form of service contracts the rules of Directive 2014/24/EU are applicable. Articles 26 to 32 of this Directive provide for different procedures depending on the specific characteristics of the case, including its urgency. When it comes to the application of the emergency public procurement procedures it is useful to consult the Commission Communication - Guidance from the European Commission on using the public procurement framework in the emergency situation related to the COVID-19 crisis (hereinafter: Communication on the public procurement in the emergency situation related to the COVID-19).[30] In Section 2 of the Communication on the public procurement in the emergency situation related to the COVID-19 the use of reduced deadlines to accelerate open or restricted procedures for the conclusion of a PSC has been explained.

According to Article 26/2 of the Directive 2014/24/EU the contracting authority can award the contract under an open or a restricted procedure. For open procedures a deadline of 35 days for the submission of tenders is applicable. In the case of restricted procedures, the Directive prescribes a deadline of 30 days for the submission of requests to participate, and an additional deadline of 30 days for the presentation of tenders. In cases of urgency, Directive 2014/24/EU allows a reduction of these deadlines; under the open procedure, the deadline for the submission of tenders may be shortened to 15 days, and under the restricted procedure, the deadline to submit a request for participation may be shortened to 15 days and to submit an offer to 10 days. In that way, the application of principles of equal treatment, transparency, and competition, even in cases of urgency has been ensured.[31]

In case of extreme urgency competent national bodies are allowed to start a negotiated procedure without prior publication under conditions prescribed by Article 32/2(c) of the Directive 2014/24/EU: "...insofar as is strictly necessary where, for reasons of extreme urgency brought about by events unforeseeable by the contracting authority, the time limits for the open or restricted procedures or competitive procedures with negotiation cannot be complied with. The circumstances invoked to

11. Directive 2014/23/EU of the European Parliament and of the Council of 26 February 2014 on the award of concession contracts, OJ L 94, 28.3.2014, p. 1.
12. Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC, OJ L 94 of 28.3.2014, p. 65.
13. Communication from the Commission: Guidance from the European Commission on using the public procurement framework in the emergency situation related to the COVID-19 crisis, OJ C 108I, 1.4.2020, p. 1.
14. See point 2.2. of the Communication on the public procurement in the emergency situation related to the COVID-19.

justify extreme urgency shall not, in any event, be attributable to the contracting authority." These conditions must be fulfilled cumulatively and interpreted restrictively.[32] From the Commission's decision-making practice steams that cases of extreme urgency have been rare. For that reason, the Commission in the Working paper suggests the Member States use open tender procedures always, even if of reduced duration for the award of a service and concession contract.

In addition to that Directive 2014/23 on the award of concession contracts does not foresee negotiated procedures without prior publication in any case. Consequently, when the PSC has the form of a concession and an emergency occurs, it is not allowed to award concessions contracts under Directive 2014/23 without the publication of a concession notice. Because of that, the Commission in the Working document invites Member States to conclude PSC on the basis of a service contract under Directive 2014/24/EU.[33]

CONCLUSION

Besides a series of State aid measures to support maritime operators, especially shipping companies and port operators because of the consequences of the COVID-19 pandemic the Member States have introduced temporary PSOs and/or PSCs to ensure the regular provision of maritime transport services previously provided on a commercial basis that become unavailable or provision of which has become difficult or economically unviable for their providers.

In the paper, we discuss the application of *Altmark* criteria in the maritime transport sector. When these criteria are fulfilled, there is a legal presumption that public service compensation includes no aid and, therefore no formal notification of aid to the Commission is required. We also analyse the Communication on public procurement in the case of emergency related to COVID-19 and relevant provisions of Directive 2014/24/EU in which the use of reduced deadlines to accelerate open or restricted procedures for the conclusion of a PSC has been regulated and also situations when negotiated procedure without prior publication is allowed.

The guidance that the European Commission gave in its Communication on public procurement in the case of emergency related to COVID-19 and in the Working document is very important because it can be used as a model in case of other exceptional occurrences when the provision of maritime transport services is interrupted or becomes difficult for their providers.

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15. Ibidem, point 2.3.
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The Salient Features of the Inchmaree Marine Insurance Clauses

Adriana Vincenca Padovan

An “Inchmaree Clause” is a special contractual clause contained in the standard hull and machinery insurance clauses of the London insurance market. It includes risks that are not directly related to the perils of the sea. Thus, for example, damages or losses occurring because of a broken shaft, bursting of boilers, a latent defect in the hull, equipment, or machinery, as well as those resulting from a navigation error, negligence of the master, officer, crew, or pilot etc., are included under the insurance coverage by virtue of such a clause. This type of standard marine insurance clause was named after a ship called “Inchmaree” involved in an English court case – Thames & Mersey Marine Insurance Co Ltd v Hamilton, Fraser & Co. (“The Inchmaree”) of 1887, in which the court ruled that damage to a ship's pump due to the accidental jamming of a vent was not due to any of the marine risks or other *eiusdem generis* risks covered by the standard hull and machinery insurance policy and was therefore not indemnifiable thereunder. Thus, it became obvious that there are numerous risks that the insured ships are exposed to during navigation, which are not covered by a standard hull and machinery insurance policy. The London insurance market reacted to such a development of law and incorporated a new, so-called “Inchmaree Clause” into the standard Institute hull insurance clauses. The content of the clause has changed over time with the introduction of new risks under insurance coverage. The aim of this paper is to analyse the background and purpose of the “Inchmaree” clauses contained in the broadly used standard insurance clauses and to study their salient features. Given that the clause was originally created in the English legal framework, the study entails an analysis of the relevant English case law, statutory law, and legal doctrine. The paper also discusses the legal issues related to the possible application of those or similar clauses in the context of marine insurance contracts governed by Croatian law. A short comparison is made to the corresponding solutions found in the Nordic Marine Insurance Plan.

KEY WORDS

Marine insurance, Institute Time Clauses – Hulls, International Hull Clauses 2003, Inchmaree Clause, Crew negligence, Machinery damage.

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INTRODUCTION

The so-called "Inchmaree" clauses are special contractual clauses commonly contained in the broadly used standard marine hull insurance clauses designed by the international insurance markets. The standard "Inchmaree Clause" was originally created by the London insurance market. Since then, it has been incorporated in the various revisions of the standard Institute Hull Insurance clauses designed by the Institute of London Underwriters, and most recently in the International Hull Clauses (1/11/2003) created by the International Underwriting Association of London.[34] It should be noted that because of the global role of the London marine insurance market, its standard marine insurance clauses have been most frequently used in practice worldwide. Their global impact is also evident in the fact that various other international, regional and national insurance markets designed their own standard insurance clauses greatly reflecting the broadly recognized solutions originally incorporated in the insurance clauses of the London market.[35] In this way, the "Inchmaree Clause" and its variants reached many insurance markets worldwide. Today such a clause with more or fewer modifications can be found in most marine hull insurance contracts that are subject to various national legal systems. Bearing in mind that the "Inchmaree Clause" was originally designed in the framework of English law and practice, in this paper we analyse the relevant English case law, statutory law, and legal doctrine, but we also discuss the legal issues related to the possible application of those or similar clauses in the context of marine insurance contracts governed by Croatian law. A short comparison is made to the corresponding solutions found in the Nordic Marine Insurance Plan.

GENERALLY ON THE INCHMAREE CLAUSE

The "Inchmaree Clause" is a special contractual clause contained in the standard Institute Clauses and International Marine Insurance Clauses for the insurance of ships.[36] The clause covers the risks that are not directly related to the perils of the sea[37]. For example, based on this clause, the insurance covers loss or damage resulting from breakage of a shaft, bursting of boilers, latent defect in the hull or machinery, error in navigation, negligence of the master, officers, crew, or pilot, negligence of

[34] The Institute of London Underwriters, established in 1884, was a trade association for insurance companies specialising in marine and aviation insurance business. The International Underwriting Association of London was established in 1999 when the Institute of London Underwriters merged with the London Insurance and Reinsurance Market Association which was the trade association representing the non-marine insurance companies. For more about the history of the Institute of London Underwriters and the International Underwriting Association of London see http://www.ilu.org.uk/ and https://www.iua.co.uk/ (access: 8 February 2023).

[35] For more on the global role and impact of the London marine insurance market and its standard marine insurance clauses see UNCTAD, *Marine Insurance – Legal and Documentary Aspects of the Marine Insurance Contract*, UNCTAD document TD/B/C14/ISL/27, November 1978, https://digitallibrary.un.org/record/8301 (access: 8 February 2023). See also Geoffrey N. Hudson, Tim Madge, Keith Sturges, *Marine Insurance Clauses*, 5th Edition, Chapter I: Introduction to the Fifth Edition, Informa Law from Routledge, Abingdon, 2012.

[36] See Institute Time Clauses Hulls 1/10/1983 (hereinafter: ITCH 1983) and 1/11/1995 (hereinafter: ITCH 1995), cl. 6.2. and International Hull Clauses 1/11/2003 (hereinafter: IHC 2003), cl. 2.2.

[37] According to the Rules for Construction of Policy, i.e. Schedule I to the UK Marine Insurance Act 1906 as amended, the term "perils of the seas" refers only to fortuitous casualties or accidents of the seas. It does not include the ordinary action of the winds and waves. As explained by Hudson and Madge, there is no complete definition of the expression. The word peril indicates that something accidental and fortuitous is envisaged; the term only covers accidents that may happen, not events that must happen. The term does not cover every accident or casualty which may happen on the sea. It must be a peril coming from the sea. The term includes marine casualties such as sinking, foundering, stranding, collision, and every variety of damage at sea directly attributable to the violent and immediate action of wind or waves. It does not cover any loss or damage directly referrable to neglect on the part of the shipowner or his servants. See Geoffrey N. Hudson, Tim Madge, *Marine Insurance Clauses*, 4th Edition, Chapter III: Marine Hull Forms, Informa Law, London, 2005. See also René de Kerchove, *International Maritime Dictionary*, 2nd Edition, Van Nostrand Reinhold Company, New York / Cincinnati / Toronto / London / Melbourne, 1983, pp. 577-578.

repairers or charterers, etc. The clause was named after a ship and case decided by the UK House of Lords – *Thames & Mersey Marine Insurance Co Ltd v. Hamilton, Fraser & Co.* (*The Inchmaree*) (1887) 12 AC 484, HL.[38] In this case, the House of Lords held that damage to the ship's small auxiliary engine caused by mismanagement on the part of the crew was not a consequence of a peril of the sea or any other maritime peril of a similar kind covered by the hull insurance policy and that therefore it was not recoverable under the insurance policy.[39] Consequently, it became evident that numerous risks the ships were exposed to during navigation were not covered under standard marine hull insurance policies.[40]

The market responded to such development of law and incorporated a new clause in the standard Institute Clauses for the insurance of ships commonly referred to as the "Inchmaree Clause". The content of the clause has evolved through time as new risks have been included therein.[41]

DUE DILIGENCE PROVISO

Because of the nature of the risks covered by the "Inchmaree Clause", especially as regards bursting of boilers, breakage of shaft, latent defect in the hull or machinery, negligence of the master, officers or crew,[42] "Inchmaree Clause" might embrace claims that in effect are a consequence of insufficient maintenance, inadequate crew management, or generally substandard management in the operation of a ship. To eliminate such claims from the coverage, the insurance market added a special condition into this clause based on which the insurer's obligation under the insurance contract is excluded if damage or loss resulted from want of due diligence of the insured, or one of the relevant persons expressly listed in the clause.[43]

According to ITCH 1983, the range of relevant persons includes the insured, owners, and managers of the ship, whereas the term owner is interpreted to include the shipowner and the bareboat charterer. The range of relevant persons was extended in ITCH 1995, whereby the due diligence proviso applies to the insured, owners, managers, or superintendents or any of their onshore management. The aim

[38] The steamship called "Inchmaree" in this particular case was insured by Lloyd's S.G. Policy. According to the terms of the policy the ship was insured against a number of named perils (perils of the sea, war, fire, restraint of princes, thieves, pirates, jettison, barratry, general average acts, arrests, of kings, princes, and people) or "all other perils, losses and misfortunes…". In accordance with the so-called *eiusdem generis* rule for construction of marine insurance policies (Rule no. 12 from Schedule I to the UK Marine Insurance Act 1906), reference to "all other perils…" contained in the standard marine insurance policies means perils that are similar in kind to the perils specifically mentioned in the policy. See Geoffrey N. Hudson; Tim Madge, *Marine Insurance Clauses*, 4th Edition, Chapter III: Marine Hull Forms, Part 1: Principal Insuring Conditions, Informa Law, London, 2005.
For clarification purposes, it is noted that Lloyd's S.G. Policy is a standard marine insurance policy form that was traditionally used until 1983 on the London insurance market. It was originally designed to cover both ship and cargo during a particular voyage under a single insurance contract. S.G. stands for "Ship and Goods". It was officially adopted by Lloyd's in 1779. It forms Schedule I to the UK Marine Insurance Act 1906. A salient feature of this policy form was that, unlike the new marine insurance policy (MAR) used with the Institute Clauses, it contained the insuring terms and conditions. See Drago Pavić, *Ugovorno pravo osiguranja*, Tectus, Zagreb, 2009, p. 420.

[39] Francis D. Rose, *Marine Insurance: Law and Practice*, LLP, London, 2004, p. 258. See also Drago Pavić, *Pomorsko osiguranje: Pravo i praksa*, Književni krug Split, 2012., p. 353.

[40] Drago Pavić, *Pomorsko osiguranje: Knjiga druga*, Croatia osiguranje d.d., Zagreb,1994, p 102.

[41] *Ibidem*. See also Donald R. O'May, Marine Insurance Law: Can the Lawyers be Trusted?, The Institute of Maritime Law Fourth Annual Lecture, *Lloyd's Maritime and Commercial Law Quarterly* [1987] 29, pp. 29 – 30.

[42] For a more detailed discussion on each individual insured peril included in the "Inchmaree Clause" see Howard Bennet, *The Law of Marine Insurance*, 2nd Edition, Oxford University Press, Oxford, 2006, pp. 366 – 392. For more details about the latent defect as an insured risk see Ralph De Wit, A Comparative Review of Recent Developments in the Concepts of Inherent Vice and Latent Defect in Marine Insurance Policies, *Marine Insurance at the Turn of the Millennium*, Volume 1, Marc Huybrechts; Eric Van Hooydonk; Christian Dieryck (Eds.), Intersentia, Antwerpen / Groningen / Oxford, 1999, pp. 51 – 69.; see also Zlatko Ćesić, Skrivena mana u strojevima ili trupu broda kao osigurani rizik, *Hrvatska pravna revija*, Vol. 4 (2004), No. 3, pp. 13 – 18.

[43] Howard Bennet, *The Law of Marine Insurance*, *op. cit.* p. 590.

was to include the lower level of management in the due diligence proviso in order to involve the persons to whom the duty of ship maintenance is directly delegated. However, such a solution turned out to be commercially undesirable and was one of the reasons why ITCH 1995 has never reached wider acceptance. IHC 2003, therefore, reassumed the variant adopted in ITCH 1983.[44] IHC 2003, however, have never received any substantial degree of acceptance. According to Hudson, Madge and Sturges, shipowners are traditionally conservative and cautious in respect of marine insurance, so even today the most preferred standard hull insurance clauses are the ITCH 1983 and the American Institute Hill Clauses of 2 June 1977.[45] This is a clear example of how marine insurers tend to promote a higher level of quality standard in shipping, in their own commercial interest of claims prevention, but also in the public interest of prevention of marine accidents, however, in that they are limited by the demands of the shipping market.[46]

Under English law, there is no relevant case law that would more precisely clarify what exactly is understood by the term "want of due diligence" in the context of an "Inchmaree Clause". The question is whether that term is different from the term "negligence" and how the burden of proof regarding such want of due diligence is distributed amongst the parties to the insurance contract.[47]

The term "due diligence" under English maritime law is used in the context of carriage of goods by sea. According to the Hague-Visby Rules, 1968, the carrier is under an obligation before and at the beginning of the voyage to exercise due dilligence to ensure that the ship is seaworthy, that it has a sufficient number of capable crew members, that it is adequately equipped, that it has sufficient stores, and that it is able to receive, preserve and transport the cargo safely to the agreed destination. In common law, this meaning of due diligence corresponds to the standard of due care, and therefore, want of due diligence or lack of due diligence corresponds to the standard of ordinary negligence.[48]

Thus, in the context of marine insurance, and specifically, in the context of an "Inchmaree Clause", want of due diligence means a lack of a reasonable degree of care to take all that is necessary, in other words, what a prudent insured, shipowner or manager would do in that capacity. Furthermore, the master, crew, and pilot, do not fall within the range of persons whose negligence or lack of due care is equated with the lack of due diligence of the insured, owner or manager.[49] Moreover, negligence of the master, crew, or pilot in connection with the performance of their professional duties is a risk covered by the "Inchmaree Clause", so the insured has the right to claim insurance indemnity for damage or loss caused by the negligence of these persons (master, crew, pilot), provided that this damage was not caused by personal negligence of the insured (shipowner or manager). The same goes for the negligence of the shiprepairer and charterer, which as well is a risk covered by the "Inchmaree Clause", provided that the shiprepairer or the charterer is not also the insured under the policy.[50]

Judging from the formulation of the due diligence in the "Inchmaree clause", one could argue that the burden of proof of the existence of due diligence of the insured, owners, and managers rests on the insured party. However, as Rose points out, proof of due diligence becomes necessary for

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[44] *Ibidem*.
[45] Geoffrey N. Hudson, Tim Madge, Keith Sturges, *Marine Insurance Clauses*, 5th Edition, Chapter I: Introduction to the Fifth Edition, 1. Whatever Happened to the Quiet Revolution?, Informa Law from Routledge, Abingdon, 2012.
[46] For more about the role of marine insurance in the prevention of marine accidents see Adriana V. Padovan, *Uloga pomorskog osiguranja u zaštiti morskog okoliša od onečišćenja s brodova*, Croatian Academy of Sciences and Arts, Zagreb, 2012, pp. 13 – 212. Especially on the "Inchmaree Clause" and due diligence of the insured see pp. 175 – 180.
[47] Francis D. Rose, *Marine Insurance: Law and Practice*, *op.cit.,* p. 258.
[48] *Ibidem*.
[49] See ITCH 1983 and ITCH 1995, cl. 6.2.3; IHC 2003, cl. 2.2.3.
[50] Francis D. Rose, *Marine Insurance: Law and Practice*, *op. cit*., p. 258.

obtaining insurance indemnity only if the insurer establishes *prima facie* negligence of the insured, owners, or managers of the insured ship. Only then must the insured prove the existence of due diligence, and only to the extent necessary to rebut the insurer's *prima facie* proof. This approach is analogous to the legal relationships arising from the carriage of goods by sea.[51]

BURSTING OF BOILERS, BREAKAGE OF A SHAFT AND LATENT DEFECT

More should be said about the risk of bursting of boilers, breakage of a shaft, or latent defect in the hull or machinery. This risk in itself also represents a loss or damage, unlike the other risks covered by the "Inchmaree Clause". However, insurance covers only damage or loss consequential to that risk, in other words, insurance covers only damage or loss caused by the risk of bursting of boilers, breakage of shaft or latent defect in the hull or machinery. For example, in case the shaft breaks due to an inherent defect and there is no consequential damage resulting from that breakage, the insured cannot claim any insurance indemnity because hull insurance does not cover the cost of replacing or repairing the broken shaft.[52] In contrast, if the ship's hull were damaged due to a fall caused by the breaking of a defective ship's crane, the insured would have the right to insurance indemnity for the resulting damage to the ship's hull.[53]

When interpreting the "Inchmaree Clause", however, two exclusions envisaged under the UK Marine Insurance Act 1906 (hereinafter: MIA 1906) must be kept in mind. Section 55 (2) (c) of the MIA 1906 prescribes that insurance does not cover ordinary wear and tear, ordinary breakage, inherent vice, or any injury to machinery not proximately caused by maritime perils. The respective statutory provisions are dispositive in nature, meaning that parties are free to alter or modify them by contracting different conditions. In particular, as regards machinery damage, this exclusion is partially modified by the inclusion of the risk of a latent defect, bursting of boilers, and breakage of shafts in the standard "Inchmaree Clause". When it comes to damage caused by a latent defect in the hull or machinery, based on the "Inchmaree Clause" it is recoverable from insurance even if the defect becomes apparent through ordinary wear and tear (for example, if a defective part through ordinary wear and tear causes material fatigue a significant period of time before the end of the life of the ship).[54]

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[51] *Ibid*., p. 259.

[52] See ITCH 1983, cl. 6.2.1. However, this part of the "Inchmaree Clause" has been modified in IHC 2003 (see cl. 2.3 in connection with cl. 2.2.1 and cl. 2.4 in connection with cl. 2.2.2).

[53] Francis D. Rose, *Marine Insurance: Law and Practice, op. cit*., p. 262. A thorough analysis of the distinction between the latent defect and the consequential damage is given in the *Promet Engineering (Singapore) Pte Ltd v. Sturge (The Nukila)* [1997] 2 Lloyd's Rep. 146. In this case involving a mobile accommodation and work platform insured under the terms of Institute Time Clauses - Hull, the 1st instance court held that the plaintiffs could not recover under the "Inchmaree Clause" because "all that had happened had been that a latent defect had become patent; to recover, they had to establish that a latent defect had caused some damage to the vessel." Court of Appeal overruled the 1st instance judgment and held that at the commencement of the insurance period, "there had been a latent defect in the welds that had already given rise to minute fatigue cracks in the surface of the legs of the platform that could also be described as latent defects. These latent defects had caused fractures in the full thickness of the metal of the legs… and these fractures constituted damage to the hull… of the vessel. The plaintiffs were therefore entitled to recover." The court held that for the purposes of the "Inchmaree Clause" the distinction between "latent defect" and "damage" could be one of degree. See Charles Mitchell, English Insurance Decisions 1997, *Lloyd's Maritime and Commercial Law Quarterly* [1998] 411, pp. 413-414.

[54] Francis D. Rose, *Marine Insurance: Law and Practice, op. cit.,* p. 263. In *the Caribbean Sea* case of 1980, the ship was insured under a hull policy that incorporated American Institute Hull Clauses containing the standard "Inchmaree Clause" covering loss of or damage to the ship directly caused by any latent defect in the machinery or hull, negligence of masters, officers, crew or pilots, provided such loss or damage has not resulted from want of due diligence by the insured, the owners or managers of the ship or any of them. The ship sank due to the entry of sea water into the engine room. The insured owners claimed total loss from the insurers on the grounds that (a) the loss was caused by the grounding which damaged the machinery which in due course resulted in failure of that part and the entry of sea water (b) alternatively that such failure was caused by a fatigue crack or cracks and that the loss was caused by a latent defect of the hull; and (c) the loss was a

Especially problematic is the potential clash of legal consequences related to unseaworthiness and insurance coverage provided under the "Inchmaree Clause". In particular, unseaworthiness may lead to a loss or damage which is covered under the "Inchmaree Clause". For example, a latent defect in the ship's hull or machinery may lead to unseaworthiness. A shaft may break, or a boiler may burst, because they were not reasonably fit to sustain the ordinary perils of a marine adventure, which would render the insured ship unseaworthy. The issue that follows is whether there is a clash between the insurance coverage provided under the "Inchmaree Clause" and the legal consequences of unseaworthiness that arise *ipso iure* in accordance with MIA 1906 (s. 39). Furthermore, if there is a clash, the question is which provisions shall prevail.[55]

In the case of *the Lydia Flag*[56] the English court interpreted the provisions of the "Inchmaree Clause" as exceptions to the expressly agreed suspensive condition of seaworthiness at the inception of insurance coverage and of due diligence in the maintenance of seaworthiness throughout the insurance period. Otherwise, if such a suspensive condition were to have priority over the "Inchmaree Clause", the result would be a significant reduction of the coverage otherwise provided by the relevant provisions of the "Inchmaree Clause" which expressly include in the coverage the risk of a latent defect, breakage of a shaft, bursting of boilers, negligence of the master, officers, crew, and pilot, etc. Such an interpretation would simply be commercially nonsensical.[57]

The same goes for the relationship between the implied warranty of seaworthiness contained in the voyage hull insurance policy based on MIA 1906 s. 39 (1) and the express contractual provisions of the "Inchmaree Clause". If the implied warranty of seaworthiness were to prevail over the express provisions of the "Inchmaree Clause", then the relevant provisions of the "Inchmaree clause" would be largely without effect. For example, insurance coverage for latent defects would be limited only to those defects that would arise after the commencement of the voyage, or which would be so small that they would not be likely to develop during the insured voyage and would not constitute a breach of the warranty of the ship's seaworthiness. We agree with Bennett stating that such an interpretation would be simply wrong.[58]

In the context of time hull insurance policies, the conflict of the provisions of the "Inchmaree Clause" and the legal consequences of unseaworthiness is unlikely. This follows from the fact that the insured's privity of unseaworthiness which is necessary for the insurer's defence to be sustained is incompatible with the risk of a latent defect. Besides, the coverage based on the "Inchmaree Clause" is subject to a due diligence proviso relating to the insured, owners and managers. For example, if the insured is aware of the possibility of the imminent breaking of the shaft and the ship has set sail, then it is likely that the damage caused by such an event is the result of the insured's lack of due diligence. Consequently, in accordance with the "Inchmaree Clause" the resulting damage or loss

result of the negligence of the master and crew in the navigation of the vessel, the negligence relating to the grounding of the vessel. It follows that the insured owners relied on the coverage provided under the "Inchmaree Clause". The insurers declined their liability under the insurance contract relying on a defence that cracks that caused the entry of sea water in the machinery room resulted from ordinary wear and tear which is excluded from insurance under MIA 1906 (s. 55(2)(c)). The English court held that "the casualty here was not simply attributable to ordinary wear and tear in that the defect upon which the owners relied consisted of the fatigue cracks ... which were attributed to two factors, (a) the manner in which the vessel was designed and (b) the effect ... of the ordinary working of the vessel ...; the result of this combination was that the fracture opened up a significant period of time before the end of the life of the vessel and therefore recovery for loss of the vessel consequent upon such a fracture was not excluded by [MIA 1906] s. 55(2)(c) ...; and the defect constituted a latent defect." See *Prudent Tankers Ltd SA v. Dominion Ins Co (the Caribbean Sea)* [1980] 1 Lloyd's Rep. 338, p. 338.

[55] Howard Bennett, *The Law of Marine Insurance*, *op. cit.,* p. 587.

[56] *Martin Maritime Ltd v Provident Capital Indemnity Fund Ltd (The Lydia Flag)* [1998] 2 Lloyd's Rep 652.

[57] Howard Bennett, *The Law of Marine Insurance*, *op. cit.,* p. 587. See also Jonathan C. B. Gilman *et al.*, *Arnould's Law of Marine Insurance and Average*, 17th Edition, Sweet & Maxwell, London, 2008, pp. 863 – 864.

[58] *Ibidem*.

would not be recoverable from the insurance policy. A conflict could possibly arise in an emergency situation where the shipowner would have to order the ship to sail in order to avoid or minimise damage or loss, knowing that the ship is not fully seaworthy. If in such a case damage would occur due to unseaworthiness, the insured would not be entitled to insurance indemnity. Namely, even if such damage were covered by the "Inchmaree Clause", and the insured could not be accused of negligence, the damage would still not be recoverable from the insurance policy because it was caused by unseaworthiness that the insured was privy of. This is in accordance with MIA 1906 s. 39(5).[59]

CROATIAN LAW PERSPECTIVE

The local marine insurance market in Croatia has traditionally been under the strong influence of the London marine insurance market. The influence of the English marine insurance law can be seen in the fact that standard English marine insurance clauses are frequently used on the local market, but also the standard marine insurance terms and conditions of the local insurance companies often follow similar solutions found in the standard English insurance clauses. Finally, the influence can even be seen in the regulatory solutions adopted in the Croatian Maritime Code (hereinafter: MC)[60] that regulates the contract of marine insurance (Arts. 684 – 747.d).[61]

In the context of this paper, it is important to mention the provisions of MC Art. 704 on insured risks and Arts. 708 and 729 on the exclusions from the coverage.

According to MC Art. 704 unless otherwise specified in the insurance contract, marine insurance covers the risks to which the ship is exposed during navigation (marine accident, natural disaster, explosion, fire and robbery). The parties to the insurance contract can also agree to include other risks, such as theft and non-delivery, manipulative risks, land transport risks, war and political risks, strikes, etc. It follows that the so-called "Inchmaree" risks are not included in the list of named perils provided by the law itself, but the parties are free to include them in the insurance contract.

Art. 708 para. (1) provides that damage or loss caused by the insured's intentional act is excluded from insurance. This is mandatory law (*ius cogens*) and cannot be modified by a contractual provision. Further exclusions relate to the insured's gross negligence, deliberate action, or gross negligence of persons for whose actions, according to the law itself, the insured is responsible (MC Art. 708 para. (2)). The latter exclusion does not apply to the master, officers and crew nor does it apply to damages caused by an act or omission of the insured when that person is also the master, or a crew member or pilot, and the negligent act or omission is made in navigation and operation of the ship. Finally, Art. 729 paras. (1) and (2) provide for the exclusion of damages caused directly or indirectly due to the ship's unseaworthiness of which the insured was aware. The latter exclusions are dispositive and can be modified by contractual provisions, including the possibility of contracting the standard "Inchmaree Clause" or similar. It follows that the effect of the "Inchmaree Clause" incorporated in a marine insurance contract that is subject to Croatian law would be the same or very similar as in the case of a marine insurance contract subject to English law. It is therefore submitted that when interpreting the specific effects of the standard "Inchmaree Clause" in the context of Croatian marine insurance law, attention should be paid to the well-established English case law, because of the power of its persuasiveness and authority, although it cannot be recognized by a Croatian court as an official source of law. The relevant English case law should be taken into account as a secondary

[59] *Ibidem*.
[60] Maritime Code of the Republic of Croatia, *Official Gazette* no. 181/04, 76/07, 146/08, 61/11, 56/13, 26/15, 17/19.
[61] For a more detailed review of the background to the issue of the influence of English marine insurance law and practice on the local Croatian marine insurance market see Drago Pavić, *Ugovorno pravo osiguranja, op. cit.*, pp. 25 – 33, 117 – 119.

source for the interpretation of the standard “Inchmaree Clause” in the interest of a harmonised interpretation of the broadly used standard insurance clauses and legal certainty and predictability.

NORDIC MARINE INSURANCE PLAN

The standard hull insurance terms and conditions of the Nordic market[62] contained in Part Two of the Nordic Marine Insurance Plan[63] (hereinafter: NMIP) have a different approach, because they are based on the concept of the so-called “all risk” coverage. Nevertheless, the final outcome is still very similar to the effect of the English clauses that, on the other hand, are based on the concept of named perils, as discussed above.

NMIP expressly states the exclusions from the coverage, such as damage or loss caused by inadequate maintenance, ordinary wear and tear, corrosion etc. Namely, according to NMIP, insurance does not cover the costs of replacement or repair of a part or parts of the hull, machinery or equipment that are in a defective condition due to the said expressly listed causes (NMIP, cl. 12-3). The clause does not refer to any potential fault of the insured or other persons, it simply lists the excluded risks (corrosion, lack of maintenance, ordinary wear and tear and the like). As soon as it is established that a part of the insured ship or its equipment is in a defective condition due to one of the excluded risks, the insurer is not liable for costs incurred in renewing or repairing that part or parts, even if those are affected by a larger damage to the ship otherwise caused by an insured risk.[64] However, any eventual consequential loss or damage caused by such a defective part is not excluded from the insurance coverage, except in the case of a total loss or constructive total loss.[65] Therefore, like in the case of insurance coverage under the “Inchmaree Clause”, insurance does not cover the replacement or repair of a defective part, but it covers the consequential loss or damage caused by the defective condition. Unlike the “Inchmaree Clause”, the coverage under NMIP is not subject to any due diligence proviso, but the insurer may rely on the exclusion of damage or loss caused by the breach of any of the safety regulations[66] (NMIP, cl. 3-22 and 3-25). Accordingly, insurance does not cover damage or loss resulting from inappropriate maintenance and failure to meet the minimum acceptable safety standard. Thereby, inappropriate maintenance should be interpreted in accordance with the ISM Code, the rules and recommendations of the classification society, and the manuals and instructions of the manufacturer. In a particular case, when the insurer relies on a defence of the breach of a safety regulation, to succeed in claiming insurance indemnity, the insured must prove that he did not breach the specific safety regulation through negligence. In this respect the insured is expected to act with due diligence of a prudent shipowner.[67] Alternatively, to recover

[62] The Nordic insurance market is represented by the Nordic Association of Marine Insurers – CEFOR. For more details see https://www.cefor.no/ (access: 8th February 2023).
[63] The Nordic Marine Insurance Plan of 2013, Version 2023, based on the Norwegian Marine Insurance Plan of 1996, Version 2010, https://www.nordicplan.org/the-plan/ (access: 8th February 2023).
[64] For example, a ship is damaged due to a collision, and it is established that *inter alia* a part of the ship’s equipment is damaged in the collision which was anyway defective due to corrosion. Insurance shall not cover the costs of replacement or repair of that part of the equipment.
[65] Trine-Lise Wilhelmsen, The Norwegian Marine Insurance Plan and Substandard Ships, *Marine Insurance at the Turn of the Millennium*, Volume 1, Marc Huybrechts; Eric Van Hooydonk; Christian Dieryck (Eds.), Intersentia, Antwerpen / Groningen / Oxford, 1999, pp. 139 – 143.
[66] NMIP, cl. 3-22, subcl. 1 defines safety regulations as “rules concerning measures for the prevention of loss, issued by public authorities, stipulated in the insurance contract, prescribed by the insurer pursuant to the insurance contract, or issued by the classification society.”
[67] For a detailed explanation of the relevant NMIP cl. 3-22 and cl. 3-25 see the official commentary on https://www.nordicplan.org/commentary/part-one/chapter-3/section-3/#clause-3-22 and https://www.nordicplan.org/commentary/part-one/chapter-3/section-3/#clause-3-25 (access: 8th February 2023).

the loss or damage from the insurance policy, the insured must prove that there is no causative connection between the breach of safety regulation and the damage or loss (NMIP, cl. 3-25).

THE CORRELATION BETWEEN THE INCHMAREE CLAUSE AND THE ISM CODE

The goals and requirements of the ISM Code actually represent the standard of care with which the behaviour of the shipowner, his servants and agents is compared, when determining and evaluating the shipowner's liability.[68] Thus, for example, failure to meet the requirements of the ISM Code can be treated as failure to comply with the standard of due care when making a ship seaworthy or maintaining it in a state of seaworthiness.[69] This can result in the shipowner's liability for damage caused by unseaworthiness,[70] and in addition it can lead to a loss of insurance coverage (hull insurance and P&I).[71]

The ISM company does not have to be the insured at the same time, nor does the designated person necessarily have to be a person from the top management of the company. However, for the purposes of the "Inchmaree Clause", in particular regarding the due diligence of the insured, shipowner and manager, as a condition for the existence of insurance coverage under the clause in question, the actions and omissions of the designated person will certainly be of key importance when assessing whether the shipowner, manager, supervisors, and their management on land, acted with due diligence.[72] Similarly, when the insured must prove that he acted with due diligence, he will succeed if he shows that in the specific case the company has properly organized the safety management system, that it has established a safe and effective reporting link, that the designated person actually followed the safety and environmental aspects of ship management, that the established reporting system between the ship and the company through the designated person was truly respected and that the necessary resource and land support were provided, as required.[73]

The designated person is the link between the ship and the company, the transmitter of important information, but in principle, this is not a person whose actions and omissions can be attributed to the personal fault of the shipowner. Commonly, this person will not be in a sufficiently high position in the corporate structure of the shipowner or ship manager to form their *alter ego*.[74] The personal fault of the designated person will therefore usually not be attributed to the shipowner himself. The designated person will, however, have access to the managing personnel of the shipowner or ship manager. Due to the system of safety management established in accordance with the ISM Code, within which a system of monitoring and notification of accidents and malfunctions related to the implementation of the Code must be put in place, in practice it is much easier to prove and determine the shipowner's liability, particularly thanks to the written reporting traces. If it can be proven that

[68] Drago Pavić, Pravni učinci primjene ISM kodeksa na ograničenje odgovornosti brodara, *Poredbeno pomorsko pravo = Comparative Maritime Law,* Vol. 40 (2001), No. 155, p. 59.
[69] In this respect, especially important is the ISM Code, s. 10 on ship maintenance.
[70] Drago Pavić, Pravni učinci..., *op. cit.,* p. 59. See also Zlatko Ćesić, Dužna pozornost u osposobljavanju broda za plovidbu, *Pomorski zbornik*, Vol. 39. (2001), p. 205.
[71] For a more detailed discussion about the legal implications of the ISM Code regarding the issue of seaworthiness in the context of marine insurance see Susan Hodges, The ISM Code and the Law of Marine Insurance, www.nadr.co.uk/articles/published/shipping/ISMMarineInsurance.pdf , pp. 4 – 13 (access: 8th February, 2023); Phil Anderson, *ISM Code: A Practical Guide to the Legal and Insurance Implications*, 2nd Edition, LLP, London, 2005, pp. 165 – 166; Oya Özçayir, *Port State Control*, 2nd Edition, LLP, London, 2004, pp. 456 – 461.
[72] In addition to s. 10 of the ISM Code, very important for the assessment of the existence of due diligence of the insured shipowner is s. 6 concerning the resources and adequate personnel.
[73] Geoffrey N. Hudson; Tim Madge, *Marine Insurance Clauses*, 4th Edition, Chapter III: Marine Hull Forms, Part 1: Principal Insuring Conditions, Informa Law, London, 2005.; The ISM Code, s. 4. For a more detailed analysis see Phil Anderson, *op. cit.*, pp. 172 – 174; Oya Özçayir, *op. cit.*, pp. 461 – 462.
[74] Susan Hodges, The ISM Code..., *op. cit.,* p. 12.

the designated person informed the highest level of management about the malfunctions, and if thereafter nothing or little was done to rectify them, then this may indicate a certain level of fault of persons in the managerial positions for any harmful consequences of the identified malfunctions.[75] Consequently, the necessary degree of fault of the shipowner or manager could also be proven based on the fault of their managerial staff.[76]

CONCLUSION

The so-called "Inchmaree" clauses specific to the standard hull insurance clauses of the London insurance market, but also incorporated in the standard marine hull insurance clauses of various regional and national insurance markets with more or fewer modifications, enable the insurers to monitor, maintain and improve the quality of the risks assumed for coverage. These standardized contractual clauses are of particular importance in the context of the prevention of maritime accidents, and the elimination of substandard ships from insurance portfolios or subsequently from the shipping market in general. Similarly to the standard insurance clauses on ship's class, compliance with the ISM and ISPS codes, change of flag, ownership or management, seaworthiness, and the like, the aim of the "Inchmaree" clauses is to link the existence of insurance coverage to a certain standard of quality of maintenance, management, and operation of ships. Therefore, the insured shipowners are obliged to comply with such insurance terms and conditions under the threat of loss of insurance coverage. On the other hand, the "Inchmaree" clauses are also a result of a compromise between the interests of insurers and the demands of the market. In that sense, on traditional and conservative international marine insurance markets, they strive to strike a fine balance of interests between the marine insurers and the insured shipowners. These tendencies are clearly seen in the example of the development of the "Inchmaree Clause" within the Institute Hull Clauses of 1983 and 1995 and International Hull Clauses of 2003 and the fact that the Institute Hull Clauses of 1983 are still the most broadly used marine insurance clauses for the insurance of ships worldwide.

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[76] The issue of want of due diligence of the insured in the context of the "Inchmaree Clause" was analysed by the South African Court (on appeal) in a recent collision case of *Viking Inshore Fishing (Pty) Ltd v Mutual & Federal Insurance Co Ltd* [2016] ZASCA 21. It was held that to exclude his liability under the insurance contract the defendant (insurer) had to establish "a want of due diligence on the part of the insured causing the loss. That does not depend on the conduct of the crew but on the conduct of those responsible at a higher level of management in the company. Want of due diligence is concerned with equipping the vessel for the voyage and not with seagoing or operational negligence, which is one of the perils insured against." See Craig Forrest, South Africa, *Lloyd's Maritime and Commercial Law Quarterly, International Maritime and Commercial Law Yearbook,* 2017, p. 188.

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Research on the Basis of Maritime Labour Convention of Defects in Seafarer Changeover by the Effect of the COVID-19 Pandemic

Zeki Yaşar

The Covid-19 global pandemic has intensely demonstrated how vital international maritime transport is for humanity's access to basic needs. The volume of global trade, which has reached seventy percent, is still realized with the possibilities of maritime trade. Around one hundred and fifty thousand seafarers working on international trade ships need to changeover every month. The reason for this changeover is to ensure the health and welfare of the seafarer, as well as a requirement of international maritime conventions. During the Covid-19 pandemic, seafarers faced problems such as getting a visa, joining or leaving the ship, airline transportation, ship crew changeover, and prolonged employment contracts. Although there are many sub-reasons of the problems experienced, the necessity of changing the seafarers draws attention as the most common topic, as the duty is carried out with a term employment contract. In order to draw attention to the problems encountered and to direct the countries to take precautions, declarations of relevant international organizations have been published. In this study, especially the seafarer's job change was emphasized, and the negative effects of the strict measures taken to prevent the spread of the pandemic were examined. On the one hand, while the supply chain is not deteriorated, on the other hand, it is examined that the pandemic measures are required to be taken completely and the process of joining or leaving the seafarers becomes impossible. The loss of rights of seafarers who could not leave the ship even though their employment contracts were terminated were examined on the basis of the International Maritime Labour Convention (MLC) and administrative conclusions were drawn from the experiences. The findings obtained as a result of face-to-face written interviews and surveys conducted with seafarers who are citizens of different countries were compared. Common problems were discussed over MLC and recommendations were made to policymakers by making determinations from the experiences gained.

KEY WORDS

Pandemic, Epidemic, Covid-19, MLC2006, Seafarer, Repatriation, Maritime Policy

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INTRODUCTION

Seafarers are the main employees of maritime transport. Maritime transport is the largest part of the global trade network. On a monthly basis, an average of 150,000 seafarers changeover their positions on merchant ships. In the global pandemic, the embarkation and disembarkation movements of seafarers were restricted. Due to visa procedures, closed consulates and ports, the mobility of seafarers was prevented. Disruptions in airline companies prevented the ship's employees from joining the ship or repatriating. The effective human factor of global trade is seen as the seafarer. During the pandemic, seafarers continued to perform their duties devotedly, away from their families, and anxiously, despite the harsh conditions, in order not to disrupt the logistics chain. Even though the maritime employment contract expired, the seafarers could not leave the ships they were working on and continued to work by exceeding their contract period.

The Maritime Labour Convention (MLC) adopted at the Maritime Labour Conference (ILC) of the Maritime Labour Organization (ILO) at the maritime session held in Geneva, Switzerland in February 2006. The Convention entered into force on 20 August 2013. The Convention establishes seafarers' rights to decent working conditions and helps establish conditions of fair competition for shipowners. The contract is designed to be the "fourth pillar" of the international regulatory regime and a global legal instrument for quality shipping. Seafarers have to work in unacceptable conditions in terms of welfare, health, safety and environmental safety on ships flying the flags of countries without effective jurisdiction and control. The industry needs effective international standards, as seafarers mostly have to work outside their homeland and shipowners are mostly not in their home country. MLC has been accepted to meet these standards (Maritime Labour Convention, 2006).

Higher attention should be paid to the living and working conditions, salaries and promotions of Nigerian seafarers during the epidemic (Okeleke, 2020). The seafarers whose psychology has been disturbed due to the pandemic have exceeded the duration of their employment contract on ships and sea platforms; states that they cannot get enough support from their families, friends and managers (Okeleke, 2020). The fuel, water, stock supply, repair, ship survey, certification and crew changeover should be given to importance in epidemic (Okeleke et al., 2020). Seafarers should gain more importance by the maritime industry, governments and international organizations (Henry, 2020). The benefits gained by the MLC since 2013 have been interrupted by the pandemic and that only one-fifth of the seafarers who cannot receive medical assistance have agreed to extend the contract period are defined (Hebbar et al., 2020). Despite the United Nations' call for seafarers to be 'key workers', it is stated that seafarers were stranded on ships during the pandemic and that the MLC was largely violated and worn out (Beukelaer, 2021). That is stated that since the Ministry of Transport does not prepare a standard guideline for seafarer changeover, accommodation and rapid covid-19 testing costs for seafarers on long voyages will be high and may cause long-term delays (Arleiny et al., 2021). There are evidences that stress factors contribute to the deterioration of seafarers' mental health, and that seafarers' mental health education is important for their development (Abila et al., 2021). Due to covid-19 pandemic when the length of stay on the ship increases, the probability of depression increases by 20% and psychosocial problems of seafarers are determined (Baygi et al., 2021). Most seafarers were affected by ship-shore interactions during the pandemic, their workload increases, they felt less safe in ports, and lacked information and support of companies (Pauksztat et al., 2020). The world's seafarers need more recognition after the pandemic (Henry, 2020). A great difficulty in renewing expired certificates, the requests for exemption of seafarers from quarantine and travel restrictions have been conveyed to organizations such as the United Nations (UN), the International Transport Federation (ITF) (Tzivakou, 2020). It is stated that seafarers with the weakest employment relations face the greatest difficulties in the pandemic

(Devereux et al., 2022). It is considered that the pandemic may be an effective factor for the recovery of MLC 2006 (Konstantidelis, 2021). It is stated that very few states allow seafarers to leave the ship and return to their homeland (Shan, 2022). It is stated that international cooperation is needed in order to improve employee rights under national and international law, as the cruise industry and its employees are greatly damaged in the pandemic (Yu et al., 2022). The lack of digital access for seafarers during the pandemic is considered as one of the important problems (Veldkamp et al., 2022).

METHOD

Study was examined and evaluations were made on the basis of the MLC. Researches in different countries such as Nigeria, Caribbean, New Zealand and China have been inspected. Declares and reports of European Union (EU), International Maritime Organization (IMO), United Nations (UN), International Transport Workers' Union (ITF), Port State Control (PSC) Memorandums (Evaluations made by organizations such as MOU) have been surveyed. In the study, the effects of the Covid-19 global epidemic, which seafarers from different countries are exposed to, on the seafarers, which is the most important part of maritime logistics, and the working conditions on the ships were tried to be determined by survey questionare. In addition to reviewing the studies conducted during the pandemic period, the method of comparing the findings obtained as a result of face-to-face oral and written interviews were used. In conclusion, international conventions and the results were compared. Questions were directed to multinational seafarers. The questions were determined as both open-ended and closed-ended. During the pandemic process, seafarers' employees in different duties and competencies were taken as an example. Some of the questions were prepared to determine the real complaints and problems experienced in the process. On the other hand, questions were asked to measure the psychology and general health of seafarers. Commentary questions were also used to develop the question set.

RESULTS

The findings obtained after the research are explained under the following headings;

Some maritime companies did not respond to the action demands of the seafarers and the necessary measures could not be taken due to the pandemic. The boarding of seafarers has been restricted in some countries. In some ports, despite the pandemic conditions, there were those who tried to enter the ship by force without complying with the pandemic precautions.

Medical mask and social distance rules were not followed in some of the domestic passenger ships operating in the domestic line area. With the onset of the pandemic, accommodation could not be found in Turkish ports due to uncertainties and authorization problems.

The leave rights arising from the employment contract could not be used. In the ship, the controlled distance rule could not be applied. Road was used instead of airway for seafarer transfers to the ship. There were shortcomings in financial support to the seafarers. PCR tests were performed each time the seafarers joined the ship.

There were problems with the use of sinks and general materials on the ships to prevent the epidemic. It was difficult to convince the seafarers who ignoring the pandemic and wanted to disembark from the ship.

Transportation expenses were undertaken by the seafarers for the participation in the ships. Some of the marine pilots did not want to wear masks. Although they were asked to wear masks, there were marine pilots who did not. Every time he boarded and disembarked on the ship, the seafarers experienced uneasiness. Within the scope of the measures taken by the countries and port authorities in joining the ship, the changeover of the crew were taken place two months later the contract period in some cases. Due to restrictions on boarding or leaving the ship, the duration of employment contracts has been extended. Reptriation took a very long time during the changeover of seafarer.

In the transfer of the seafarer, a test of Polymerase Chain Reaction (PCR) was also performed in each country and there was a period of one or two days in quarantine. The isolation caused social difficulties on board. Quarantine processes were long. Visa process was delayed. Port procedures got heavier. Skepticism and shyness arose among the ship's personnel towards foreign seafarers or newcomers. Disambarkation restrictions at ports caused stress, depression and anxiety problems. In the first days of the pandemic, the port times were extended as food supply, Cargo loading and agency works were tried to be done without visiting the ship. The small number of designated ports for crew changeover delayed ambarkation, for example only three ports. PCR tests, vaccinations, medical reports, fact sheets, quarantine etc. slow procedures made joining and leaving impossible. Quarantine times were long. PCR test repetitions caused delays due to the fact that the tests were valid for two days and the ship was late. The necessity of disinfecting food and stores during supply increased the workload.

DISCUSSION

The delay in taking measures by maritime authorities and companies has led to prolongation of many processes and delays in taking decisions. The pandemic was a situation that the international maritime organization and organizations could not foresee. For this reason, the fact that there is no explanation about the pandemic in the MLC explains why it is late in taking measures. It is considered that it is not prepared for the conditions of the pandemic.

Restriction of transport and temporary accommodation of seafarers; seafarer transfer costs to seafarers; Among the expenses to be provided by the shipowner, the rights such as the seafarer's joining the ship from his country and returning to his country are the subject of a flag state application. The MLC specifies this in standard A.2.5, paragraph 2. Despite this, it has been determined that some companies do not pay the transportation costs of seafarers during the pandemic process. Compensation for these damages emerges as an important issue.

Processes such as the inability to use the permission rights arising from the employment contract, the extension of the contract periods, the long quarantine process, the prolonged visa procedures, the aggravation of port works, port exit restrictions, test-vaccination have caused delays and these delays have turned into the problem of prolonging the duration of the employment contract. MLC does not set a maximum duration for employment contract periods. Considering the pandemic conditions, the determination of the contract upper period will contribute to the reduction of anxiety disorder and other psychological symptoms. Failure to comply with mask, distance, hygiene rules on board; the isolation causing social difficulties on board; skepticism towards the new seafarer; The disinfection of food and materials and the increase in workload directly or indirectly affect the health of seafarers and increase their stress levels. There is no standard health form in the MLC and it is noteworthy that there is no regulation on the solution of the psychological health problems brought by the pandemic.

The MLC agreement discusses that it has no grounds for what to do in the event of a global pandemic. In this context, there is a need for regulations that can address the problems brought by the pandemic and adapt on the MLC agreement.

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Sustainability in Maritime Container Transport Technology

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Containerisation has changed the world and enabled modern globalisation. The invention and usage of containers notably facilitated and expedited the transportation of various commodities and enabled enormous progress in transport technology. However, in addition to all its advantages, container shipping by sea also has disadvantages, such as emissions of noxious gases, which pollute the environment and negatively affect people's health. Therefore, it is necessary to make the transport of containers by sea more environmentally friendly and sustainable. The paper presents the most prominent methods by which container shipping by sea is evolving to be more sustainable. The authors reviewed and used available literature dealing with techniques like reducing energy consumption, navigating at a reduced speed or optimising the sailing route. In addition, methods like using alternative energy sources for the propulsion of container ships, such as liquefied natural gas, and measures undertaken at container terminals, are presented. Moreover, automation and digitalisation of the transport process, along with using smart containers, are introduced. Digitalisation and smart containers are considered the future of containerisation and represent the path toward a sustainable and safe technology for container shipping by sea.

KEY WORDS

Containerisation, Maritime transport, Sustainability, Smart containers, Container terminals.

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INTRODUCTION

Containers are used for the transportation of miscellaneous commodities, from consumer goods such as food and clothes to smartphones, dangerous goods and cargoes in bulk. The largest container ships nowadays are able to carry 23,992 TEU (twenty-foot equivalent unit). According to the United Nations Conference on Trade and Development (UNCTAD), in 2017, an estimated 752.2 million TEUs were handled worldwide in container terminals. Container trade accounted for 17.1% of total maritime trade in 2017. The International Maritime Organization (IMO) has developed and adopted several requirements to ensure safe transport and specific guidelines for packing and securing containers (International Convention for Safe Containers, 1972; International Maritime Dangerous Goods Code, 2022; 2014 IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units (CTU Code); Code of Safe Practice for Cargo Stowage and Securing, 2021).

Containerisation is a set of interconnected means of work and technological procedures for the automated manipulation and transport of aggregated cargo units, i.e. containers from the producer to the consumer. After palletising and packaging, containerisation is the first modern transport technology accepted worldwide. Containerisation is a system in which bulk, unit piece or palletised loads are connected in aggregated load units - containers, thus enabling the creation of a continuous transport chain from the raw material base to the final consumer. Containerisation can be considered the most effective form of integral transport since it separates the cargo from the means of transport utilising containers. Integral transport can be called any form of transportation in which the shipment is not directly loaded onto the means of transport but, as is the case with containerisation, into containers, which then, together with the goods being transported, become cargo for transportation, which can then be handled by the means various branches of traffic. Moreover, the containerisation system is compatible with other transport technologies such as palletisation, Roll/on-roll/off (Ro-Ro), Load/on-Load/off (Lo-Lo), huckepack, and bimodal transport technology. However, the primary task of containerisation is achieved only when the goods are placed in containers at the manufacturer and are emptied by the consumer. Containerisation, according to Skender et al. (2019), is a process that, utilising connected means of work and various technological procedures, uses containers and thus enables easier manipulation and transport of consolidated cargo units on the way from the producer to the consumer.

Maritime transport is the most efficient way of transporting goods over long distances. In the “hyperconnected” world, where manufacturing and consumption centres are scattered globally, goods are transported utilising very large container ships along major routes between Asia, Europe and the Americas. Estimates suggest that about 90% of goods consumed and used daily reach the consumer by spending at least part of their journey on a container ship. In addition to intercontinental networks, at the regional level, there are “feeder” services that interconnect “smaller” ports with the most important container ports (hubs), where containers are transhipped and routed to and from container terminals worldwide. All maritime container transport can be considered intermodal transport for the reason that usually, the connection between the start (production centre) and end of the transport (distribution centre), with ports of entry, is done by road or rail transport. As a result, the enormous economy of scale, enabled by ultra large container ships (ULCS), has gradually reduced transportation costs per unit of cargo and, consequently, the part of transportation costs in the products’ final price. That significantly contributed to the evolution and growth of international trade and could be considered one of the key factors of globalisation, which characterised recent decades’ world economy. Modern container transport is enabled by the cooperation of several stakeholders, such as shipping companies, freight forwarders, maritime agents, customs, terminal container operators, public institutions and additional service providers, and by adopting standard norms and practices. Nowadays, this complex structure is the spine of overseas trade and has reached an astonishing size (CSWindow, 2020).

With the increasing expectations of users of container shipping services for environmental protection and sustainable business worldwide, thriving companies are adapting their business models to provide trustworthy service at a low cost. Notwithstanding that nowadays, container shipping is one of the most environmentally friendly and sustainable freight transportation modes, improving its ecological sustainability is needed (AsianaUSA, 2020). However, although it is considered environmentally friendly since it accounts for 1/3 of world trade, it cannot be denied that it significantly affects the environment (AsianaUSA, 2020). As a result, industry leaders continue to look for means to remain lucrative, resilient, adaptable and responsible towards the environment. Furthermore, because the demand for imported goods is growing globally and probably will not change, container shipping companies seek more environmentally friendly ways to reduce fuel consumption, abate emissions and mitigate negative ecological impacts (AsianaUSA, 2020). The IMO developed various regulations and initiated numerous projects related to the Sustainable Development Goals (SDGs), thanks to the 70th session of the United Nations (UN) General Assembly, which adopted the "Resolution Transforming our World: Agenda 2030 for Sustainable Development" ("Resolution Transforming our world: the 2030 Agenda for Sustainable Development") (UN General Assembly Resolution 70/1, 2015). One of the IMO's aims is to launch modifications on ships and ports to make maritime transport and logistics more ecologically sustainable and resistant to adverse external influences. The IMO Initial Greenhouse Gas (GHG) strategy includes ambition for a reduction in carbon intensity (CI) of international shipping by at least 40% by 2030 compared to 2008, pursuing efforts to achieve a 70% reduction by 2050, compared to 2008, and reduce the total annual GHG emissions from international shipping by at least 50% by 2050 (Resolution MEPC.304(72), 2018).

Sustainable marine transportation and logistics include a complex system that merges economic, environmental and social components. Components are interrelated and overlapped and thus make the system sustainable (Hasanspahić et al., 2021). Nevertheless, the social component is becoming more significant than the others because port areas of many cities have been affected by ship emissions. Exhausts like SOx, NOx, and PMs from port-related activities are dangerous for the population of those cities and can cause lung cancers and heart-related diseases (Lee et al. 2019). This paper deals with sustainability in the technology of container transport by sea, intending to present the most important and most common measures in container transport by sea.

SUSTAINABILITY AND ENERGY EFFICIENCY TRENDS IN CONTAINER SHIPPING

Business transparency is an appearing trend that various industries worldwide are experiencing as a part of ecological sustainability. Currently, customers and stakeholders look for environmental responsibility from potential partners and businesses. Now more than ever, all stakeholders in a particular industry, including the container industry, seek a new level of commitment from business partners. When selecting a company to collaborate with, potential partners nowadays expect that a specific company has implemented methods reducing its carbon footprint and improving ecologically sustainable business. As a result, shipping companies are becoming more and more transparent about their ecological sustainability. In addition, they are investing more in clean energy sources and ecologically sustainable operations, such as designing energy-efficient ships and installing environmentally friendly equipment (AsianaUSA, 2020). Some of the ecological sustainability and energy efficiency methods applied in container shipping are presented in Figure 1.

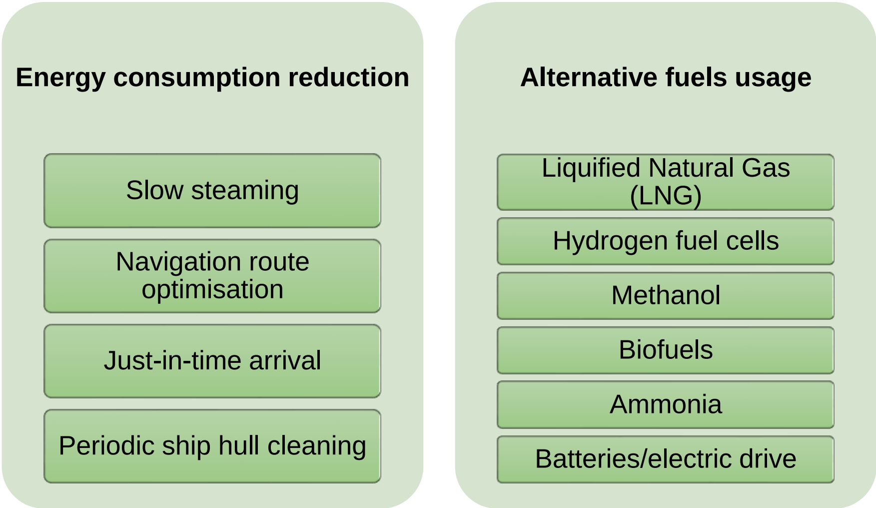

Figure 1. Energy efficiency methods applied in container shipping (prepared by authors).

Energy consumption reduction

One of the ways that individuals and organisations can reduce emissions of harmful gases into the environment is by reducing the amount of fuel they use. For example, shipping companies are significantly revising their operations and building ships with reduced noxious gas emissions and improved ecological sustainability. Some of the ways shippers are trying to improve sustainability by reducing energy consumption are sailing at a reduced speed, optimising the ship's route with the help of digitalisation and artificial intelligence (AI), implementing a ship arrival system on time and improving the reduction of ship hull resistance by periodic cleaning.

Slow steaming

At its core, slow steaming is the deliberate reduction of the ship's sailing speed. This intentional deceleration is first and foremost done to reduce fuel consumption and emissions abatement. A speed decrement brings a decrease in fuel costs. According to Barreiro et al. (2022.), container vessels can save "between 16 and 19% of fuel with only a 5% reduction in speed". For example, if a specific container vessel typically consumes 200 tons of fuel daily at a speed of 24 knots, sailing at a reduced speed of 21 knots would reduce fuel consumption to about 125 tons per day (XChange, 2019). As mentioned, this is primarily done for financial and environmental benefits. For shipping companies to survive when fuel prices rise and a recession hits, sailing at reduced speed becomes more necessary than optional.

Nevertheless, the commitment to operate their ships at a reduced speed makes many shipping companies environmentally responsible. Environmental benefits are associated with using less fuel. For example, when the ship reduces its speed by 10%, the engine power is reduced by almost 30%. Less main engine power required implies less needed fuel. When less fuel is used, fewer exhaust emissions are produced, which results in reduced air pollution and contributes to the solution of the climate change problem. Therefore, slow steaming becomes almost a requirement in maritime shipping. However, the impact of reduced speed shipping on the stakeholders of the container shipping industry is essentially mixed. Although economic and environmental benefits exist, precautions must be taken to avoid possible damage (XChange, 2019). For example, ships are not designed to run a ship's main engine at low loads. Therefore, there is a need for frequent, regular and thorough inspections, which might reduce the risk of engine breakdown. In addition, one of the disadvantages of slow steaming is a time factor affecting all stakeholders.

However, it must be noted that proceeding at a reduced speed increases the duration of the container transportation time. This affects customers who expect their goods as soon as possible, and it is necessary to educate them about the need to sail at a reduced speed and to explain all the potential benefits to them. It is also required to train ship engineers in a specialised manner in connection with slow steaming so they can know all the possible consequences of such a mode of operation of the main engine (XChange, 2019).

When global shipping speeds are reduced by 10%, this will reduce carbon dioxide (CO_2) emissions by almost 20%. According to Cariou (2011), slow steaming has reduced emissions by about 11%, which is a significant achievement, considering that no state-of-the-art technologies were introduced for the purpose. Furthermore, research done by Gospić et al. (2022) showed that significant savings in fuel consumption could be achieved when slow steaming, especially for the slowest steaming speed. Also, in the same research, it is shown that slow steaming significantly reduces CO_2 emissions. Another study corroborating container shipping's slow steaming benefits stated that container ships following typical sailing routes through the Mediterranean Sea could reduce CO_2 emissions by up to 286 tons (Degiuli et al., 2021). Therefore, navigation at a reduced speed in environmental protection proved justified and effective.

Optimisation of the route

Reducing navigating speed increases the ship's passage time between loading and discharging ports, leading to higher transportation costs. Therefore, it is necessary to address possible ways of improving the level of shipping service and, at the same time, reducing the voyage cost. The route planning should be executed to meet the demand in different ports, reduce the cargo transportation cost and comply with safety and security requirements. Modern technologies make predicting weather and sea conditions along the planned route possible, enabling and facilitating route optimisation. Ships' operators and charterers have realised they must decide the optimal shipping route based on carefully analyzing such data. Avoiding sailing routes where adverse weather conditions prevail, such as stormy weather accompanied by strong waves, can notably reduce the amount of fuel required to be burnt to execute the planned voyage. By selecting the most energy-efficient route, ship operators and charterers can reduce costs, expedite container delivery times, and minimise their negative environmental impact (Ji et al., 2015; Bui-Duy and Vu-Thi-Minh, 2021; Poulsen et al., 2022). Artificial intelligence plays an essential role in route optimisation. For example, the paper by Bui-Duy and Vu-Thi-Minh (2021) deals with selecting the container ships' optimal operating routes to minimize fuel consumption using an asymmetric travelling salesman problem (ATSP) methodology. The authors used five variables for the developed model: the ship's average speed, cargo capacity, sailing time and speed and direction of the wind. So, some software companies have developed special software tools that contain modules for evaluating the operational efficiency of previous trips to optimise or improve future trips' efficiency when similar variables and trends are used. Previous trips are assessed automatically with the help of collected data, and the software tool finds the optimal route for the ship's trip. The ship's journeys are automatically analysed by unique operational efficiency algorithms, which consider waves, weather conditions and other factors that affect the ship's navigation (Pomorac.hr, 2019).

Just-in-time arrival

Just-in-time arrival (JIT) is a method in which the ship maintains an optimal navigation speed during the voyage to arrive at the pilot boarding area only when their availability for service, mooring services and approach channel (if applicable) availability is confirmed. The Global Industry Alliance (GIA) has identified the concept of just-in-time as a possible chance to abate GHG emissions. GIA developed the "Just In Time Arrival Guide" with this goal (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020). The Guide was created to aid sustainable and environment-friendly shipping, based on scientific and professional roundtables, which gathered almost 50 companies and organisations leading stakeholders in the ship-to-port operation. Implementing JIT arrival can significantly abate shipping emissions, optimise ships' speed with port terminal calls, and improve terminal efficiency. On-time arrivals also reduce the time the ship stays at the anchorage and minimise congestion in the port area. According to some studies, it is estimated that cargo vessels spend up to 9% of their voyage time awaiting at anchorages, which could be shortened by implementing JIT arrivals. The Guide presents a comprehensive perspective on JIT arrivals, taking into account charter party aspects of its implementation and operational ones. The focus is intended to be a valuable tool for various stakeholders, including ship owners and operators, charterers, ship agents, ship brokers, port authorities, terminals, and nautical and shipping service providers. They eventually play a decisive role in implementing the necessary changes and easing the communication exchange necessary to realise JIT arrivals (GEF-UNDP-IMO GloMEEP Project and members of the GIA, 2020; IMO, 2020).

Periodic hull cleaning

The condition of a ship's hull affects energy efficiency because of the deterioration of the hull condition and propeller performance over time, mainly because of biofouling and mechanical damage. Even smaller biofilms jeopardise the ship's hull hydrodynamics by increasing resistance and, thus, the required propulsion power. The study by Farkas et al. (2022) performed on Post Panamax and Post Panamax Plus containerships showed that the annual increase in fuel consumption for sailing in calm seas is up to 153,689.9 t/year, while an increase in CO_2 emission is up to 478,590.5 t/year (Post Panamax), and 157,650.7 t/year and 490,924.1 t/year (Post Panamax Plus).

Biofouling conditions can worsen if the ship has long idle periods (long periods at anchor or frequent port calls). In addition, the fouling rate increases with higher sea temperatures. Hull fouling results in excessive fuel consumption when cruising at a specific speed or loss of speed when maintaining engine power (Kane, 2012). Regular hull cleaning operations and propeller polishing can prevent these adverse effects on the vessel's energy efficiency. It is worth mentioning that an additional ecological benefit of hull cleaning is the removal of potentially invasive marine species (biofouling), the transfer of which represents a significant threat to marine ecosystems and the preservation of biodiversity (Adland et al., 2018). Therefore, ship hull cleaning can reduce harmful exhaust emissions and improve the energy efficiency of the world's fleet. Nevertheless, hull fouling significantly contributes to increased emissions and is the only primary driver over which the shipowner has a significant degree of control (Adland et al., 2018).

The means of assessing the condition of the underwater part of the ship's hull is most often a visual inspection. However, fouling may not uniformly cover the surface of the hull, and in addition, heavy fouling may not be visible by visual inspection only. For that reason, divers who inspect the condition of the underwater part of the hull are most often engaged. Besides engaging divers for hull inspection and cleaning, a remotely operated underwater vehicle (ROV) could be used. It could be expected that

AI applications and a combination of various novel technologies will facilitate underwater hull cleaning and lead to the development of next-generation underwater cleaning robots (Song and Cui, 2020). According to Adland et al. (2018.), the results of research on the influence of hull cleaning on the ship's energy efficiency show the following:

- "Periodic hull cleaning leads to a significant reduction in daily fuel consumption";
- "Dry-docking the ship leads to a greater and significantly different reduction in fuel consumption than underwater cleaning of the hull, approximately 17% versus – 9%";
- "The energy efficiency effect of hull cleaning is more significant when the ship is laden than in ballast condition".

With all of the above, the ship owner decides on the frequency and quality of periodic maintenance on the underwater part of the ship's hull. Still, it can be concluded that adequate cleaning is a very effective and necessary method. In addition, it is worth mentioning that decision support systems (DSS) were developed to facilitate ship operator decisions for scheduling underwater hull cleaning (Dinariyana et al., 2022). Furthermore, in addition to the mentioned methods, the use of alternative fuels is increasingly being mentioned as a way to prevent harmful exhaust gas emissions.

Use of alternative fuels

The maritime industry, which traditionally relies on standard fossil fuels, is arranging to transform to meet international climate goals. This transformation has led to an increased focus on alternative and low-carbon fuels. Because the container shipping industry is highly competitive, maritime shipping companies must carefully assess potential costs and benefits when reviewing the best options for sustainability improvements.

Liquefied natural gas

Liquefied natural gas (LNG) is commonly recognised as "the largest segment of the alternative fuel market", especially for ocean-going ships (Gard, 2022). It is considered the leading option because it does not contain sulphur, thus meeting the requirements of the IMO 2020 on the limitation of sulfur emissions (Resolution MEPC.305(73)). Also, its carbon dioxide emissions are approximately 20% lower than those of very low sulfur fuel oils (VLSFO) (Gard, 2022). According to Det Norske Veritas (DNV) predictions, more than 40% of marine fuels will be LNG by 2050 (Maritime Forecast to 2050, 2022). LNG is already being considered for part of the world fleet as there are more than 500 (as of June 2021) LNG ships sailing and on order (not including LNG tankers). However, LNG as a marine fuel has drawbacks since it is highly flammable and poses an increased safety threat (Iannaccone et al., 2018). The "International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels" (IGF Code) provides standards for the design of natural gas ships and came into force as a mandatory code on 1 January 2017 for vessels required to meet the requirements of the International Convention for the Safety of Life at Sea (SOLAS) that also use natural gas or other point fuels ignition temperature lower than 60 °C (Resolution MSC.391(95)). Petroleum fuels may continue to dominate the market soon, but LNG is likely to gain the upper hand due to its competitive price and reduced emissions (Gard, 2022). However, according to the research done by Balcombe et al. (2021), LNG-fueled engines are incapable of meeting the industry's 50% GHG emissions reduction goal without additional improvements. Therefore, it remains questionable will the LNG fueled ships dominate the market in the future.

Hydrogen fuel cells

The use of hydrogen as a marine fuel is under development, as it is considered that it could be an essential component on the way to decarbonising shipping (Five lessons to learn on hydrogen as ship fuel, 2021). Hydrogen as a fuel burns without emitting carbon or greenhouse gases and is nonpoisonous, colourless and odourless. Nevertheless, hydrogen has a significant flammability range and low ignition energy (NRDC, 2021). Most hydrogen production nowadays is made from coal or natural gas, and depending on the production methods, the most common colours of hydrogen are grey, blue and green (NRDC, 2021; Gard, 2022). Hydrogen also faces obstacles to widespread use. Currently, hydrogen is not feasible for ocean shipping, as the energy density of hydrogen is about half that of other traditional marine fuels, and the low energy density fuels create a storage problem, which affects the available range of operations (Van Hoecke et al., 2021). This is further complicated as space on ships is limited, so availability is vital issue, especially as larger fuel storage tanks would significantly reduce cargo-carrying capacity. Also, facilities for the supply of liquid hydrogen (bunkering facilities) may have higher capital costs than facilities for the supply of LNG. In this regard, recent reports indicate that while alternative fuel prices remain uncertain, hydrogen fuels may be cheaper than gas and biofuels, although much more is needed across the sector to develop price certainty and economies of scale (Gard, 2022).

Methanol

As with other alternative fuels, there are no specific regulations governing methanol as a marine fuel; therefore, assessments of the equivalence of methanol as a new fuel for use will follow. In addition, shipowners are unable to set up plans for newbuildings with an alternative propulsion fuel until IMO and other regulatory bodies have defined relevant regulations and requirements (Methanol as an alternative fuel for container vessels, 2022). However, the IMO interim guidelines for ships using methyl or ethyl alcohol as fuel (MSC.1/Circ.1621, 2020), together with the IGF Code for ships using low-flashpoint fuels (Resolution MSC.391(95)), clear the way for financing and exploring methanol-fuelled ships. Methanol is produced using natural gas as a feedstock and is a liquid at room pressure. Its temperature makes storage and handling much more straightforward than other alternative fuels (Verhelst et al., 2019, Gard, 2022). However, there may be better options than methanol due to methane emissions during production and combustion. It can only provide relatively limited reductions in carbon dioxide emissions compared to traditional marine fuels, although it has been suggested that biomass-derived methanol can deliver up to 50% reductions in emissions (Gard, 2022). According to de Fournas and Wei (2022), renewable methanol derived from forest residue gasification can attain considerable GHG emissions reduction. Compared to traditional shipping fuels, reduced lifecycle emissions range from 38 to 165%, depending on the system and scenario investigated. According to Ammar (2019), from an environmental perspective, using a dual-fuel marine engine with 89% methanol and 11% marine diesel oil (MDO) will comply with the required IMO emission regulations, as set in MEPC.305(73). This will lead to reductions of 76.8% in NOx, 89% in SOx, 55% in CO, 18.1% in CO_2 and 82.6% in particulate matter (PM) emissions. To minimise the expenditure of the fuel for the dual engine to that of the “common” diesel engine value at maximum continuous rating (MCR), slow steaming by 28% is proposed by the author (Ammar, 2019). Therefore, it can be concluded that dual fuel marine engines using methanol and MDO in combination with slow steaming could lead to significant savings and reduction of harmful gas emissions from containerships.

Biofuel

Biofuels are commonly sulphur free and consequently do not emit SOx. Resulting NOx emissions are normally somewhat higher or at the same level when burning biofuels compared to those made when burning distillate fuels (EMSA, 2022). Biofuels are being explored as alternative fuels and are already used as marine fuels (Gard, 2022). Nevertheless, their current usage for driving marine engine applications is very limited (EMSA, 2022). They are renewable and have low carbon emissions. In the US, “biomass” refers to “organic matter that is available on a renewable basis, including crops and agricultural waste and residues, wood and wood waste and residues, animal waste, municipal waste, and aquatic plants” (Gard, 2022). In the EU, biomass mainly comes from agriculture and forestry. Nowadays, biofuel production is primarily based on biomass from crops (EMSA, 2022). On the other hand, “biofuel” means “any gaseous, liquid or solid fuel produced by biomass conversion” (Gard, 2022). Biofuels can be mixed with traditional marine fuel oils derived from crude oil or used as direct replacement fuels derived from various raw materials such as corn, ethanol or sugar through various processes. Significant obstacles preventing the widespread use of biofuels include environmental, economic and technical issues. To become a “green” option, biofuels must come from sustainable raw materials. Other problems are related to scalability, market competition, and the long-term storage of some biofuels (Gard, 2022). But, aside from problems that must be dealt with, according to Watanabe et al. (2022), using biofuels as a fuel for marine engines has great potential for mitigating climate change compared to fossil fuels commonly used in shipping. In addition, as concluded by Kesieme et al. (2019), from a technical perspective, it is possible to replace marine fossil fuels with biofuels, both for newbuildings and retrofitting. However, additional safety barriers are considered necessary for each part of the biofuel system (Kesieme et al., 2019).

Ammonia

Another carbon-free fuel option being considered is ammonia. Similar to hydrogen, most ammonia is produced using natural gas. Ammonia can be used as an energy source for fuel cells or can be part of the fuel source for an internal combustion engine. It is significant that “green” ammonia offers a double potential towards transport with zero emissions, namely in the entire process of fuel production, delivery, and use on board, as well as all emissions that arise (well-to-wake) and emissions of the whole process of using or burning ammonia from the ship’s tank (tank-to-propeller) (Al-Aboosi et al., 2021). However, manufacturing scalability and availability remain obstacles, as do new engine technology designs, safety considerations and supply chain concerns. Moreover, there are regulatory and technical barriers to the use of toxic fuels. Although there are many competing fuel options in several scenarios, particularly in the recent “Maritime Forecast to 2050. Energy Transition Outlook 2022”, DNV predicts that “ammonia is one of the most promising carbon-neutral fuels, although for ammonia to be a viable future option, it must be produced by low-carbon processes” (Maritime Forecast to 2050, 2022). Despite what has been said previously, according to Cardoso et al. (2021), ammonia is still far from being largely recognised as a dominant fuel for marine applications. To change the point of view and find a solution, it is necessary to do adequate high-quality studies and administrations’ agencies, makers and other maritime stakeholders need to assign substantial amounts of resources (Cardoso et al., 2021).

Batteries/electric drive

Electric and hybrid systems using batteries or fuel cells represent another option for zero emissions. All-electric operations remain in the early stages of development, as presented in the study by Gagatsi et al. (2016). With the limitations of current technology, battery-powered operations would likely be suitable for short sea voyages or domestic passenger ferries. However, variants are being explored for a “hybrid” ship, where the ship could be equipped and powered by electric propulsion engines with lithium-ion batteries that could be charged from onboard diesel generators or when connected to a shore power source (Gard, 2022). The paper by Torreglosa et al. (2022) deals with developing a detailed model of a hybrid-electric ship, combining diesel generators and batteries. Their study showed that the proposed system had an adequate performance under different conditions and could be used to mitigate harmful emissions. However, according to a paper by Nguyen et al. (2020), a hybrid propulsion system commonly opts for ships sailing below 40% of their maximum speed over most working hours. According to the above mentioned, containerships are not eligible candidates for hybrid propulsion due to their need for speed, at least with the current technology. Nevertheless, it is still necessary to emphasise some of the advantages this type of propulsion offers, such as reduced noise level and enhanced propulsion availability when the total electrical power system must be distributed during operation (Nguyen et al., 2020).

SUSTAINABLE MANAGEMENT OF PORT CONTAINER TERMINALS

Port sustainability could be defined as the strategy and operations managed by the specific port to meet the present and future users’ needs and, at the same time, protect human and natural assets. Likewise, “green ports” could be described as engaged in proactive development, implementation and monitoring processes aimed at minimising adverse ecological impacts. While green ports focus mainly on ecological concerns, port sustainability considers social, economic and environmental issues (Dalhousie University, 2021).

The utilisation of logistics to find answers to ecological problems and implement sustainable growth concepts began in the 1980s. Scholars have pointed out that logistics has a significant influence and perspective regarding controlling transportation systems, minimising and controlling environmental pollution, and energy and resource-saving process management (Rakhmangulov et al., 2017). A pro-environmental attitude has become a segment of the “green” marketing of liner shipping. Therefore, for a logistics operator, one of the most important features of its activities is its impact on the environment. Nowadays, large companies dealing with logistics, such as DHL, Schenker AG, Green Cargo Kuehne Nagel, UPS, COSCO Group and others, use “green” technologies and solutions in their processes. They define green logistics as “an effective approach to managing technological processes, resources and energy flow to reduce environmental and economic damage” (Rakhmangulov et al., 2017).

Nikitakos (2012) and Hasanspahić et al. (2021) state that the ecological element of sustainability is an important feature of seaports, which are a key component in the maritime supply chain. Today, “green” logistics is of special interest, and seaports are rapidly introducing state-of-the-art technologies that contribute to reducing greenhouse gases. The ecological concept in seaports aims to achieve zero emission of harmful gases, which could be based on smart grid technology connected mainly to renewable energy sources. Renewable energy sources include wind, solar, geothermal, wave, biomass, and earthquake energy, among others.

Ecologically differentiated port dues based on ship emissions, i.e. the ship’s participation in “green” rating systems, such as, for example, the Environmental Ship Index (ESI), are also one of the means that increase the sustainability of the seaport. Ships that are “greener” than others receive fixed or proportional deductions from regular port dues. Measuring ship emissions is an essential aspect of seaport sustainability. Therefore, it is necessary to monitor emissions to reduce their adverse effect. One of the innovative solutions in seaports is using unmanned aerial vehicles to ensure the safety of port operations and monitor the state of the natural environment. For example, the new yetiSense comprehensive system for monitoring air pollution emissions, created by the SeaData company, has been implemented in the area of the port of Gdynia. Such actions not only serve customers' expectations but also increase the port's social responsibility and thus care for the environment (Poland@sea, 2018).

Maritime shipping is a source of air pollution that is very difficult to regulate, but it is also an essential part of international trade. Since ships are getting bigger, they need more and more electricity. Therefore, most ports worldwide are exploring the possibility of using shore power. Onshore Power Supply (OPS) is an electrical system that allows the ship to be supplied with electricity while moored. This means that all systems on board can operate without using auxiliary engines. Such a system was implemented mainly in Sweden – ports of Gothenburg and Stockholm (Port of Gothenburg, Ports of Stockholm) and Germany - Lübeck, Hamburg, Cuxhaven and Kiel (Krämer and Czermański, 2020). In addition, it is worth mentioning that some of the largest Northern Europe ports authorities (Antwerp, Bremerhaven, Hamburg, Haropa Port and Rotterdam) signed a Memorandum of Understanding (MoU) to improve the usage of OPS systems for Ultra Large Container Vessels (ULCV) by 2028 (Offshore Energy, 2021). Furthermore, four Baltic ports (Aarhus, Copenhagen, Stockholm and Helsinki) are partners on a project which has the objective of provisioning sustainable OPS systems in these ports (Four Ports – Onshore Power in Baltic Seaports). It can be concluded that maritime transport tries to improve the ecological element of sustainability and implements various measures and solutions to reduce emissions. However, the effectiveness of specific actions and solutions could be questionable under certain conditions (Hasanspahić et al., 2021). Maritime technologies are advancing rapidly, and the opportunities for improved efficiency, reduced transport costs and more accurate real-time information mean that the coming years could see massive changes.

SMART CONTAINERS

Traditional ways of tracking transport containers are primarily manual and unreliable. The above information is constantly outdated, making it difficult to predict the precise container's arrival time at the port. Wrongly estimated time of arrival can lead to port congestion and unnecessary delays in unloading cargo for the next stage in the supply chain. In addition, the traditional way of the data collection process is costly, error-prone, incomplete and can be fraudulent (GIHub, 2020). A solution could be smart containers, transmitting data in real-time during transportation, thus providing precise information to port operators and facilitating better plan facilities for inbound shipments, storage and further distribution (GIHub, 2020). "Smart Containers are transport containers used in freight transport and logistics that are integrated with Internet of Things (IoT) technologies, sensors, GPS tracking and solar panels" (GIHub, 2020). According to United Nations Economic Commission for Europe (UNECE, 2020), smart containers are equipped with devices and sensors to enable advanced monitoring of container identification, location and physical parameters (for example, temperature, humidity, vibration and others). Besides monitoring above mentioned elements, smart containers may include data such as: "Estimated Time of Arrival (ETA) update, Actual Executed Transit Time, Empty at Gate-In at Depot, Trip Tracking, Exception alerts such as Schedule Deviation Alert, Unexpected Door Opening, Unexpected Temperature or Humidity Change and Overlanded Container" (UNECE, 2020). The collected data is automatically entered into a digital shipment record, which can be shared with the owner to provide real-time tracking and can be used to more accurately predict the time of arrival at port to enable optimised container unloading and distribution to the next stage of the supply chain. In addition, smart containers can be self-powered through solar panels built into their sides and have batteries that enable energy storage (GIHub, 2020). However, there is a need to emphasize the utmost importance of trustworthy and precise information for the container location (Voorspuij and Becha, 2020).

Another problem associated with traditional container transport operations happens when they arrive at the port and are discharged at the terminal. They can remain to lie on the quay or be delivered to the wrong port, and it often happens that this is discovered after a few months. Smart containers can solve this problem by providing real-time information to operators to detect such issues quickly. In addition, autonomous seaports and autonomous ships are also being developed in many countries. With these additional developments, soon, smart containers will be able to communicate directly with autonomous systems on ships and in ports. Such communication between systems will enable simple, efficient, faultless operations from commencement to completion (GIHub, 2020).

The transport and logistics industry is going through a digitisation process that will enable efficient data exchange between all parts of the supply chain. However, in practice, this means that the shipping industry needs to overcome some existing barriers to digitisation, such as expensive and limited network bandwidth, cost-saving and risk-perceived mindsets, lack of standardised infrastructure, opposition to data sharing for the greater good of the industry, regulatory compliance issues, and cyber security problems (Dualog, 2020).

However, measures have been taken at the regulatory level to facilitate this process and contribute to sustainability. In 2020, the European Union approved a new "Regulation on electronic freight transport information (eFTI)" in an attempt to help the digitisation of the industry, intending to increase sustainability by reducing the use of paper and encouraging energy efficiency of operations by ensuring all stakeholders have access to the most relevant data (EUR-Lex, 2020). Meanwhile, organisations like the Digital Container Shipping Association (DCSA) aim to establish standards for a common technology foundation (such as that will enable global collaboration. They aim to make transportation services "easier to use, more flexible, efficient, reliable and sustainable" (DCSA, 2022). Digitisation and big data will be increasingly important in a post-pandemic world where stakeholders focus on the sustainability and efficiency of every part of the supply chain. Of course, a significant portion of the sustainability of maritime transport comes down to the willingness to reduce carbon emissions. Still, the digitalisation of the entire logistics network also plays a crucial role.

CONCLUSIONS

Containerisation includes the transportation of goods in containers using modern means of cargo handling and has experienced a tremendous expansion due to its irreplaceable property of delivering goods on the principle of "door-to-door" service, combining maritime with road and rail transport. It belongs to the most effective modern transport technologies and therefore achieves several advantages, such as reduced packaging costs, increased work productivity and faster cargo handling. Maritime technologies have come a long way from the pre-containerisation era when cargo was transported as general cargo or in bulk. Technology has enabled the automation of container terminals and thus reduced the dependence on manual work and increased efficiency, but also improved safety. Digitalisation, usage of "green" fuels and renewable energy, smart containers, JIT arrival concept, voyage optimisation methods (AI usage) and robotics (underwater hull cleaning) are some of the factors that enabled entering into a new era for container shipping industry (Lind et al., 2021). As stated by Lind et al. (2021), "the only real certainties are that the next 10 or 20 years will see as much change in shipping as has been experienced in the past 100 years and that whatever those changes may be in the future, they will have to be ever efficient, cost-effective, and environmentally friendly".

Some ports advance rapidly; however, outdated technologies are still used in less developed areas. It could be decades before state-of-the-art technologies are implemented in these ports, challenging the maritime shipping industry. Furthermore, container ship sizes continue to grow, and the development of mega-ships creates further challenges around the world regarding the ability of container terminals to handle such large cargo capacities.

As ambitious emissions targets set by the IMO for 2030 and 2050 approach, container shipping companies are considering how best to invest in reducing the environmental impact of their ships. Some methods are sailing at a reduced speed, regular cleaning of the underwater part of the hull, optimisation of sailing routes and arriving on time. Another solution is the use of alternative fuels. However, at least for now, liquefied natural gas is the only one that has come to life in the transoceanic transport of alternative fuel for container vessels. However, not only ships are expected to be managed sustainably. Port container terminals are switching to green energy sources, and transhipment vehicles usually powered by diesel engines are increasingly powered by electric battery power. Furthermore, terminal automation and digitisation are key in reducing harmful gas emissions, increasing efficiency, and improving safety. In addition, smart containers will revolutionize data collection and prompt data reporting across supply chains (Becha et al., 2020). The sustainability of port container terminals becomes crucial for their competitiveness in the market, so operators invest in new technologies to achieve it and do all this transparently and responsibly.

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Training of Employees in a Maritime Company Brodospas

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Training is a tool of management to ensure and develop high-quality employees. Those who have developed, initiated, and continuously invested in the training and education process have an advantage in the human resources field, ensuring quality employees who can perform work according to predetermined standards. Daily changes in the external and internal business environment encourage companies to invest as much as possible in the training and education of employees as one of the most effective ways of achieving a competitive advantage. The main goal of this paper is to study the approach of methods, training, and education programs of Brodospas p.l.c. as well as how the company manages human resources. The paper investigates the types of training organized in the company, including the administration and seafarers, who is responsible and who conducts it, on what basis, how are decided to conduct training, and evaluated their results. The meaning of the concept and characteristics of the training process, the assumptions of successful training, and the need for personnel training are explained. Every year Brodospas p.l.c., invests in the training of its employees and organizes special programs, recognizing the strategic importance of training.

KEY WORDS

Employees, Training, Maritime company, Management

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INTRODUCTION

Education of seafarers began now when it was realized that for sailing not only one's own experience is sufficient, but also the knowledge and experience of other seafarers. The quality of seafarers' work is a basic requirement and the most important factor in maritime affairs, which most directly and intensively affects the safety and rationality of work (Pupovac and Zelenika, 2004). Maritime companies must recognize and combine, through planning, all key factors that ensure the company's survival, growth, and development. And it is education that is the key factor for the creation of human capital. For this reason, special attention should be paid to education, practical training, and continuous professional development. Over the last thirty years, there have been significant innovations in the organization of shipping companies and general shipping management. The modern concept of human resource management in the maritime industry emphasizes processes and assumes that employees should not be controlled by goals, but that they are the ones who should determine the goals and record the success of the company's activities (Pupovac and Zelenika, 2004). Training is also one of the most important forms of human resource management because it is the basic prerequisite for a company to enter the market and challenge its competitors. Training is a demanding process that involves several business activities, from the identification of training needs to the evaluation of training results. It is necessary to make certain assumptions regarding the existence of a training policy and to find an appropriate organization capable of implementing it. Investment in training and development brings many benefits to the company, but also to the employees themselves, who in this way increase their motivation to learn and work better. To successfully perform the work daily, it is necessary to improve and train employees through various training programs. Seafarers have specific knowledge and skills acquired through formal education and work experience, and maritime companies should recognize this potential, whether it is a company with integrated management or an external human resources management company. For this reason, special attention should be paid to education, training, and continuous professional development.

EDUCATION, TRAINING, AND DEVELOPMENT OF HUMAN RESOURCES

Investment in human resources, such as expenditures on training, education, and staff development, used to be considered a business cost. New insights into human resource management (HRM) have led to a change in the perception of investment, i.e., HRM costs. The impact of education has a positive effect on both the individual and the company. Therefore, the impact is equally important to the company and to the individual, as both parties have increased benefits that translate into greater individual satisfaction, teamwork, cooperation, cost reduction, increased productivity, innovation, etc. People today are becoming a means to achieve profits. Without effective planning, organization, and training of staff, it will be difficult to achieve the desired positive business results. Therefore, both the employer and the employee must invest in human resource development (Schultz, 1985). It is necessary to distinguish between education and training, as they are different concepts. The quality work of seafarers is the basic assumption and the most important factor in maritime affairs, which most directly and intensively affects the safety and rationality of work. The intangible value of the business process derives from knowledge, abilities, and skills of employees in maritime companies. Thanks to an appropriate and well-developed human resources management system, maritime shipping companies can successfully cope with competitive challenges, and the key to confronting them is a motivated, trained and committed workforce.

The training process has a variety of effects on the employees, but also on the company itself. Employees improve their knowledge and skills to find employment as easily and quickly as possible and influence their professional development. Training means preparation for an occupation or specific skills; it is not so much person-oriented as job-oriented (Buble, 2009). In contrast, education is the process of acquiring knowledge and skills that are generally necessary for life. Education is of social importance, while training is of importance to the organization and the individual (Buble, 2006). According to Bubble (2000), the term training refers to a relatively permanent change in employees that involves improving their job performance. It involves changing employee’s knowledge, skills, abilities, attitudes, and behaviours, and may include changing employee’s knowledge, work practices, and attitudes toward work, colleagues, and the organization. Stewart and Brown (2009) define training as a planned effort by the organization to help the employee acquire knowledge, skills, and attitudes.

Training and education are therefore of great importance to both the employee and the employer, with training being even more important because it directly affects the way a particular job is performed in the organization. Fitz-enz (2000) points out that training is an interactive exercise whose main objective is to develop personal skills and abilities. Today's world is characterized by strong modernization in terms of technology and IT. When training employees, it should be determined whether the training will be carried out inside or outside the company and whether this task will be entrusted to people from within the company or it will be outsourced. Thus, training can be defined both from the perspective of an individual and from the perspective of a company. From the individual's perspective, training is defined as a more or less organized program to perform a physical or intellectual activity or physical or psychological characteristics or as a process to change behaviour and attitudes of employees in a way that increases the likelihood of achieving goals (Bakotić and Bogdanović, 2013). From the organizational perspective, training is defined as a planned effort by the organization to help an employee acquire knowledge, skills, and attitudes, or organizational activities and programs aimed at enhancing and developing employee’s knowledge and skills (Bakotić and Bogdanović, 2013).

According to Jelavić (1995), education can be defined as pedagogically (didactically) designed and systematically organized learning, that is, the experience of individuals manifested in the growth (quantity and quality) of knowledge and skills and the development of abilities. Education is the acquisition of general and professional knowledge and skills (in a particular profession, but not in certain specific occupations or in relation to a particular organization), it means the expansion of general knowledge, skills, and abilities of a person, which enable him or her to make independent decisions and act in various situations (Bahtijarević-Šiber, 1999). Modern companies are allocating more and more of their resources (money, time, information, energy, etc.) to the education and continuous training of their employees. Company management increasingly recognizes that continuous education and training of employees is one of the most effective means of achieving a competitive advantage, which is the basic prerequisite for entering the market and competing for the favour and trust of consumers. This is the result of large and rapid changes in the external and internal environment of modern companies, which place knowledge, constant innovation, and learning new things at the forefront of economic development. This is true for organizations as well as for society as a whole. Investment in education is becoming a key indicator for understanding what is happening in the modern (global) economy and competition.

The goal of education and training is to develop new knowledge to enable higher levels of productivity. The acquisition of knowledge and professional development are particularly important today, since, due to accelerated scientific development, the so-called technological life has become much shorter than human life. Lifelong education and development become very important for both individuals and organizations. In addition to skill and career development, training can also have a socialization function. Training activities can aim to develop unity and team spirit, increase individual and organizational loyalty, and promote both workplace and overall organizational success (Šverko, 2012). The training and development program will improve the skills that employees need to work in an organization. Training and education programs bring all employees to a higher level and provide them with similar knowledge and skills. In this way, weak links within the organization are reduced and unity among employees is strengthened. Training and education are important because it creates educated workforce with employees who can rely on each other and work as a team when needed, but who can also complete work tasks independently and without supervision. Employees who undergo training are better in performing their jobs than employees who do not undergo training programs. As a result, they become competent and quickly adopt the changes that are common in the industry. All this helps the company itself to maintain its leading position in the market (Baruch, 2006).

The last of the three mentioned concepts is the concept of human resource development. Human resource development is carried out through training, a proper communication system, and good dissemination of information within the organization (Maalej et al., 2014). Through training, management creates a permanent change in the way employees work, which is mainly reflected in the development and increase of work potential, which consequently affects the improvement of the overall efficiency of the organization (Ziyae, 2016). Employee training can be referred to as a link that connects employees to their work and through which employees get the urge to innovate and create new opportunities to improve existing products and services or start completely new processes within the organization (Ziyae, 2016).

The education of seafarers, despite not being internationally unified and depending on country to country, is partly regulated by STCW convention, which prescribes the level of competence confirmed through certificates that seafarers must possess to work and stay on board. Informal education of seafarers includes various training programs that supplement formal education. The STCW Convention prescribes additional training programs because educational programs are very often not aligned with rapid technological development. Additional training enables the acquisition of special knowledge for specific purposes and for certain types of ships. Shipping companies invest in additional training for seafarers because formal through education, it is not possible to acquire all the knowledge necessary for the work performed on board (Gundić, Ivanišević & Zec, 2016). One of the reasons for the importance of investing in new and existing personnel, i.e., training and education, is changes in maritime technology. The development of technology in the management of ships has experienced significant progress, and the demands for even faster development and changes posed to maritime technology by global economic opportunities, as well as requirements for protection environment, influence even greater progress in the field of navigation safety and automation. There is a strong need for education and training of existing and new staff to work on highly sophisticated and extremely technologically advanced vessels. Adequate skills of all workers in the maritime industry are a requirement for good and efficient management of technologically advanced vessels and systems. The education of seafarers was improved during years and will still have to be improved to be in line with the progress of technology that changes from year to year.

EMPLOYEE TRAINING IN BRODOSPAS PLC

Brodospas was founded in 1947 with the task of cleaning Croatian ports, shipyards, and waterways from the numerous remnants of the Second World War, which were a hindrance to safe sea navigation. The company's headquarters were first in Rijeka, but in the mid-1950s they moved to Split. This change led to the development of a series of maritime technical activities: underwater activities, diving operations, salvage of sunken and stranded vessels, lifting and transferring heavy loads, and towing of vessels between the Adriatic ports and in the world's oceans. Brodospas then focused on specialized marine-technical services for offshore drilling platforms, as well as for cargo transportation.

To achieve the most favorable results in the performance of the activities for which the company was established, the Rulebook on the Internal Organization established a work organization that ensures the rational, economic, and efficient flow of work procedures and functions, the division of the total work, and the connection and development of parts and the entire business process, as can be seen in Figure 1.

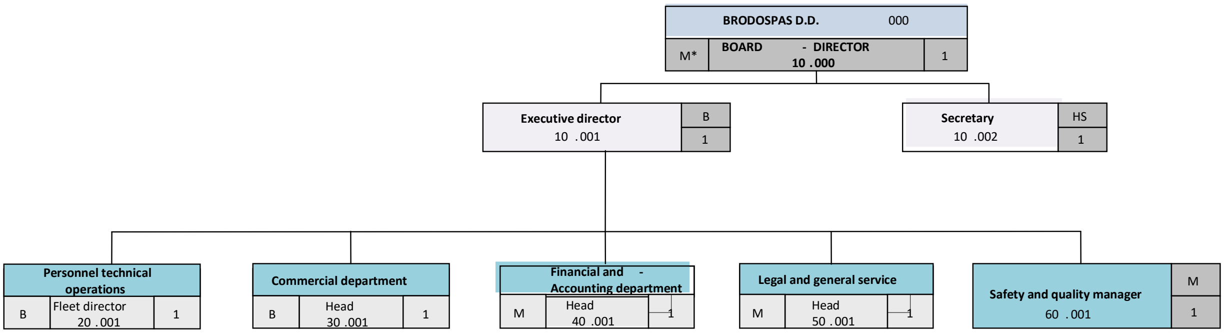

Figure 1. Internal organization scheme (Source: Brodospas p.l.c., 2008a)

*M=Master, B=Bachelor, HS=High School

Figure 1 shows the organizational structure of Brodospas. The company is headed by the Board and the Executive Director. Furthermore, there are 5 special departments, namely Personnel technical operations, Commercial department, Financial and accounting department, Legal and general service and Safety and quality manager.

Brodospas corporate policy is to ensure that:

- employee selections are in line with the needs of the organization,
- newly hired employees undergo the necessary training period,
- employees are involved in the continuous process of professional development.

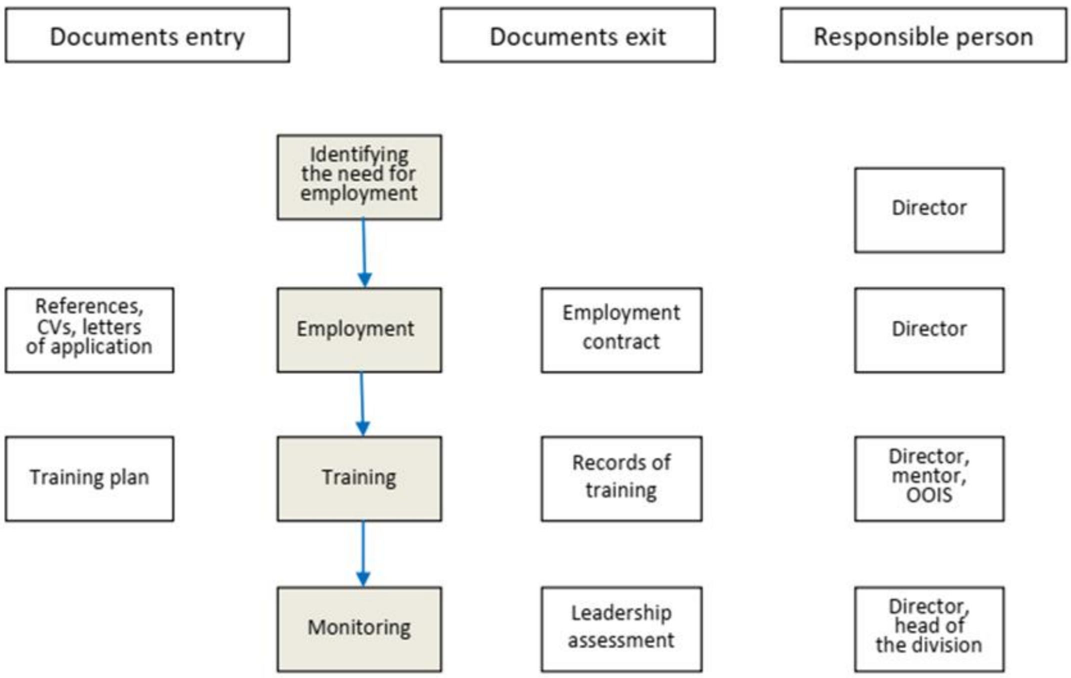

Figure 2. Flow chart of management procedures (Source: Brodospas p.l.c., 2022)

The management is responsible for selecting new employees and hiring them, as well as training new employees and training and supervising the work of all other employees. The heads of the departments are responsible for expressing the needs of new officers. The Fleet Director and the Chief of the Personnel Department are responsible for making decisions on personnel needs, interviewing seafarers, and making decisions on the renewal of seafarers' employment contracts. The Human Resources Officer is responsible for keeping documentation and for computer input of new employees.

The need for employment of the new staff is defined at company meetings where the need for employment and the potential employee's profile, professional training, work experience, etc. are discussed.

Qualifications, i.e., professional qualifications and ratings, as well as the necessary experience for a particular position on board, are prescribed by:

- STCW 1995 convention
- Rulebook on titles and ratings of crew members of merchant vessels of the Republic of Croatia,
- National regulations of the ship's flag state.

When hiring new employees, a job vacancy is advertised in the media (internet, newspapers, etc.), in the employment office, or recommendations are obtained about potential employees as they contact the company in search of employment. Word-of-mouth recommendations are obtained from former employers or from relevant agencies that have insight into potential employee's skills. Applicants send their CVs (fax, mail, in person) to the HR department. If Brodospas is interested in hiring an applicant, he/she is invited to the headquarters for an interview. The director and/or the head of the fleet and the head of the department, in which the employee is to be employed, will interview the applicant, and fill in the recruitment questionnaire. During the interview, the applicant is familiarised with the safety and quality policy and working conditions. The director selects the candidate who meets the set conditions. The decision on signing the employment contract is made by the director. All applications are kept in the order in which they are received for 2 years. The personal data about seafarers are stored electronically in the computer in the personnel records directory and in a personal file (Figure 2). The safety and quality manager is an authorized person as defined in Article 4 of the ISM of the Code and a representative of the management as defined by article 5.5.2 of the ISO 9001:2015 standard and overall responsible for safety, environmental protection and quality on ships and in Brodospas management.

Training and education of seafarers

Onboard training consists primarily of on-the-job training, with senior officers explaining the work. As part of the onboard training program, Brodospas sends its employees various publications and other materials related to training. A shipmaster must establish a training program that must include the application of Management Systems and the use of the required equipment. The program is prepared for a period of 3 months. A copy of the program must be sent to the safety officer. If the training includes the acquisition of the appropriate rating, seafarers are also obliged to take the appropriate examination and/or fulfill other obligations required for the acquisition of the rating. The training of seafarers is also carried out due to a change in work technology or the application of new technologies, i.e., the acquisition of a new vessel.

	TRAINING	**RESPONSIBLE**	**MONTH** ____________	**MONTH** _____________	**MONTH** _____________	**SIGNATURE**
1	PROTECTION AT WORK					
2	ENVIRONMENTAL PROTECTION					
3	EMERGENCY PREPAREDNESS					
4	CARGO OPERATIONS					
5	FIRST AID					
6	TOWAGE AND SALVAGE					
7	ANCHOR HANDLING OPERATIONS					
8	PASSENGER CARE					
9	SMS					
10	LSA					
11	ISPS CODE					

Table 1. Quarterly crew training plan (Source: Brodospas p.l.c., 2018)

Table 1. shows the three-month crew training plan implemented by the Master of the ship. In the table you can see all the trainings that are done on the ship like protection at work, environmental protection etc.

The Master must interest himself in the advancement and training of the Officers and ratings. The Chief Mate must be given every opportunity to gain experience in ship handling, commercial practice, and command situations. Other Deck Officers must be encouraged to improve their navigational skills with particular emphasis on radar plotting, position fixing and general watchkeeping techniques in clear weather and in reduced visibility as well as with cargo operations. Efficient and effective training must be given to cadets. All personnel must participate in all emergency drills and exercises. Realistic exercises must be devised for all emergency situations such as fire (particularly in dangerous or enclosed spaces), abandon ship, search, and survival techniques.

Brodospas calls for individual captains, engine managers, 1st deck officer, and engine officer, if it is necessary while they are on leave, to the headquarters at a certain time, where they are involved in active work. The training includes analysing and commenting on the reports received from the ships, working in the headquarters, and getting to know new procedures and legal provisions.

The Safety and Quality Manager is responsible for the implementation and preparation of these procedures. He/she must provide the necessary tools to conduct the training in a professional manner, such as training room, projector, TV and video, etc. for shore-based training and materials/manuals and documentation for training on board.

Getting to know each other on board

All crew members who are on board the ship for the first time and other persons (wives, children, inspectors, etc.) who will be on the ship must take a tour and familiarize themselves with the ship and safety procedures. The mutual familiarization should take place as soon as possible, but no later than 24 hours after setting sail. The familiarization is conducted by the 1st deck officer or another member of the Safety and Quality Committee.

The tour and familiarization of the vessel includes the following:

- meeting point in case of fire;
- the location of the lifeboat and muster station (each individual must become familiar with his or her muster station and duties in the event of an emergency);
- the location of key safety equipment items;
- the location of the hospital and first aid equipment;
- exits for escape from the engine room and living quarters;
- precautionary measures;
- the part of the Ship's Manual - General Operations that relates to safety and environmental protection;
- measures to prevent pollution on board;
- tasks and duties of each individual related to safety and environmental protection exercises;
- general tour of the ship.

Promotion of officers and crew

The promotion of officers and crew members is carried out in accordance with the needs of Brodospas based on a review of the ratings of individual officers and other seafarers. The proposal for the promotion of a seafarer is given by the master or the chief engineer and the personnel, technical and commercial services. The chief executive officer confirms the proposal, based on which a person is promoted to a new position. For promotion to the rank of a master and a chief engineer, consent by the executive director, the fleet director and the head of the commercial service must be obtained.

Crew cyber security training

Before being assigned to duty, the 1st officer and the chief engineer, or an officer designated by them, must brief and instruct all new crewmembers coming on board on safety principles in accordance with the Basics of familiarization with safety principles form. In addition, the 1st officer and the chief engineer officer, or an officer designated by them, must demonstrate their duties to all newly embarked officers and other crew members on their duties and familiarize them with procedures, equipment, and devices. Both must make sure that each new crew member correctly understands his or her assigned duties. A copy of each form must be given to a trained crew member.

Shipboard systems that use digital technology to control or monitor operations (Operation Technology - OT) and shipboard computers used for data processing and communications (Information Technology - IT) may be the target of a cyberattack or failure. Continuous training and awareness of crew members and office staff are key elements to mitigate and effectively address cyber risks.

Brodospas offers initial cybersecurity training that is mandatory for all crew members and shore-based employees. Training is organized on shore or on board, with mandatory records of attendance in accordance with the relevant parts of the SOM and SMM.

For new employees (in the headquarters and on board), cyber security training is a part of the induction training.

The training includes:

- The context of cyber security in ISM,
- IMO regulatory framework for cyber security- resolution and guidelines,
- Understanding the functional elements of cyber security,
- Understanding cyber threats and risks,
- Understanding personal responsibility and safe cyber behavior, e.g., an awareness of
  - Risks associated with e-mail and safe behavior.
  - Risks associated with the internet use, including social media, chat forums, and cloud file storage, where the movement of data is less controlled and monitored.
  - Risks associated with using personal devices.
  - Risks associated with the installation and maintenance of software on the organization’s hardware using infected hardware (removable devices) or software (infected package)
  - Risks associated with inadequate software and data security practices when virus protection or authentication checks are not performed.
  - Protection of user data, passwords, and digital certificates.
  - Cyber risks associated with the physical presence of outsourced personnel, e.g., third-party technicians working on devices without supervision.
  - Detection of suspicious activity or devices and how to report a potential cyber incident.
- Understanding how to implement preventive maintenance routines such as virus and malware protection, patching, backups, and incident response planning and testing.

- Service provider procedures for protecting removable media before connecting to the ship's systems.

Logs

The tour and familiarization of the ship and the briefing of persons boarding for the first time must be recorded in the official ship's logbook. The training program and training records, as well as Basic familiarization with safety principles and Special familiarization on board forms, are kept in binders. The retention period is 5 years for the program and records and for the forms until the crew member disembarks the ship.

TRAINING AND EDUCATION IN THE HEADQUARTERS

A new employee goes through a training period during which the following activities are carried out:

- introducing the employee to the company (mentor),
- introducing the employee to his or her work duties (mentor),
- “side by side” training with an employee selected by the company manager (mentor),
- continuous monitoring of the training process by the management.

The control of the effectiveness of the training period is carried out through the analysis of the daily monitoring of the training process based on the verbal report of the mentor. After the training, the management places the employee on a permanent contract, which allows him to work independently. All other employees are subject to a continuous training process to which special attention is paid. Depending on the needs (by profession), the QHSE manager proposes an annual training plan for the employees, which is approved by the management, and the completion of the training is registered in the employee's personal file or a certificate of completed training is attached.

EMPLOYEE EDUCATION 2021.						
DEPARTMENT	**DATE**	**COURSE**	**PLACE OF EVENT**	**Certificate Name**	**No**	**FUNCTION**
QHSE; FINANCIAL AND ACCOUNTIG	24.02.2021	Support for the climate neutral vision Europe until 2050	Ministry of the Economy WEBINAR	NIL	3	QHSE;Financial director
QHSE	09.03.2021	Open-es: Workshop	ENI WEBINAR	NIL	1	QHSE
QHSE	24.03.2021	Obligations of the EU climate policy 2021-2030 EU Funds: Reconstruction and Recovery Plan; new investment period New Law on Waste Management	HGK-SPLIT WEBINAR	NIL	1	QHSE
QHSE	08.06.2021	Role of the DPO according to EU GDPR	EU GDPR ACADEMY WEBINAR	NIL	1	QHSE
QHSE	16.09.2021	The carbon intensity indicator (CII) – a closer look	DNV-GL WEBINAR	NIL	1	QHSE
Technical department	08.12.2021	Fit for 55 and changes to the ETS directive	Mare Nostrum Webinar	NIL	1	Inspector of the ship
Technical department	16,17.11.2021	METSTRADE Innovation fair.	Amsterdam	NIL	1	Technical department
TUGBOAT	16.11.2021	INTERNAL ED PRED:QHSE	ALTAIR	NIL		ALL THE CREW
TUGBOAT	17.11.2021	INTERNA ED PRED:QHSE	SMJELI	NIL		ALL THE CREW
TUGBOAT	13.12.2021	INTERNAL ED PRED:QHSE	ALKAID	NIL		ALL THE CREW
TUGBOAT	16.12.2021	INTERNAL ED PRED:QHSE	RIGEL	NIL		ALL THE CREW

Table 2. Employee education 2021 (Source: Brodospas p.l.c., 2022)

The table shows the annual education of employees on ships and in the headquarters in 2021. All education details are displayed, from time, place, department, course, certificate, etc.

Through the implementation and monitoring of positive regulations, constant training of ship crews and employees in the Directorate and at authorized Institutions/Centers and continuous internal training in the Brodospas is possible achievement of system progress goals. During 2021, due to the impact of the pandemic, most training is conducted online.

Brodospas will undertake necessary measures to enable all shipboard personnel to improve their personal professional skills.

Monitoring of employees' work and development

Brodospas monitors and evaluates work and behavior of all crew members while they are on board. Before boarding, the Human Resources Department must inform each crew member that their work will be monitored and assessed at the end of the contract or at disembarkation.

Crew members are assessed upon disembarkation using the elements of the Seafarer Assessment form, and others as needed (promotions, violations of work discipline, etc.). The Fleet Director, the Heads of the Personnel and Technical Departments, and the Head of the Commercial Services are responsible for assessing the master and the chief engineer. The assessment is made once a year. The members of the deck department are assessed by the master, and members of the engine department by the chief engineer. The assessment is co-signed by the master. The assessment is made according to the elements from the Seafarer Assessment form. The Fleet Director gives the final grade using the same form. After disembarking from the ship, the Personnel Department may invite the master and the chief engineer to the headquarters, where a meeting is held with the people who monitor their work.

Human resource development involves raising the level of knowledge, skills, and abilities of employees in a maritime company. Not only the employee is interested in his/her personal development, but also the company is interested that its employees acquire a higher level of knowledge and skills.

The head of the HR department must analyze seafarers' assessments. The result of the analysis may be the development of a new procedure or the modification of an existing procedure, instructions, or the introduction of other employees to an event or action with the aim of improving Brodospas business. The Fleet Director reviews the assessment or individual events with other individuals evaluating the master, the chief engineer, and other crew members, as needed, and jointly takes appropriate action to improve and enhance safety, quality of work, expertise, and discipline. The head of the HR department must analyze assessments and prepare the results of the analysis for the management assessment meeting.

CONCLUSION

This paper focuses on people, who are the only living segment in business that has certain knowledge, skills and abilities and cannot be copied as material resources. They are the main driving force of entrepreneurial activity and form the basis for the survival and development of the company. Therefore, it is necessary to constantly improve their work skills, which is achieved through various training programs. Great competition does not allow carefree business; therefore, it is necessary to continuously invest in the training and development of employees. The training process is complex, as it involves a series of activities, from the identification of training needs to the evaluation of the results of the conducted training. For training to be carried out well, it is important to have prerequisites for the existence of a training policy, as well as an appropriate organization for the implementation of this policy. Training is a demanding process for the company and for the individual, but it brings multiple benefits for both parties. In addition to training, investment in education is also important. Companies that invest in training and education are significantly more successful than other companies. Corporate investment in training and development provides a competitive advantage, requires planning and monitoring of results, and improves work performance. It is extremely important that an organization is familiar with and properly applies all segments of employee training.

This paper presents the process of staff training in Brodospas Company. The company tries to keep up with the trends in the world and therefore invests in staff training. Due to the frequent changes in the industry, it is very difficult to find an employee who possesses all the qualities required to perform the tasks in the company, so regular staff training is necessary. The formal and additional education system should ensure the training of new and the continuous development of existing employees in the maritime sector. Considering the strong competition in the market, maritime personnel must be highly trained. Many seafarers have recognized the opportunities of the free market and are aware of the importance of investing in knowledge and training through additional programs. Thanks to an appropriate and well-developed human resources management system, maritime companies can successfully meet the challenges of competition, and the key to success is a motivated, trained, and dedicated workforce. Since the management of human resources is the basis for achieving a competitive advantage, Brodospas company gives particular importance to the development in this area.

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Port Infrastructure Construction Projects for Sustainable Intermodal Passenger Transport in the Port of Split

Josipa Bukarica[1], Vice Mihanović[2], Mihaela Bukljaš[3]

Road congestion is a principal problem, especially in port cities. It wastes passengers' time and consumes more fuel than other modes of transport, making it environmentally unsustainable. The number of vehicles passing through the Port of Split increased two and a half times in the last two decades. Vehicle traffic to the City Port Basin is one of the leading causes of traffic congestion in the city centre and environmental pollution. In the latest two decades, the Port of Split Authority doubled the operational area in the City Port Basin to allow for optimal traffic flow. There are also potential challenges due to the expected significant growth in vehicle traffic. Intermodal transport could solve the problem of road congestion, and ports could play a notable role in this process. The paper examines the hypothesis of whether port infrastructure construction projects by the Port of Split Authority contribute significantly to sustainable intermodal passenger transport in the Port of Split, the City of Split and Split-Dalmatia County. The methods used are case study and descriptive statistical analysis. The paper could provide information and initiatives in the transport sector, especially maritime transport, and propose topics for academic discussion. The projects in the Port of Split shorten the waiting period for vehicles and reduce fuel consumption to be more environmentally beneficial than today. The Port of Split Authority has already used and intends to continue to use all available resources, including the port area, to shift traffic from road to sea through the construction of new port infrastructure for RoRo vessels and trucks in the Stinice area and catamarans in the Resnik area. These efforts can only make the optimal contribution with synergy with other stakeholders. These include the state-owned company ''Hrvatske ceste'' for better access roads, the railroad company - ''Hrvatske željeznice'' for the railroad network expansion to the Split Airport and shipping companies, which must be ready to include new lines with enough vessels. Under the current circumstances, the results show that the construction projects of the Port Authority Split contribute to sustainable intermodal passenger transport in the Port of Split, the City of Split and Split-Dalmatia County.

KEY WORDS

Passenger port, Maritime traffic, Port infrastructure, Sustainable development, Intermodal transport, Motorways of the sea

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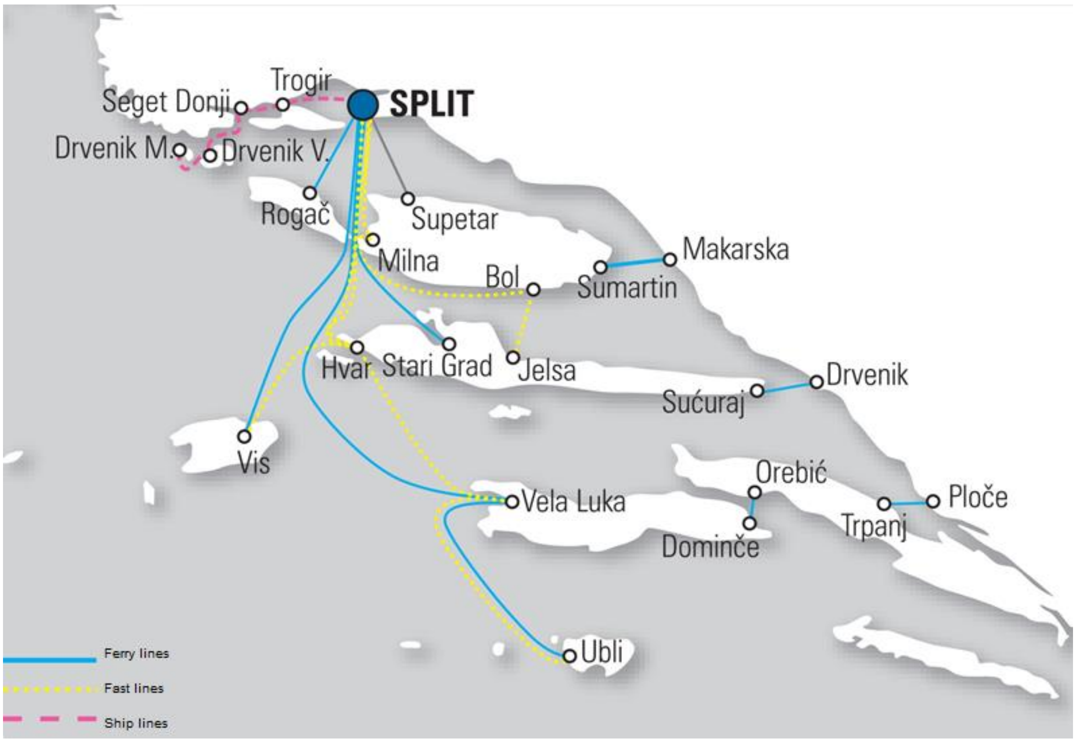
INTRODUCTION

The Port of Split Authority is a non-profit legal person established by the Government to operate, construct and use the Port of Split, a port of special (international) economic interest for the Republic of Croatia. There are six functionally different port basins: the City Port Basin and Kaštela D Basin are used for passenger traffic. In contrast, the Vranjic-Solin basin and the Kaštela B and C basins are used for cargo traffic. The Komiža Basin will be used as a fisheries port once the new infrastructure is constructed. The Port of Split is the most significant transport hub connecting Central Dalmatian islands to the mainland. The connection with Port of Split is a prerequisite for maintaining the economy, quality of life and development on the islands of Brač, Hvar, Šolta, Vis, Lastovo, Korčula and Drvenik Veli and Mali. Around 45 thousand inhabitants of these islands are connected to the mainland exclusively or predominantly through the port of Split. The port is crucial for developing tourism in Split and the region and is a key influence on the local and regional economy. The Port is a part of intermodal transport infrastructure via the Split – Zagreb railroad, the Split Airport and the A1 motorway between Split and Zagreb.

Map 1. Port of Split basins (Port of Split Authority, 2023).

The Port of Split Authority expects an increase in the number of tourist trips to Split, as there is a particular growth trend in tourist traffic in Split, as the city has become a popular tourist destination and not just a transit centre as before. Split is now a place where tourists stay and from where they make day trips. It is, therefore, necessary to plan the development of the port infrastructure, taking into account the previous experience of traffic growth, so that there is no further traffic congestion in the Port of Split but also in the city of Split. However, it is also important to consider a broader framework in which the Port of Split operates. The areas that are not in the immediate vicinity of the

City Port Basin in Split, including the towns of Solin and Kaštela, should also be considered to reduce traffic congestion. The development of intermodal transport seems to be an obvious solution to the traffic congestion problem. This paper discusses the theoretical framework of intermodal transport with particular reference to maritime transport and ports and evaluates the efforts of the Port of Split Authority to solve the congestion problem by promoting intermodal transport.



Map 2. Local passenger traffic lines (Port of Split Authority, 2023).

PORT OF SPLIT TRAFFIC VOLUME

The Port of Split is the largest passenger port in Croatia and is one of the twenty largest ports in the EU. Over the past two decades, the port has experienced tremendous growth, with passenger traffic more than tripling, which has had a significant impact on tourism and the economy in the region. The passenger traffic grew to 5.6 million annually in 2019, while in 2022 it was 5.3 million. Vehicle traffic has more than doubled in two decades and now stands at 916 thousand vehicles per year passing through the port, surpassing 2019, the peak year before COVID-19 crisis. The growth trend has averaged five percent per year in recent years and is expected to remain in this range (Port of Split Authority, 2023).

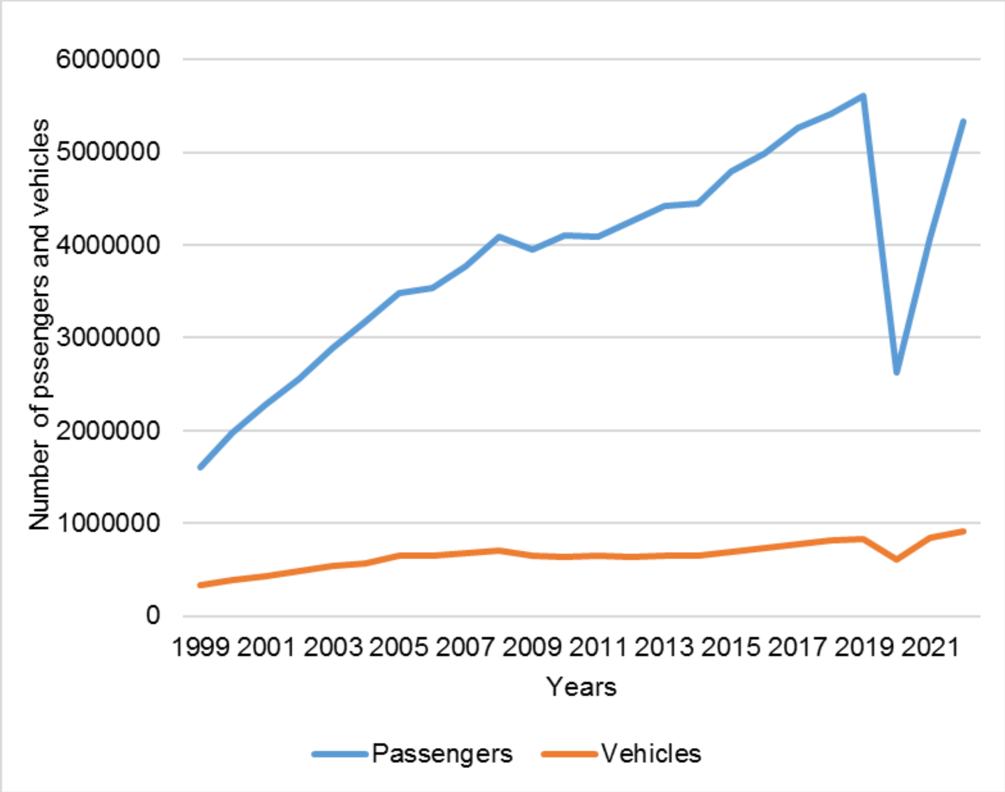


Table (Graph) 1. Number of passengers and vehicles in the Port of Split (Port of Split Authority, 2023).

The main problem of the port of Split is to cope with the large volume of traffic when loading and unloading vehicles in the peak summer months when the traffic is at its highest point. Almost forty percent of passenger traffic is handled in July and August, while almost two-thirds of annual passenger and vehicle traffic is handled from June to September (Port of Split Authority, 2023). Traffic jams near the City Port Basin in the centre of Split have been a major cause of the inconvenience for local citizens, passengers and tourists.

The traffic jams are not primarily due to the traffic infrastructure in the port area but rather to deficiencies in the traffic infrastructure on the approaches to the port area. However, congestion can be expected in the summer months even with additional development of port and access infrastructure. It would be too expensive and likely not feasible from an urban planning perspective for traffic infrastructure to be built to accommodate peak loads. The state-owned company "Hrvatske ceste" is working with the Port of Split Authority and other stakeholders to reduce congestion on access roads during the summer season by creating additional road routes (Port of Split Authority, 2023).

The Port of Split Authority has mitigated the challenges caused by traffic growth by making significant investments in port infrastructure, more than doubling the operational area. Two decades ago, the operating area in the city basin of the Port of Split, the largest port basin, was approximately 20,000 square meters. However, the current operating area is 44,000 square meters. This is due, among other things, to the expansion of St. Peters Pier and St. Domnius Pier, Piers 23 and 24, Pier 20, the construction of two outer piers on the breakwater and the expansion of the Eastern Coast (Port of Split Authority, 2023). This was done without requiring a single complete reconstruction of the port infrastructure. Instead, the port infrastructure improvements were made gradually so as not to disrupt traffic flow.

THEORETICAL FRAMEWORK FOR SUSTAINABLE INTERMODAL PASSENGER TRANSPORT SOLUTIONS

This research focuses mainly on passenger transport and the Ro-Ro shipping segment, where specific definitions are considered for sustainable intermodal transport. However, there is no general agreement on the definition of intermodal transport, especially passenger transport. However, Žgaljić et al. (2015) provided a working definition of intermodal passenger transport - the transport of passengers without significant interruption in the successful use of two or more modes of transport (Žgaljić et al., 2015).

There is general agreement that ports could be key players in intermodal passenger transport. The key elements in the maritime part of intermodal passenger transport concepts are motorways of the sea, short sea or coastal shipping links. The consensus is that roads are congested. Road transport is the least fuel-efficient and, thus, the least environmentally friendly compared to the other transport sectors. Therefore, transport, in this case, passenger transport, should be shifted from roads to sea and railroads where possible. Jugović points out that short sea shipping is a term used to describe the transport of cargo and passengers between ports on waterways that cover at least part of the sea, particularly in the Baltic Sea region, Scandinavia, Iceland, Western Europe, the Mediterranean Sea, North Africa, and the Black Sea (Jugović et al., 2010).

Violić explains that the congestion of modern road transport is mainly caused by passenger traffic and not only by cargo traffic. The concept of motorway of the sea has its origin in cargo traffic. Therefore, Violić argues, it is necessary to consider its qualities and economic impact in the context of maritime passenger transport. Although intermodal transport is ecologically the most optimal of all transport modes, there is an argument that it may be rather expensive. Violić notes that although the idea of a coastal link or short sea shipping was motivated by the excessive increase in congestion, it may increase transport costs while decreasing the quality of transport services. Violić points out that this concept is directly related to the transport of cargo and passengers by sea over shorter distances and includes both international and domestic maritime transport to nearby islands, river and lake systems (Violić, A., 2014).

At full capacity, maritime transport is more fuel efficient and cheaper than road transport and other transport sectors, with significantly lower greenhouse gas emissions such as CO_2 per ton/kilometre or passenger. Violić argues that the purpose of relieving congested roads through maritime transport is not limited to port connections but also promotes intermodal transport. Violić points out that coastal shipping reduces both the number of vehicles on the roads and energy consumption, air pollution, traffic accidents, and social costs, while also contributes to shipbuilding. Coastal transport significantly reduces environmental pollution and makes accidents at sea less likely. (Violić, A., 2014).

Violić further argues that the establishment maritime motorways of the sea system, such as intercity ships and high-speed lines between cities and islands, would require cost-effective use of existing infrastructural and suprastructural potentials and capacities. In addition to ports, there are vessels that could serve the motorways of the sea or coastal shipping, such as catamarans, which have been underutilised (Violić, A., 2014). However, this does not exclude potential infrastructure investments in ports, which are often necessary for ports to play their role in the intermodal system.

Intermodal transport is also held back by a lack of coordination between transport sectors. Jugović argues that IT systems could stimulate the use of intermodal routes such as shipping and railroads as current situation benefits road carrier companies with a simple but much less environmentally acceptable transport model for moving goods and people. IT systems would help intermodal transport to be simple, financially and organizationally competitive (Jugović et al., 2010). An appropriate IT system could integrate ticket purchase and cargo handling, as well as timetables of operators in various transport sectors.

Given the growth of passenger traffic and increasing road congestion, there is definitely a potential for intermodal passenger transport development, with crucial role of the maritime sector. Notteboom states that a port is a hub where sea and inland transport lines meet and intertwine in an intermodal place of convergence (Notteboom et al., 2020). Forte notes that cargo traffic has increased considerably, especially in the Mediterranean. The author also states that passenger traffic is significant in certain areas, such as between Sweden and Finland and the Mediterranean. Forte claims that the competitiveness of a port should be directly related to the existence of transport services in combination with other nodes of the national route network (Forte et al., 2014). Renne suggests that more research is needed on best practices related to integrated passenger and cargo transport solutions in congested cities near major ports, including land use around ports. (Renne, J., 2018).

Better coordination between transport sectors including digital technology is a necessity for intermodal transport to flourish. The IT solutions that help find the best options to move people while ensuring sustainability and the lowest greenhouse gas emissions should include both infrastructure operators and transport companies.

DISCUSSION

Hypothesis: Port infrastructure construction projects of the Port of Split Authority contribute significantly to sustainable intermodal passenger transport in the Port of Split, the City of Split and Split-Dalmatia County.

The projects prepared by the Port of Split Authority will significantly reduce waiting time and travel distance for cargo and passenger vehicles. According to the calculations of the Port of Split Authority based on the EMEP/EEA air pollutant emission inventory guidebook, the Handbook on External Costs of Transport, DG MOVE of the European Commission and shipping companies, the fuel consumption data can be approximated as follows. The average idle car fuel consumption is 0.6 litres per hour, and the average car fuel consumption while driving is 0.085 per kilometre. The average idle lorry fuel consumption is 3.2 litres per hour, while the average lorry fuel consumption while driving is 0.24 per kilometre. A RoRo vessel, i.e. ferry, consumes an average of 35.6 litres of fuel per nautical mile (Port of Split Authority, 2023).

The Project of reconstruction and expansion of the Northern Port in the area of the Vranjic-Solin Basin (Stinice area), led by the Port of Split Authority, envisages the expansion of the port infrastructure of the Vranjic-Solin Basin, which would significantly shorten the road route and shift the transport of trucks at least partly by ferries. The project aims to build a new operational coastl for the transport of trucks with deliveries to the islands and back, moving them from the port basin in the centre of Split. Six new RoRo berths and an auxiliary berth will be constructed in the Stinice area, enabling the Port of Split Authority to load and unload cargo trucks for the islands.

It is expected that in the next few years more than one million vehicles, including more than 200 hundred thousand trucks, will pass through the Port of Split. This project will help to avoid congestion in the Split City Port Basin by diverting more than a third of the traffic to and from the City Port Basin to Stinice. This project will shorten the waiting time for passenger vehicles boarding and disembarking, which will speed up the traffic of these vehicles in Split and reduce their engine idling time (Port of Split Authority, 2023).

The distance from the motorway to Stinice is three kilometres shorter than to the City Port Basin - 15.7 kilometres compared to 18.7 kilometres and four minutes shorter without traffic - 15 minutes compared to 19 minutes. This estimated time does not consider the congestion on the road. The sea route to the Stinice location instead of City Port Basin is seven nautical miles and about thirty minutes longer. The three kilometres shorter route to Stinice for trucks compared to the route to City Port Basin will result in greater fuel savings than the fuel consumed by RoRo ships because of the seven nautical miles longer sea route, and thus will cause less congestion. Therefore, compared to fuel savings from the trucks that will be using the Stinice area port infrastructure, the amount of fuel used by RoRo ships, i.e. ferries will be significantly lower.

Vehicle operating costs will be reduced by decreasing unnecessary engine hours, and vehicle boarding and unboarding times will be shorter. The project is consistent with the established functional specialisation of the port basins of the Port of Split. The estimated cost of the project is 49 million euros, co-financed by EU funds. Most importantly, the Project will significantly contribute to shifting traffic from road to sea (Port of Split Authority, 2023).

The same principle of shifting traffic from roads to sea applies to the goals of building new infrastructure with the Project Maritime and passenger Terminal Resnik-Divulje in the port area of Kaštela D Basin - Resnik near Split Airport, with an impressive 2.9 million passengers in 2022. It is planned that this Port Basin will be used for high-speed lines such as catamarans for passengers arriving at or departing from the Split Airport, relieving road traffic by transferring it to the sea. It is located 22.3 miles from the City Port Basin in Split. The sea distance between the City Port Basin in Split and the Port Basin Resnik - Kaštela D near Split Airport is 11.2 kilometres or seven nautical miles. Here it is clear that the fuel and time savings, as well as greenhouse gas emissions, would be even greater than in the case of the infrastructure in the Stinice region (Port of Split Authority, 2023).

In Resnik, there are forty metres of coast, and after the implementation of the project, there will be a total of 198 metres of operational coast. Currently, there is one berth for catamarans, while after the completion of construction, there will be four. The estimated cost of the project is 2.5 million euros. It is co-financed from European Union funds (Port of Split Authority, 2023).

In order to enhance the flow of passengers and vehicles in the City Port Basin, in the area west of the entrance to the "outer berths" next to the breakwater, a new international Passenger Terminal in the City Port Basin will be built. The Project will involve demolishing existing buildings and building new one. Some prominent public and traffic facilities, such as the Schengen border crossing, will be moved there. Many of these are located at St. Domnius Berth in the City Port Basin in the Maritime and Passenger Terminal building. The operating area on the Pier of St. Dominus of about 14,000 square metres could be used for local traffic instead for international traffic. Thus the Project will and reduce waiting times for vehicles by increasing traffic flow, which will less idling of vehicle engines. The estimated value of the project is 15 million euros. It will be co-financed by the EU (Port of Split Authority, 2023).

In addition, the Project of the reconstruction and expansion of St. Peter's Pier in the City Port Basin is currently being prepared. The project involves increasing the operational area by 5,350 square metres and adding two RoRo ramps for ferries at St. Peter's Berth from the north side, bringing the total to five. There will be two berths of hundred meters, while other berths will be 108 meters, 147 meters and 188 meters long. There will be five ramps, and one will be thirty meters wide, while the others will be twenty meters wide. This will help streamline vehicle traffic in the City Port Basin in Split and reduce vehicle waiting times as well as fuel consumption. The expected cost of the project is approximately 14 million euros, which will be co-financed by EU funds (Port of Split Authority, 2023).

It could be argued that the Port of Split Authority has used or intends to use all available port area to shift traffic from road to sea and also reduce waiting times for vehicles, both of which would reduce fuel consumption. However, although the adopt the same approach, they should keep the pace despite all the objective difficulties they face.

CONCLUSION

The goal of the Port of Split Authority is to work in accordance with the strategic determination of the European Union and the Republic of Croatia to shift as much traffic as possible from road to sea if possible, or to railroads. Therefore, the Port of Split Authority follows these guidelines in its strategic planning. The reason for this lies in the fact that maritime transport is the most environmentally friendly mode of transport compared to other modes of transport because it uses less fuel than other modes of transport.

The Port of Split Authority, as an individual stakeholder, makes the best possible use of its capacities in terms of the use of the port area and the financial resources available for the implementation of intermodal sustainable transport, mainly from EU funds. The projects of the Port of Split Authority contribute to the protection of the environment through reduced fuel consumption, time savings in traffic, and waiting time for passengers. The construction of new port infrastructure in Resnik would enable shorter passenger traffic route to the City Port Basin in the centre of Split and the islands, by shifting some of the traffic from the road. The new infrastructure in Stinice would result in a seven nautical mile longer sea route for RoRo vessels transporting trucks to and from the islands. On the other hand, the shorter road route for trucks to Stinice compared to the road route to the City Port Basin more than offsets the higher fuel consumption of the RoRo vessels. In addition, the option of extending the railroad line inside the Vranjic-Solin Basin from the Northern Port to Stinice is envisaged.

In terms of integration of the intermodal transport system, it is crucial that other stakeholders operate in the same manner, despite that fact that they often face serious challenges. For example, the construction of new infrastructures in Stinice and Resnik, together with the connection of Split to the Split Airport by railroad, would have a significant synergistic effect. The Croatian railroad company ''Hrvatske željeznice'' is working on a solution for the completion of the railroad line from the City Port Basin in Split to the Split Airport, but for this, it needs to find a solution for the line with the City of Kaštela, which is located between the Split Airport and City of Split. In addition, the Port of Split, the Split Airport, 'the 'Hrvatske željeznice'', and shipping companies such as the ''Jadrolinija'' could establish a one-stop-shop ticketing system, including joint baggage handling, and synchronise schedules as much as possible to reduce waiting times. The ''Hrvatske ceste'' company should complete the solution for optimal port entry and exit road to the City Port Basin, reducing congestion on the state access road outside the City Port Basin. The company should also work towards completing better port entry and exit road next to the future port infrastructure in Stinice as well as towards completing an optimal the port entry and exit road between Split Airport and the Resnik - Kaštela D Port Basin, for instance for shuttle buses. Shipping companies must also be ready to introduce new lines to the new port infrastructure, possibly with subsidies from the Coastal Liner Services Agency.

In the Split region, with neighbouring municipalities, the Port of Split Authority and other stakeholders are moving towards the development of sustainable intermodal transport, albeit at different paces. Thus, it could be concluded that the hypothesis is mainly correct. Under the current circumstances, the port infrastructure construction projects of the Port of Split Authority contribute significantly to sustainable intermodal passenger transport in the Port of Split, the City of Split and Split-Dalmatia County. However, there is still much to be done by both the Port of Split Authority and the other stakeholders, in close mutual cooperation. The Port of Split Authority has a number of infrastructural projects to complete. It can be stated that the Port of Split Authority is making an important contribution to intermodality and sustainability goals. In cooperation with the stakeholders, the goals could definitely be achieved successfully. Such cooperation would make the Port of Split a smart port. Certainly, there are opportunities for digitalisation and coordination for all the stakeholders that would benefit the passengers. At the moment, the functional integration of the various modes of transport needs to be significantly improved. However, there has been a powerful momentum towards enhancement of the current state of play.

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Management of Business Processes in a Maritime Company

Marina Brodarić Ivačić[1], Maja Krčum[2], Anita Gudelj[2]

In today's world economy, which under the influence of globalization expands markets, but also brings competition closer, many companies are looking for ways to increase efficiency and reduce business costs. As a sequence of events, the acceptance of the process approach, as a key element of business, appears. Process orientation helps companies think through how their activities and tasks add or subtract value for consumers and adds a new dimension of complexity to organizational structures. The importance of process orientation best reflects the conclusion of the Gartner consultancy: "Business process management wins the triple crown: for saving time, for saving money and for adding value". She also expands the business and emphasizes the importance of technology in designing a strategy that provides a competitive advantage. Finally, process management brings both short-term return on investments and long-term value on invested capital to the company. For all processes, jobs, and tasks in the shipping organization to be performed effectively and efficiently, and in order to see the complete picture of the organization and its environment, shipping organizations need to develop information systems and software products for processing transactions and resort to the synthesized combination and aggregation of data from of many separate, but unconnected, or inappropriately connected, systems. This work will show how the company Brodospas performs and organizes ship processes.

KEY WORDS

Business processes, Ship processes, Decision management, Information systems.

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INTRODUCTION

In the past decades, a large increase in the use of information and communication technologies can be observed in the transport department - including shipping. A process is a connected set of activities and decisions that is carried out based on an external stimulus to achieve some measurable goal of the organization (Bosilj Vukšić, Hernaus and Kovačić, 2008). It spends time and converts input resources into specific products or services of importance to the customer or user. For a company to achieve and maintain a competitive advantage on the market, it must efficiently and effectively manage its own resources and financial resources. Business Process Management (BPM) is a systematic approach to business improvement based on the design, measurement, analysis, improvement, and management of processes (Bosilj Vukšić, Hernaus and Kovačić, 2008).

According to Bosilj Vukšić, Hernaus and Kovačić (2008), business process management achieves:

- higher quality,
- shorter time,
- lower costs,
- improvement,
- reduced business risk.

Business process management can be characterized as a broader term, given that its determinants are process automation, process analysis, operations management and work organization (Van der Aalst, Rosa and Santoro, 2016). Today, the very concept of business process management is an integral part of every organization that wants to become and remain competitive. The efficiency of a process is measured by the time and costs required to convert the input values of a process into the output result. Every manager is responsible for some business process and should consider possible improvements that are needed so that the organization can better adapt to its business environment. Business processes are the nervous system of every company and that is why it is important to manage them. Business process management combines a managerial approach with appropriate technology to improve company performance. Informatization of the shipping organization can be defined as the application of computers and other IT and communication means and devices in the automation of information processes and flows and the automation of the information communication organization with its relevant environment.

MANAGEMENT OD BUSINESS PROCESSES

From a pragmatic point of view, business processes describe the way something is done in an organization. However, a single definition of a business process does not exist and depends on the context in which it is used. An extensive definition of a business process was presented by the authors Brumec and Brumec (2018), who defined it as a connected set of activities and decisions, which is carried out on external stimulus to achieve some measurable goal of the organization, lasts a certain time, and consumes certain resources, turning them into specific products or services of importance to the customer or user. Combining definitions and characteristics, it can be said that a business process is a structured, analytical cross-functional set of activities that requires continuous improvement. These are activities with a clearly defined beginning and end, during which value is created for consumers at more or less constant intervals (Vuković, 2019).

Business is a system of integrated processes. Bosilj Vukšić, Hernaus and Kovačić (2008) define the basic characteristics of business processes as follows:

- every process has a purpose,
- every process has an owner,
- every process has a beginning and an end,
- inputs enter the process, and outputs exit,
- the process is composed of sequentially feasible activities,
- based on the input and output of the process, it is easy to determine the success of the process,
- for the process to survive, it is necessary to have known internal and external suppliers and consumers,
- process improvement is inevitable.

Depending on the context in which the business process is mentioned, there are several classifications of the process. Each company represents a special case and must be viewed through the interconnectedness of business processes and their associated dimensions. No matter how special they are or think they are, all companies have a whole series of common processes and business dimensions:

- division by organizational structure,
- division by time intervals,
- division by territory,
- division by categories of products and services,
- division by suppliers and customers (Panian et al., 2010).
- Business processes can be classified into two basic groups:

1. Basic (primary, key, central) processes - create a certain value for the company, a set of all activities that take place to design, produce, promote, deliver, and support the production line.

2. Supporting (secondary) processes – enable the successful functioning of the basic processes. They should be included in a unique value chain, since only in this way is it possible to realistically monitor and calculate the costs and realized profits of the company (Panian et al., 2010).

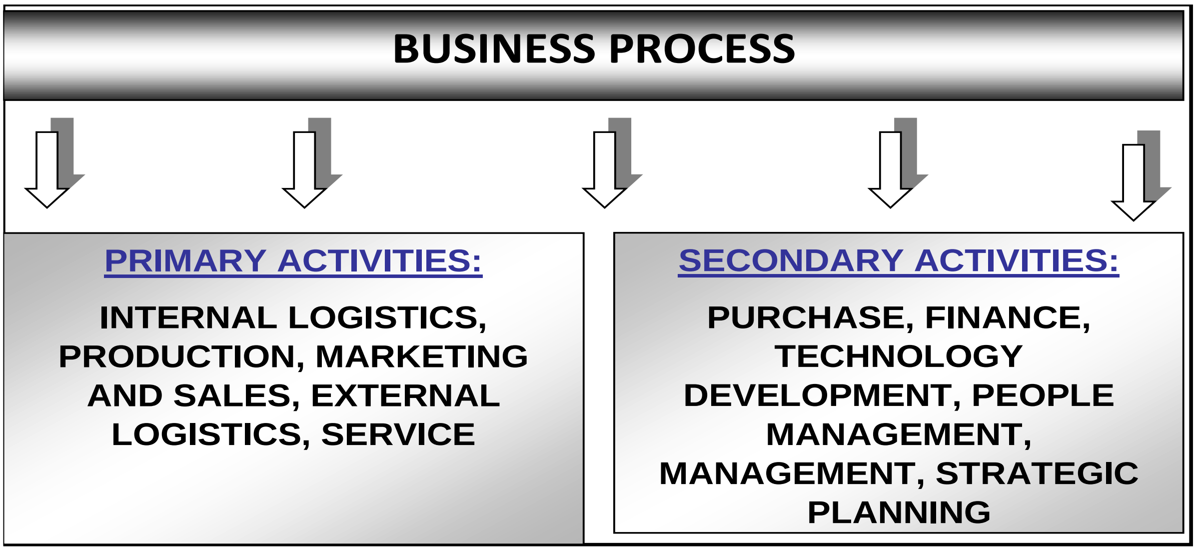

Figure 1. Division of business processes into activities according to Michael Porter (Source: Cingula, M. and Fabac, R., 2010.)

M. E. Porter can be considered the initiator of focusing attention on business processes, who presented the concept of the company as a value chain in the book Competitive Advantage: Creating and Sustaining Superior Performance from 1985. The value chain encompasses multiple business processes, from new product development and ordering to sales to the customer and post-sale support. According to Porter, the value chain consists of primary and secondary activities. All secondary activities must be included in a single value chain. Unlike primary activities, secondary activities do not generate direct value for the company but are necessary for its functioning.

According to the field of operation of processes within the organization, processes are divided into three different types:

- individual processes performed by individuals,
- vertical (functional) processes that are part of a functional unit or department of the organization,
- horizontal processes that pass through several functional units (Lagunda and Marklund, 2005).

For easier understanding of business processes and their divisions, the hierarchy of business processes is presented. It is divided into processes, sub-processes, activities, tasks, and steps. Subprocesses are groups of activities that characterize the company's activity, and tasks are subgroups of activities. Looking in more detail, certain tasks should be broken down into steps to perform them more efficiently.

The process is part of the value chain, and depending on the complexity, it can be divided into smaller parts, i.e., sub-processes, for example, procurement is divided into ordering, negotiation, contracting, receiving, storage, payment, etc. An activity is the smallest part of the process that makes sense to model and display diagram. An activity can represent a relatively complex work task that does not need to be considered in detail for the needs of a specific project, but also the simplest operation that cannot be broken down further and is called a step (Bosilj Vukšić and Kovačić, 2004).

Business around the world is under enormous pressure from high competition, a rapidly changing business environment and increasingly demanding customers. There are three trends that contribute to this pressure, namely:

- globalization,
- technological, legislative, and regulatory changes,
- increasingly agile and flexible organizations (Bosilj Vukšić and Kovačić, 2004).

All these pressures have created an interest in analyzing how business can become more flexible and effective. Every organization is defined by many business processes that describe the way the organization conducts its business. Some processes are crucial for the organization's operations and constitute its comparative advantage. Some are not so crucial but are still essential for its functioning. Business process management relies on the business approach of change management due to the improvement of business processes with the goal of achieving business goals, whereby changes encompass the entire life cycle of the process: from definition and modeling to execution, analysis, and optimization of the process.

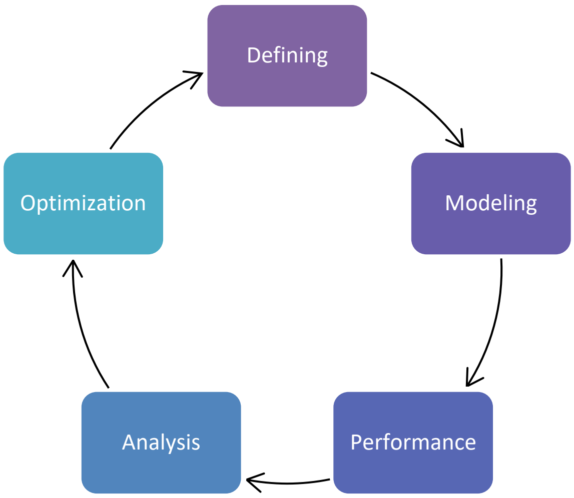

Figure 2. Life cycle of business process management (Source: Bosilj Vukšić, V., Hernaus, T. i Kovačić, A., 2008.)

Figure 2 shows the life cycle of business process management. The process consists of five phases, in chronological order: definition, modeling, execution, analysis and optimization of the business process. Defining business processes is the first and most important step in which business process owners play an important role. Their knowledge of business processes and interactions between them are key to achieving a company's competitive advantage. The next stage is business process modeling, which includes collecting enough details to understand the functioning of the business process and displaying the business process using a flow diagram. The business process is then implemented and executed, and the key indicators of the company's performance are followed by monitoring. Unexpected behavior, non-optimized flows and bottlenecks are identified through the analysis, and the business process is optimized based on this.

Alotaibi (2014) claims that the implementation of quality process modeling brings many advantages; above all, the improvement of organizational performance, the identification of irregularities that are present, and the engagement of employees as a significant advantage.

MANAGEMENT OF SHIP PROCESSES IN THE COMPANY BRODOSPAS D.D.

Brodospas was founded in 1947, with the task of Croatian cleaning ports, shipyards, and waterways from numerous remains from the Second World War, which were a hindrance to safe sea navigation. The company's headquarters were first in Rijeka, but from the mid-1950s it moved to Split. Several maritime technical activities logically developed from this: underwater activities, diving jobs, retrieving sunken and stranded vessels, lifting, and transporting heavy loads, towing between Adriatic ports and then on the seas of the world. Brodospas then focused on specialized maritime technical services for offshore drilling platforms, as well as cargo transportation. The company Brodospas was taken as a case study as a maritime company with a long tradition of business that has a high-quality integrated management system in accordance with the requirements of the ISO 9001:2015, ISO 14001:2015 standards and the ISM code.

To achieve the most favorable results in the performance of work from the activity for which the company was founded, the Ordinance on Internal Organization established a work organization that ensures a rational, economical and efficient flow of work procedures and functions, the division of the total work, as well as the connection and development of parts and the whole of the business process.

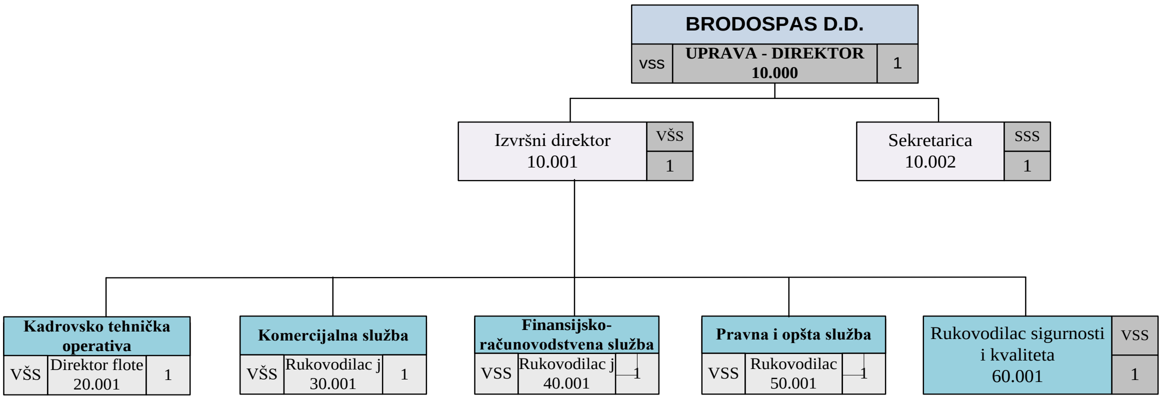

Figure 3. Internal organization diagram (Source: Brodospas p.l.c., 2008.)

For the implementation of the company's work process, in the technical sense, the Technical Service is a key factor, especially with the function of maintaining vessels, means and equipment in orderly function for use for commercial use. In this sense, technical works ensure the coverage of the basic responsibilities of each shipowner or shipowner, as the carrier of the navigation enterprise, by maintaining facilities and equipment in orderly useable condition, while respecting technical regulations and rules of the profession in terms of equipment. The function of technical affairs deals with the increasing technical requirements of commercial ship users, focused on the quality of services and the safety of work performance, and ensures the implementation of increasingly emphasized modern requirements for the protection of the environment, especially human lives, in activities with emphasized risks, such as shipping, to reduce existing objective risks to a reasonable level.

In the complex of technical services, the basic groups of jobs refer to:

- planning and organizing current and investment maintenance of the company's vessels, assets, and equipment, including planning, and organizing all ship inspections (for class, annual and others), as well as all ship repairs, at ship repairers or in the organization of the company;
- on the basis of the function of monitoring the condition and needs of current and investment maintenance, assessing the need for technical improvements, in accordance with regulations and market requirements, as well as the needs of renewing the fleet and equipment, the technical service, in connection with other services, participates in creating plans and making decisions for investing in new purchases of ships and equipment in the technical sense and in this connection, in the selection of the most favorable bidders during the purchase, construction and reconstruction of facilities; management of construction, reconstruction, etc. in a technical sense;
- organizing the smooth functioning of the safety, quality and protection management system in its service and on vessels;
- proposing elections and maintaining relations with classification societies in the best interest of the business;
- electronic data processing (Rules on the internal organization of Brodospas d.d., 2008).

Business process management has an important task in contributing to the fulfillment of the organization's mission. Neglecting the business result and striving for its quality would call into question the fulfillment of the requirements of interested parties in the shipping business. Failure to fulfill a request for information may cause a disturbance that has the character of non-compliance in relation to the request of customers/users. Depending on the nature of the non-compliance and the intensity of the deviation from the target sizes (standard values) determined by the process documentation, the following may occur:

- excessive consumption of ship plant resources;
- delays in procurement of spare parts and their delivery;
- unnecessary costs (costs due to poor maintenance quality);
- dissatisfaction of the captain/owner of the ship
- financial loss caused by the unreliability of the long-term ship maintenance process (Batinica, 2007).

Management system of ship processes

The ship is a system with a unique goal function, so the system for managing the processes that take place on the ship must enable the optimal realization of that goal. The process management system has different tasks and, within the same process, accomplishes them according to different priorities. For this reason, the process control system consists of several subsystems divided according to the functions they perform:

- Management;
- Supervision;
- Management (in the narrower sense);
- Regulation;
- Protection (Batinica, 2007).

Since today's process management systems are based on microcontrollers, each of the above tasks is realized using computer technology.

A) Management of ship processes

The basic task of management is to manage the execution of ship processes. It used to be the task of the operator (man) only. Since man cannot have a direct insight into the process, nor can he directly influence it, so he does it through the management and supervision system, management does not supervise the process, but does it through the supervision system. Today, processes are conducted via computer. The basic composition of a system (its functioning) can be mathematically represented using algorithms. An algorithm is, therefore, a series of instructions for the operation of that system. The task of the algorithm is, first, to accurately display the entire process and break it down into the required number of sub-processes arranged in the correct order. An algorithm can be defined as a certain series of instructions, the execution of which will solve the set problem (in this case, the implementation of a certain ship process). At the same time, the instructions must be unequivocal, i.e., they must indicate the operation to be performed known to the executor. If a guidance algorithm is set for a ship system controlled by another ship system, then this process can be imitated using an algorithm that will be performed on a computer. In this way, shipboard processes can be managed using an algorithm on a computer.

B) Supervision of ship processes

The function of monitoring ship processes is in the service of better realization of other systems, such as regulation, management, guidance, etc. Each process is determined by physical quantities called indicators or process parameters. Process parameters consist of basic measurement quantities (temperature, pressure, speed, angle, etc.) that can be directly measured using sensors, from derived quantities obtained by processing one or more basic quantities. Process parameters are forwarded to the monitoring system via received process signals. Since several parameters are simultaneously monitored in ship systems, the computer system that enables this consists of several interconnected microprocessors. With the monitoring system, the decision to intervene in the process is not made by the system, but it only forwards high-quality and fast information about individual quantities from the process to other systems. The function of the monitoring system is to permanently supply information to other systems, to realize the management of ship processes. The monitoring system acts as a type of information system. It can be represented by the link man - process - man. It does not affect the process, but only forwards information about the process. Based on the information obtained, the process manager (human or computer) makes all decisions and performs any interventions. The number and variety of information is a special problem of monitoring ship processes. There is also a problem with visibility and availability of information at any time. For this reason, it is logical that digital data processing technology was first applied to surveillance, so process computers were first used in these subsystems. Through the implementation of microprocessor technologies at the level of system components and the realization of the ship's integral computer network, information about individual ship processes becomes available to all networked computers. This makes it possible for the information to be used in other processes, such as, for example, maintenance, in addition to managing ship processes. Given that maintenance costs are significant costs of the shipping company's business, solutions to minimize them are based precisely on the timeliness and accuracy of all relevant information, which is achieved through the implementation of an integral information monitoring system.

C) Management of ship processes

The term control, in the narrower technical sense, is used for systems that are open circuits, and analogously for all those systems where the input and output are not connected to each other by a feedback link. It can be said that the input to the system governs the size of the output from the system, i.e., that, under the influence of some variable quantity at the input, the system outputs a quantity that is a function of the input.

D) Regulation of ship processes

Regulation means regulation of one quantity with the use of a closed circuit. For a quantity being regulated, there is a certain "desired value" of that quantity. The actual size from the process is compared to this desired value. The difference between these values is amplified by feedback in a closed circuit, and efforts are made to reduce it to a value as small as possible. This is achieved by changing the regulated quantity, so that it is as close as possible to the desired value.

E) Protection of ship processes

The task of the protection system is to protect technological equipment and people. Protection acts directly on the process, based on the processing of information obtained about the process. To obtain the best possible information about the process, redundancy of several information providers is often used. Modern monitoring and control systems on ships are based on proven standardized automatic systems and components used in the industry. Compared to previous solutions, modern monitoring and management systems are characterized by great simplicity of design, installation, and maintenance, as well as greater complexity of the tasks they can perform. Logical automata (Programmable Logic Controllers – PLCs), processing units of compact, robust, and modular construction with integrated analog and digital input and output channels, adapted for connection to complex multi-level communication networks, take center stage. The system of supervision and management is distributed and decentralized in implementation, but centralized monitoring of processes and interventions on them is still possible. Such systems perform all classic monitoring and control functions, such as processing and presentation of sensor information, alarm detection and signaling, local and remote manual control of individual devices, whereby many control operations can be partially or fully automated. Additional functions, among others, include automatic archiving of selected events and process parameters, as well as increasingly better diagnostics and self-diagnostics.

Many norms, requirements and rules are in force when designing and implementing ship surveillance and management systems. Thus, there are regulations for equipping certain classes of ships (for example, a list of mandatory navigation equipment), requirements for the quality of materials used, standards for the manufacture of ship devices (for example, the required IP degree of protection against moisture, dust, and contact), rules for designing the layout and connection of individual devices (norms for cable distribution, grounding, etc.). Norms are increasingly covering the software side of the monitoring and control system, primarily in the form of standards for the communication connection of individual devices (NMEA standard, CAN protocol, etc.), and more recently also the quality (integrity, security, functionality, completeness) of the software. Many of the regulations and standards, especially those related to safety, are set by the International Maritime Organization (IMO). Further development of standards and control of their application is carried out by classification societies, such as Lloyd's Register (LR), Bureau Veritas, Det Norske Veritas, etc. When adopting their rules, classification societies consider the recommendations of the IMO, as well as the experiences of the world's leading ship equipment manufacturer. Specific rules for electronic monitoring and control systems have been in force since the 1980s (thus LR introduced its Rules for Programmable Electrical Systems in 1985, which have been amended and modified several times since then). Classification societies issue certificates of compliance with certain standards, both to ships and manufacturers of ship's equipment and materials for it.

Depending on the monitored system and the achieved degree of automation, monitoring and control systems can perform different functions. Some of the most important functions are, according to Batinica (2007):

- collection and processing of information from various sensors, including filtering, calculation of mean values and other derived quantities;
- display of data for operators using analog indicators, light bulbs, mimic diagrams (blind diagrams), LCD screens and monitors;
- acceptance of operator commands using buttons, switches, joysticks, potentiometers and keyboards;
- control of actuators (control transmissions, switches, valves, motors), manual or automatic;
- alarm detection and signaling (illegal process states), including basic and derivative alarms;
- various protective functions, such as, for example, automatically stopping the engine in the event of a breakdown or preventing the start of a sensitive operation if the necessary conditions are not met;

- recording registered alarms, events, and data on paper and/or archiving them in computer memory
- health monitoring and detection and localization of failures on the monitored process (diagnosis) and on the monitoring and management system (self-diagnosis).

Monitoring and management can be local, from a desk in the immediate vicinity of the monitored and controlled device, or remotely, from a remote desk in another room. Remote monitoring and management are often centralized, they are realized from common desks located in the ship's control cabins or on the bridge, from where all devices entering the observed subsystem or group can be accessed. Control can be manual, done when the monitoring and control system directly transmits control signals from the operator's keyboards or joysticks to the corresponding actuators (executive bodies), or automatic, realized when the actuators are controlled by the process unit of the system, performing a series of operations according to the memorized program. Between these two extremes, there is the possibility of semi-automatic control, as well as manual control with automatic conditioning of the control signal or its distribution to several actuators. Automatic control can be initiated manually, at the request of the operator, or automatically, for example, as a result of the action of a protective function. The automatic control mode can then cover the execution of a task, for example, starting the engine and stopping after that task is completed, and it can last indefinitely, until the operator turns it off.

Brodospas has established the concept of partial automatic data processing within individual business functions. Existing applications of automatic data processing do not have a well-founded system basis, from marking to standard design procedures. The snapshot of the state of the information support on the ships referred to the list of software support of the computer equipment that is on each ship. The data shows that the Microsoft Office software package is used on each ship, and on each ship, there is ship-land satellite communication (Inmarsat C, mini-M, Fleet 33). The office also uses the Microsoft Office software package for networked computer equipment, and specific software packages are used in some departments, such as AMOS in the technical service, LOTUS for electronic mail, Swing Process Manager for tracking documents, contacts, and customer relations items. (contracts, correspondence, fax and e-mail messages, minutes of meetings, other documents, comments and notes), POINT 2000 works according to the Windows system, and is used for bookkeeping, finance and commercial affairs. The KADAR software package is intended for the collection, management, and use of personnel data in the Brodospas joint-stock company and serves only the needs of the personnel department, which allocates personnel to individual ships, all according to the needs of the job and in accordance with maritime regulations (Brodospas, 2022). The program was created in the FoxPro programming language.

The management of ship processes in the company Brodospas contributes to improving the accuracy and reliability of data, increasing the speed of processing, control and transparency of operations and increasing the efficiency of ship processes, better communication between the ship and management, maintenance planning based on relevant data, managing the costs and investments of ship maintenance, increasing competitive advantages with better operational readiness of ships.

Weaknesses in the management of ship processes in Brodospas are the following: lack of internal knowledge, experience and resources for managing development projects, IT experts do not have the experience and knowledge necessary to introduce and maintain new application systems and technologies in ship maintenance, necessary adjustments to business processes and business models for successful introduction of the information system, ready-made solutions do not have functionality according to the concept of the company's business processes, but the company must adapt, lack of documentation of the company's existing information system, inappropriate management of costs and investments, non-integrated application system that does not allow for quick acquisition of critical information for decision-making in ship processes, non-standard technological equipment, investments in the development of the information system significantly lower than the average.

The company's goal is to take advantage of opportunities and eliminate threats.

CONCLUSION

Nowadays, which is characterized by the explosive development of new technologies based on the application of modern means of information technology (computer and other equipment as well as software and tools that are at a fairly high level of development), computer-supported design is no longer a futuristic idea, but a realistically based scientific one. professional discipline, which in the conditions of modern production and business grows into an elementary need. For the core activity of Brodospas d.d. could perform as efficiently as possible, it is necessary for managers of different levels to ensure accurate insight into the operations of associates, therefore, it is necessary to provide a simple, efficient and fast way of accessing information that circulates in the Brodospas business system. This is one of the important preconditions that enable managers to make timely and correct decisions in a dynamic business environment. To ensure the accuracy required for such a solution, the application of modern information and communication technologies, as well as appropriate IT integration, is necessary. At the same time, the implementation should be based on a more efficient organization of human and material resources, their best possible redistribution within Brodospas and outside it, and the lowering of costs, which results in an increase in the company's income and leads to an even better business result, as a business premise in conditions of constant economic changes. In order to more effectively monitor the process, it is necessary to select and introduce a specialized information system for management support that will enable determination of the current state of all business resources (employees, spare parts and materials, means of work, etc.), introduction of preventive maintenance and its monitoring and analysis in order to plan future activities and related costs. Cost reduction, especially in times of economic crisis and recession, can be achieved with a good strategy, optimal preventive or corrective activities, optimal availability of spare parts, purposeful organization, and quality management of shipping processes. By applying computer technology in solving business tasks, business is improved and a higher level of business and organizational efficiency is achieved. The top management of the company needs information, considering the decisions they make (mostly strategic ones). The aim is to formalize decisions as much as possible, i.e. make them according to predetermined programs, so that they are made faster and with less expenditure of resources and work. This certainly leads to cost reduction. Information is a resource that is very necessary for the development of any business process. Ensuring this resource requires the ability to apply methods and procedures, a certain amount of time, work and financial resources, and a built information system. Business process management has an important task in contributing to the fulfillment of the organization's mission. Neglecting the business result and striving for its quality would call into question the fulfillment of the requirements of interested parties in the shipping business. The quality of decision-making in the business process is closely related to the quality of the information base.

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Implementation of European Union Law in the New Act on Liner Shipping and Seasonal Coastal Maritime Transport

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The new *Act on Liner Shipping and Seasonal Coastal Maritime Transport* was adopted in 2022. It regulates the system of public liner maritime transport, which ensures regular maritime connections between inhabited islands and the mainland, and among inhabited islands. The new *Act* is fully harmonized with the regulations of the European Union. The *Act* adopts, into the Croatian legislation, *Decision 2012/21/EU* on the application of Article 106, paragraph 2 of the *Treaty on the Functioning of the European Union* to State aid in the form of public service compensation granted to certain undertakings entrusted with the operation of services of general economic interest. Furthermore, the *Act* ensures the implementation of the European Union act relating to the application of the principle of freedom to provide services to maritime transport within member states (maritime cabotage) – *Council Regulation (EEC) No 3577/92* and the European Union act relating to the rights of passengers when travelling by sea and inland waterways – *Regulation (EU) No 1177/2010*. The paper specifically analyses the regulations of the European Union governing state aid in public liner maritime transport and the judgments of the Court of Justice of the European Union in case C-208/00 Altmark and case T-454/ 13 – SNCM.

KEY WORDS

Public liner maritime transport, Act on Liner Shipping and Seasonal Coastal Maritime Transport, European Union regulations, Judgment of the Court of Justice of the European Union in case C-208/00 Altmark, Judgment of the Court of Justice of the European Union in case T-454/ 13 –SNCM

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INTRODUCTION

The Croatian coast with its islands is one of the most indented in the world. About 130,000 inhabitants live on 50 permanently inhabited islands. By investing significant financial resources in the islands in recent years, the Republic of Croatia has shown that it recognizes the island area, the population and life on the islands as an area of special national interest and as an area with great natural, economic and tourist potential. A high quality and modern legal framework is a prerequisite for the realization of three key elements that are important for the development of the island: fast and daily connections between the island and the mainland, faster and more even development of the economy with emphasis on tourism, and sustainable development and protection of the environment. The realization of the above elements requires a continuous adaptation of the legal framework.

The Act on Liner Shipping and Seasonal Coastal Maritime Transport (hereinafter: *Act*) regulates the system of public transport in coastal liner shipping, which ensures regular traffic connection of inhabited islands with the mainland and other inhabited islands. The new *Act* was adopted by the Croatian Parliament on 28 January 2022 and entered into force on 19 February 2022. With the entry into force of this *Act*, the *Act* from 2006 expired. Article 1 of the 2022 *Act* defines and determines its subject matter and scope. Thus, it states that the *Act* regulates the system of public transport in coastal liner shipping that ensures regular traffic connection of inhabited islands with the mainland and other inhabited islands and regulates the activities, working methods and public authority of the Coastal Liner Services Agency. The new *Act* was adopted in order to harmonize with the European Union regulations and to improve the legal framework and existing practice in coastal liner maritime transport in the Republic of Croatia.

EUROPEAN UNION LAW

Treaty on the Functioning of the European Union

The Treaty on the Functioning of the European Union (hereinafter: *Treaty* organizes the functioning of the Union and determines the areas of, delimitation of, and arrangements for exercising its competences (Article 1 of the *Treaty*). Articles 14, 93, 106 and 107 of the *Treaty* are relevant to the system of liner maritime transport.

Article 14 of the *Treaty* provides that, without prejudice to Articles 93, 106 and 107 of the *Treaty,* and given the place occupied by services of general economic interest in the shared values of the Union as well as their role in promoting social and territorial cohesion, the Union and the Member States, each within their respective powers and within the scope of application of the *Treaty*, shall take care that such services operate on the basis of principles and conditions, particularly economic and financial conditions, which enable them to fulfil their missions. The European Parliament and the Council, acting by means of regulations in accordance with the ordinary legislative procedure, shall establish these principles and set these conditions without prejudice to the competence of Member States, in compliance with the *Treaty*, to provide, to commission and to fund such services.

According to Article 93 of the *Treaty*, aids are compatible with the *Treaty* if they meet the needs of coordination of transport or if they represent reimbursement for the discharge of certain obligations inherent in the concept of a public service.

Article 106 of the *Treaty* provides that, in the case of public undertakings and undertakings to which Member States grant special or exclusive rights, Member States shall neither enact nor maintain in force any measure contrary to the rules contained in the *Treaty*. Undertakings entrusted with the operation of services of general economic interest or which, by their very nature, constitute revenue-producing monopolies shall be subject to the rules contained in the *Treaty*. Undertakings entrusted with the operation of services of general economic interest or having the character of a revenue-producing monopoly shall be subject to the rules contained in the *Treaty*, in particular to the rules on competition, in so far as the application of such rules does not obstruct the performance, *de iure* or *in fact*, of the particular tasks assigned to them. The development of trade must not be affected to such an extent as would be contrary to the interests of the Union. The Commission shall ensure the application of the provisions of this Article and shall, where necessary, address appropriate directives or decisions to Member States.

Article 107 of the *Treaty* states that, unless the *Treaty* provides otherwise, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favoring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market. In addition, paragraph 2 of the same Article defines the types of aid that are compatible with the internal market:

- aid having a social character, granted to individual consumers, provided that such aid is granted without discrimination related to the origin of the products concerned,
- aid to make good the damage caused by natural disasters or exceptional occurrences.

In addition, paragraph 3 of the same article specifies the types of aid that may be considered compatible with the internal market:

- aids to promote the economic development of areas where the standard of living is abnormally low or where there is serious underemployment, and of the regions referred to in Article 349 of the *Treaty*, in view of their structural, economic and social situation;
- aids to promote the execution of an important project of common European interest or to remedy a serious disturbance in the economy of a Member State,
- aids to facilitate the development of certain economic activities or of certain economic areas, where such aid does not adversely affect trading conditions to an extent contrary to the common interest,
- aids to promote culture and heritage conservation where such aid does not affect trading conditions and competition in the Union to an extent that is contrary to the common interest and
- other categories of aids as specified by decision of the Council on a proposal from the European Commission.

It follows from the above-mentioned articles that state aids are normally incompatible with the concept of the internal market of the European Union.

Article 107 of the *Treaty* defines such incompatible aid in case of cumulative fulfilment of the following conditions:

- selectivity and economic advantage - aid places certain undertaking or the production of goods in a more advantageous position,
- attributable to the state - it is granted by the member state or from state resources,

- effect on market competition - aid distorts or threatens to distort market competition and
- effect on trade between Member States.

Thus, government aids are essentially a form of state interventionism that results in a particular undertaking being selectively placed in a better position. This is contrary to the functioning of the internal market, which is based on the idea of creating an area without internal borders and the free movement of persons, goods, capital and services within the territory of the European Union under equal conditions.

It follows that the internal market is sustainable only under the conditions of regulation of state aid at the level of the European Union, which determines when and under what conditions it is exceptionally allowed. Otherwise, each Member State would be allowed to intervene in its market to the extent it deems necessary, which could ultimately lead to a state aid *war* between different Member States and the restoration of strict national borders and the destruction of the level of integration achieved and of the European Union, as we know it today.

Furthermore, European Union Law, in particular Article 107 of the *Treaty*, prescribes absolute and relative exceptions (Stanković, 2018) to the basic prohibition of state aids described above. This is a situation of market failure where the European Union recognizes that the intervention in the market brings more benefit than harm.

Exceptions to the general prohibition of this type of state interventionism apply in particular to services of general economic interest. State's interest is in ensuring permanent, uninterrupted and regular traffic connection between inhabited islands and the mainland and/or the other inhabited islands in situations where the free market fails. This means a sufficient number of regular traffic connections in both directions, in order to promote the demographic and sustainable economic development of the island and to improve the living and working conditions of the island population, an interest defined in Article 5, item 33 of the *Treaty* and that is addressed, among others, in this paper.

This follows from Article 106 of the *Treaty*, which provides for the application of competition rules to undertakings entrusted with the operation of services of general economic interest only in so far as the application of such rules does not obstruct the performance, in law or in fact, of the particular tasks assigned to them. In this way, a balance is ensured between the general social interest in the provision of ensuring durable, continuous and regular traffic connection of inhabited islands and the mainland and/or the other inhabited islands in the Republic of Croatia and the general European Union rules on market competition.

Article 14 of the *Treaty* also reaffirms the importance of services of general economic interest as part of the common values of the European Union. It imposes the obligation on the European Union and the Member States, within the framework of their respective competences, to ensure that these services are provided in accordance with the principles and under the conditions, in particular economic and financial, which enable them to fulfil their missions.

Finally, Article 93 of the *Treaty* determines the compatibility of aids with European Union rules if they represent reimbursement for the discharge of certain obligations inherent in the concept of a public service. This is understood as durable, continuous and regular traffic connection of inhabited islands and the mainland and/or the other inhabited islands under conditions that the shipowners, considering their own economic interests, would not undertake or would not undertake to the same extent or under the same conditions.

From the aforementioned provisions of the *Treaty* derived numerous decrees and directives, which further regulate the field of state aids and services of general economic interest in the internal market of the European Union, including those in maritime transport.

In the Republic of Croatia, European Union Law in this area was implemented by the *Act,* which ensures the implementation of the Directive:

- Regulation (EEC) No. 3577/92 of December 7, 1992, applying the principle of freedom to provide maritime transport services within Member States (maritime cabotage),
- Regulation (EU) No. 1177/2010 of 24 November 2010 concerning the rights of passengers when traveling by sea and inland waterway and amending Regulation (EC) No. 2006/2004.

The following is incorporated into Croatian legislation by the *Act:*

- European Commission Decision of 20 December 2011 on the application of Article 106(2) of the Agreement to State aid in the form of public service compensation granted to certain undertakings entrusted with the operation of services of general economic interest (Official Journal L 7, 11. 1. 2012).

The *Act* also contains provisions harmonized with the following acts of the European Commission:

- Communication from the Commission on the interpretation of Council Regulation (EEC) No 3577/92 applying the principle of freedom to provide services to maritime transport within Member States (maritime cabotage) (COM /2014/232 final),
- Notice from the European Commission on the application of EU state aid rules to compensation for the provision of services of general economic interest (Official Journal C 8 of 11.1. 2012),
- European Commission Communication - European Union framework for State aid in the form of public service compensation (Official Journal C 8 of 11.1. 2012).

Regulation (EEC) No. 3577/92 of 7 December 1992 applying the principle of freedom to provide services to maritime transport within Member States (maritime cabotage)

Regulation (EEC) No 3577/92 of 7 December 1992 applying the principle of freedom to provide services to maritime transport within Member States (maritime cabotage) (hereinafter Regulation 3577/92) extended the European Union's internal market to certain maritime transport services. In fact, it imposed the obligation to abolish gradually restrictions on the provision of maritime cabotage services in order to ensure an area of free movement of persons, goods, capital and services within the territory of the Member States, that is, what essentially the internal market comprises.

This unrestricted freedom of movement of persons, goods, capital and services by sea has been ensured by liberalizing the conditions for access to and provision of maritime cabotage services. A shipowner who meets all the conditions for carrying out cabotage in the Member State in which his vessels are registered can provide this service without interruption in any other Member State of the European Union.

Thus, *Regulation 3577/92* liberalizes the maritime cabotage market, which is defined in Article 2, point 1 as services normally provided for remuneration and shall in particular include:

- mainland cabotage: the carriage of passengers or goods by sea between ports situated on the mainland or the main territory of one and the same Member State without calls at islands;
- off-shore supply services: the carriage of passengers or goods by sea between any port in a Member State and installations or structures situated on the continental shelf of that Member State;
- island cabotage: the carriage of passengers or goods by sea between ports situated on the mainland and on one or more of the islands of one and the same Member State, and ports situated on the islands of one and the same Member State.

The country in which maritime cabotage is to be carried out has considerable authority to enact its own national regulations, but only those pertaining to the ship's crew. Therefore, for vessels carrying out mainland cabotage and for cruise liners, all matters relating to manning shall be the responsibility of the State in which the vessel is registered (flag state), except for ships smaller than 650 GT, where host State conditions may be applied. For vessels carrying out island cabotage, all matters relating to manning shall be the responsibility of the State in which the vessel is performing a maritime transport service (host State).

The Republic of Croatia applies the described principle of freedom to provide maritime transport services, so according to Article 9 of the *Maritime Code* and Article 5, item 4 of the *Act*, Croatian shipowners and shipowners from other Member States are equal in terms of performing maritime cabotage on the territory of the Republic of Croatia. They are also subject to special regulations regarding the number and composition of crew, working language, living and working conditions on vessels up to 650 GT in coastal cabotage. The exception is for vessels over 650 GT carrying out island cabotage, when the voyage concerned follows or precedes a voyage to or from another State; this is regulated by the *Regulation on the Conditions for Maritime Cabotage in the Republic of Croatia*.

By way of derogation from the principle of freedom to provide services, and in view of the importance of ensuring an adequate supply of regular traffic connections to, from and between islands, and in cases where it is not economically viable for shipowners, *Regulation 3577/92* exceptionally allows the imposition of public service obligations and the conclusion of public service contracts.

Regulation 3577/92 therefore ensures that, when imposing public service obligations, Member States shall be limited to requirements concerning ports to be served, regularity, continuity, frequency, capacity to provide the service, rates to be charged and manning of the vessel. Public service contracts may cover, inter alia, transport services satisfying fixed standards of continuity, regularity, capacity and quality, additional transport services, transport services at specified rates and subject to specified conditions, in particular for certain categories of passengers or on certain routes and adjustments of services to actual requirements.

Consequently, *the Act*, as evident in Articles 19, 21 and 23 implements the rule of liberalization of the maritime cabotage market. It stipulates that state, county, inter-county and local lines, as lines of general economic interest involving public service obligation, may be established only after public consultation with the island population and the shipowners. This is possible only after carrying out studies, which purpose is to determine whether the general economic interest can be realized without imposing public service obligations on all shipowners i.e. without imposing a public service contract.

In the organization of maritime transport and regular traffic connection to, from and between the islands, the *Act* gives priority to the possibility of organizing a regular service on the free market. This is only possible if the shipowner does not have only his own commercial interest in mind and assumes the obligation to maintain the service in the manner required by the interested public, i.e. the island population. It is possible to limit the principle of freedom to provide services, enshrined in *Regulation 3577/92*, by imposing a public service obligation or, subsidiarily, by concluding a public service contract.

Regulation (EU) No. 1177/2010 of 24 November 2010 concerning the rights of passengers when traveling by sea and inland waterway and amending Regulation (EC) No. 2006/2004

The objective of competition right, which in a broader sense also includes right on state aids, to which most of the European Union regulations are applicable, implemented by the provisions of the *Act*, i.e. creating the conditions for direct application, is, among other things, to increase consumer welfare, protect them, ensure choice, innovation and ultimately lower prices. Such a high level, comparable to other modes of transport, is to be ensured by the application of *Regulation (EU) No 1177/2010 of 24 November 2010 on the rights of passengers when traveling by sea and inland waterway and amending Regulation (EC) No 2006/2004* (hereinafter: *Regulation 1177/2010*).

Article 1 of *Regulation 1177/2010* stipulates the rules on the rights of passengers in sea and inland waterway transport. It relates to the non-discrimination between passengers with regard to transport conditions offered by carriers; non-discrimination and assistance for disabled persons and persons with reduced mobility; he rights of passengers in cases of cancellation or delay; minimum information to be provided to passengers; the handling of complaints; general rules on enforcement.

Pursuant to Article 102, paragraph 1 and Article 109, paragraph 1, item 1 of the *Act,* the competent national body responsible for the implementation of *Regulation 1177/2010* in the Republic of Croatia designates the Coastal Liner Services Agency. The *Act* also prescribes the relevant sanctions for administrative offenses, which ensure all conditions for the direct implementation of *Regulation 1177/2010*.

JUDGMENTS OF THE COURT OF THE EUROPEAN UNION

The fundamental task of the Court of Justice of the European Union is to ensure that European Union Law is interpreted and applied in the same way in all Member States and that the Member States and the institutions of the European Union comply with it. In this sense, it settles disputes between the governments of the Member States and the European Union institutions. It can also, in certain circumstances, be used by individuals, companies or organizations to take action against European Union institution, if they feel it has somehow infringed their rights (Court of Justice of the European Union, 2023).

Relevant judgments of the Court of Justice of the European Union in the area of public transport in coastal liner shipping:

- Case C-240/83 ADBHU,
- Case T-106/95 FFSA,
- Case C-53/00 Ferring,
- Case C-208/00 Altmark,
- Case T-454/13 – SNCM.

Cases C-208/00 Altmark and T-454/13 - SNCM are discussed separately later in the paper.

Case C-208/00 Altmark

Under Article 107 of the *Treaty*, as explained above, four cumulative criteria are established for the existence of State aid:

- the aid is granted by the Member State or is granted through state funds,
- puts one or more companies in a more favorable position, i.e. a selective advantage is present,
- the aid distorts or has the potential to distort competition on the market,
- affects trade between the countries of the European Union.

As the Court of Justice clarified in the Altmark case, a financial grant to undertaking (e.g., as compensation for the provision of a service of general economic interest) does not necessarily constitute state aid under certain conditions if selectivity is excluded as one of the characteristics of state aid. Namely, the Court establishes that the granting of a selective advantage may be excluded if the following four conditions are cumulatively satisfied:

- the recipient undertaking is actually required to discharge public service obligations and those obligations have been clearly defined,
- the parameters on the basis of which the compensation is calculated have been established beforehand in an objective and transparent manner,
- the compensation does not exceed what is necessary to cover all or part of the costs incurred in discharging the public service obligations, taking into account the relevant receipts and a reasonable profit for discharging those obligations,
- finally, where the undertaking which is to discharge public service obligations is not chosen in a public procurement procedure, the level of compensation needed has been determined on the basis of an analysis of the costs which a typical undertaking, well run and adequately provided with means of transport so as to be able to meet the necessary public service requirements, would have incurred in discharging those obligations, taking into account the relevant receipts and a reasonable profit for discharging the obligations.

It is questionable whether the fulfilment of the fourth condition entails the obligation to conduct public procurement procedures, since such an interpretation would not be consistent with the possibility that the law itself determines the fulfilment of the public service obligation[1]. It is also questionable how the fulfilment of this assumption is related to the possibility of granting exclusive rights, i.e. transferring the fulfilment of a public obligation by direct contract to the so-called house operator in maritime transport. Indeed, such a possibility is regulated by *Regulation (EC) No. 1370/2007 of the European Parliament and of the Council of 23 October 2007 on public passenger transport services by rail and by road and repealing Council Regulations (EEC) No. 1191/69 and (EEC) No. 1107/70* (hereinafter: *Regulation 1370/2007*), Article 1 of which, in defining the purpose and scope prescribes the following: *"2. This Regulation shall apply to the national and international provision of public passenger transport services by rail and to other types of transport by rail and road, with the exception of transport services operated primarily for their historical or tourist significance. Member States may apply this Regulation to public passenger transport services on inland waterways*

[1] For example, in the field of postal services: see Article 67 of the Postal Services Act (Official Gazette, No. 144/12, 153/13, 78/15 and 110/19) HP – Hrvatska pošta dd is a universal service provider based on the Act itself.

and, without prejudice to Council Regulation (EEC) No 3577/92 of 7 December 1992 applying the principle of freedom to provide services to maritime transport within Member States (maritime cabotage) (14), to national seas".

Regulation 1370/2007 thus allows Member States to apply it to public maritime passenger transport, which would be possible with minimal changes to national maritime law and the inclusion of a reference to the provisions of *Regulation 1370/2007* in the legislative text.

This would allow the granting of the exclusive right for public passenger transport on lines of general economic interest with public service obligations and the *direct conclusion* of a public service contract with a public service operator without a prior tendering procedure, as provided for in Article 2(f) and (h) of *Regulation 1370/2007*. This makes questionable the practical application of the criteria from the Altmark case, which will have to be refreshed by a possibly new case law of the Court of Justice in the light of the above.

Since the fulfilment of the fourth condition presupposes that the undertaking has been selected in transparent and non-discriminatory public procurement procedure or, if this is not the case, the remuneration for this service is reasonable in comparison with other comparable undertakings, it should be noted that in the case of a single bidder (which is the case in the Republic of Croatia) there is no de facto competition between several credible bids, so that the reasonableness of the remuneration for the service of economic interest on a specific line could be positively assessed a priori (i.e. it could be established with certainty in advance that it is indeed undertaking that will provide a public service at the lowest cost to the community) and, consequently, it can be assumed that *no selective advantage* has been granted and that, in conclusion, it is not a matter of granting state aid.

Precisely because of the risk of non-compliance with the above criterion in the context of the public tender procedure, as well as the difficulties in carrying out the cost analysis that a typical undertaking, well run and equipped with the necessary resources, would have to carry out in the absence of such a tender, Member States decide to apply the rules on state aid, in particular Article 106 paragraph 2 of the *Treaty,* i.e. to *apply to the European Commission for the aid program* so that the compatibility of such aids with the internal market of the European Union can be irrefutably confirmed by the European Commission.

Such practice is not in line with the trend of decentralization set by the European Union through Commission Regulation (EU) No. 651/2014 of 17 June 2014 on the assessment of certain categories of compatible aids in application of Articles 107 and 108 of the Treaty (EEA-relevant text), as amended and supplemented, which provides for the discharge of the Commission in the ex ante control of certain categories of aid. With the consistent application of the Altmark, the Commission could be relieved from the state aid programs for lines of general economic interest with public service obligations exceeding 300.000 passengers, which is currently hampered due to the difficulties in applying the fourth criterion, which is why Member States, including the Republic of Croatia, opt for the safer line, i.e. apply for an aid program for a specific line in order to check an aid ex ante for its compatibility with the relevant European Union legislation.

Case T-454/13 – SNCM

The 2022 *Act* regulates state, county, inter-county and local lines in Articles 19, 21 and 22.

State lines are lines of general economic interest to the Republic of Croatia on which there is an obligation to provide public service and on which the average annual passenger traffic is less than, equal to or more than 300,000 passengers in the period of two financial years preceding the year in which the provision of public service was entrusted (Article 19, paragraph 1 of the *Act*). The state lines are determined by the decision of the Government of the Republic of Croatia on the proposal of the Ministry of Sea, Transport and Infrastructure and after conducting a public hearing of the interested public in order to express the interests of the island population and shipowners, i.e. to determine whether the general economic interest can be realized without imposing a public service obligation on all shipowners, without entrusting a public service contract (Article 19, paragraph 2 of the *Act*). *The Regulation on the evaluation of the criteria for concluding public service contracts and granting concessions in public liner shipping regulates* in more detail the procedure for conducting public consultations in accordance with the SNCM test, following the case law of the Court of Justice of the European Union.

County and inter-county lines are lines of general economic interest for one or more units of regional self-government on which public service obligations exist and which average annual traffic does not exceed 300,000 passengers in the period of two financial years preceding the year in which the provision of public services of general economic interest was entrusted (Article 21, paragraph 1 of the *Act*). County and inter-county lines cannot be established alongside the same type of service on existing state and local lines with public service obligations, nor can they be established on routes involving ports open to public transport and excluded from ferry, fast ship or liner shipping services on county and inter-county lines (Article 21, paragraph 2 of the *Act).*

Local lines are lines of general economic interest for one or more local self-government units on the territory of the same county, on which there is an obligation to provide public services and on which the average annual traffic does not exceed 300,000 passengers in the period of two financial years preceding the year in which the provision of public services of general economic interest was entrusted (Article 22, paragraph 1 of the *Act*). Local lines cannot be established alongside the same type of transport on existing state, county and inter-county lines, nor can they be established on routes involving ports open to public transport and excluded from ferry, fast ship or liner shipping services on local lines with public service obligations (Article 22, paragraph 2 of the *Act*).

The provisions of the *Act* regulating state lines shall be applied to county, inter-county and local lines in a subordinate manner (Article 19, paragraph 8 of the *Act*).

State lines are established by a decision of the Government of the Republic of Croatia. This decision is not discretionary, but is made on the basis of detailed analyzes of supply and demand (implementation of the so-called SNCM test) and only if it is determined that the general economic interest can be realized without imposing a public service obligation on all shipowners (horizontal public service obligation), i.e. without concluding public service contract.

The SNCM test essentially involves three steps:

- demand analysis (interest of the local, island population),
- supply analysis (shipowners),
- making one of the following conclusions:
  a) it is not a line which maintenance is of general economic interest, from which follows: a failure of the test, the government's decision on the establishment of the line is not made,

b) it is a line which maintenance is of general economic interest, there are interested shipowners who would maintain the line without government intervention (support of general economic interest or grant of exclusivity), from which follows: the government decision on the establishment of the line is made, horizontal public service obligations are imposed on the line itself (the so-called PSO), interested shipowners start maintaining the line,
c) subsidiarily, the government decision on the establishment of the line is made after the approval of the aid program, the public tender procedure is launched, and after the selection of the most favorable bidder, the so-called PSC contract is concluded.

The cited articles consistently implement the principle of freedom to provide services as interpreted in the *Regulation*, and the text of SNCM as established in the case law of the Court of Justice in Case T -454/13 - SNCM is further elaborated.

As already stated in section 2.2 of this paper, the *Act* gives priority to the possibility of establishing a specific line on the free market, while only if there are no shipowners who, taking into account their own commercial interests would assume the obligation to maintain the line to the extent and in the manner proposed by the interested public, it provides for the possibility of limiting the principle of free movement of services from the *Regulation*, first by imposing a public service obligation or subsidiarily by concluding a public service contract.

A public service obligation imposed horizontally on all interested shipowners (the so-called PSO) who, through a test, demonstrate their interest in maintaining the line (together or independently, if there is only one shipowner) without government intervention and support to the extent and in the manner as previously proposed by the interested public, is a less invasive way of restricting the principle of freedom to provide services, and therefore, as can be seen from Article 19 paragraph 3, the *Act* gives it priority over the conclusion of a public service contract (the so-called PSC contract). Thus, the conclusion of a PSC can be considered only if the imposition of a public service was not possible.

It is questionable whether in practice there will be shipowners in the Republic of Croatia who will have an interest in the imposition of public service obligations (PSO), since they do not provide security or exclusivity on the line, and also no possibility of income planning and economic calculations in relation to the eventual profitability of line-maintenance with an imposed public obligation, to the extent and in the manner established for a particular PSO line.

The flexibility described does not benefit consumers who, if such a line ceases to operate for the reasons stated above, will lose their only real connection to the mainland and all the basic rights that go with it - connection to their administrative centers on the mainland, access to adequate health care, education, courts, and land-based jobs.

Since it is not possible to impose a quality criterion when imposing public obligations, as opposed to entering into a public service contract, as already stated in point 2.2 of this paper, it is not clear why public obligations are considered a more appropriate way to restrict the freedom to provide services. As stated in *Regulation 3577/92*, this is not in line with the program for a sustainable maritime economy and the European Union's plans to reduce greenhouse gas emissions by 2055, especially considering that the *digital and green agenda* is one of the main objectives of the European Union in this period.

CONCLUSION

The European Union legislation is ripe for changes that must be primarily aimed at improving the quality of public maritime transport, i.e. the maritime cabotage market. Improving the quality of services through the rejuvenation of the fleet, the application of environmentally friendly technologies and the promotion of the fuel of the future is currently possible through the so-called PSC contracts and the implementation of public tenders that will favor vessels of this quality.

Pending relevant amendments to the *Regulation* that would bind quality criteria and public service obligations under certain conditions, PSC contracts continue to be a more realistic choice for shipping companies that can combine the maintenance of lines of general economic interest with a public commitment to the application of *green and digital standards* that the European Union promotes every day through various programs related to the sustainable economy, the *Fit for 55* package and similar measures.

In order for the implementation of public tenders leading to the conclusion of PSC contracts to be as transparent and efficient as possible, the European Union must consider the question of applying the fourth criterion from the Altmark judgment, due to which Member States still decide, as a precautionary measure, to notify all funding programs to the European Commission in order to verify their compatibility with the internal market, which ultimately unnecessarily prolongs the conclusion of the PSC contract and imposes an additional administrative burden on the European Commission.

Consequently, the definition and implementation of future policies of the European Union and the Member States in the field of the organization of maritime transport, which ensures regular traffic connection of inhabited islands with the mainland and other inhabited islands must reconcile the requirements of the liberalized and open internal market of the European Union and the protection of national interests (both consumers and shipowners), as well as the needs, the realistic options and the realization of green agendas in the coming period; which is not an easy task, but not impossible either.

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Using Machine Learning Techniques for Predicting Electrical Data of PV Panels from RGB Images

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The need for renewable energy sources in the maritime industry has been raised with the goal of creating more eco-friendly transportation by reducing fuel costs and the negative environmental effects of harmful gases. Among the different green transportation solutions, solar energy has shown to be a reliable source for maritime energy applications. Solar photovoltaic (PV) panels can be installed on ships to generate electricity, which will be utilized to supplement the diesel generators and reduce the amount of power needed from these machines. Dynamic Reconfiguration (DR) and Maximum Power Point (MPP) tracking in PV systems are important for maximizing power output. Each panel must include a significant number of voltage and current sensors in order to be reconfigured, which increases costs, expands the size of the installation and lowers installation reliability. With the aim of reducing the number of sensors and analog to digital converters image-based methods can be used to reconfigure PV systems and enhance MPPT solutions and diagnostics. The possibility of predicting electrical data of PV panels from RGB images using Machine Learning (ML) techniques is discussed in this paper.

KEY WORDS

PV panels, Machine Learning, Predicting, Relevant to, RGB images.

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INTRODUCTION

During the past few decades, photovoltaic (PV) systems have emerged as an alternative to traditional energy sources in various sectors, including maritime. Due to space limitations and the high cost of fossil fuels, PV systems are becoming an increasingly popular choice for powering ships. Future developments in these technologies are expected to lead to greater system efficiency and reliability, as well as cost reductions and environmental benefits. The development of PV systems on ships is happening in two main directions: improving the efficiency of PV systems and improving their integration into ship systems (Karatuğ and Durmuşoğlu 2020; Knežević et al. 2022; Ghenai et al. 2019).

Partial shading can significantly impact the performance of the PV system on board ships. Due to limited space, PV panels are typically installed horizontally on the ship's deck, making them vulnerable to shading from various ship elements. This shading can negatively affect the PV system's performance and reduce energy production. When a portion of a PV panel is shaded, current can still pass through other parts of the panel, raising the temperature in those areas. High temperatures can shorten the system's lifespan and increase the chance of damage (Krishna and Moger 2019; Belhaouas et al. 2017). To mitigate the problem of high temperature in PV panels, two solutions can be implemented. One approach to reduce the effects of partial shading on photovoltaic modules is to use bypass diodes (Vieira et al. 2020). Bypass diodes allow the current to bypass the shaded parts of the panel, so that the overall power of the panel is not reduced (Gonzalez Montoya et al. 2018). Another solution to address the high temperature issue is to dynamically alter the electrical connection of the PV panel. However, this method necessitates a significant number of voltage and current sensors, as well as analog-to-digital converters. These sensors are employed to gather current and voltage (I-V) data for each panel, which is critical for process optimization and for the development of safe connection detection algorithms for PV panels (Mai et al. 2017). This solution is effective, however it can be expensive and demanding to implement. In addition there may be problems with the reliability of the system due to the large number of sensors and transducers required for its operation (Spagnuolo et al. 2015).

Alternatively, a single visual sensor can replace the need for multiple sensors, by using image-based methods for the reconfiguration of photovoltaic systems. These methods employ a camera to capture images of solar panels, enabling the detection and monitoring of changes in solar panel performance, such as shadowing, dirt accumulation, or damage to reduce power loss in a PV system. Thus, machine learning can be employed since it has become an essential tool for solving various computer vision tasks. Moreover, ML is used in visual inspections to improve the accuracy and efficiency of detecting faults in various applications, including manufacturing, construction and transportation. Through a review of the literature, numerous solutions for identifying faults in PV systems have been found (Madeti and Singh 2017; Dunderdale et al. 2020). Ali et al. (2020) propose a new approach to hot spot detection and classification of photovoltaic panels using a Support Vector Machine (SVM) model based on hybrid features and infrared thermography. In Venkatesh and Sugumaran (2022), the researchers used Convolutional Neural Networks (CNNs) to extract image features of PV panels and different ML algorithms (Decision Tree, Random Forest and SVM) for efficient fault detection and classification. Gaussian Process Regression (GPR) is used in (Villegas-Ceballos, Rico-Garcia, and Ramos-Paja 2022) to estimate electrical data from RBG images of PV panels.

This paper explores the potential for predicting electrical data of photovoltaic panels using RGB images and applies several ML techniques, including Neural Networks (NN), Gaussian Process Regression (GPR), Random Forest (RF) and SVM. The paper is structured as follows. Section 2 presents a diode model of a solar cell. Availabe database, used for training the considered ML techiques, as well as the obtained experimental results are in Section 3. The prediction of the short circuit current (Isc) and the power at the MPP (Pmpp) from the RGB image features is also analyzed in this section and the performance of several machine learning models is compared. The paper is finished with concluding remarks.

SINGLE-DIODE SOLAR CELL MODEL

Photovoltaic panels are composed of a large number of photovoltaic cells connected in series or parallel. Each cell consists of a semiconductor material, usually silicon, and when it receives a photon from sunlight, it generates a DC voltage according to the principle of the photoelectric effect (Luque and Hegedus 2011). To increase the output current or voltage, cells are connected in series or parallel. This creates a photovoltaic panel that is used to generate electricity from sunlight (Masters 2013). Photovoltaic panels are very useful for the production of clean and sustainable energy (green energy) and can be used in different systems, such as marine energy production systems, home systems or large solar power plants (Karatuğ and Durmuşoğlu 2020; Luque and Hegedus 2011; Rekioua and Matagne 2012).

The mathematical model of a photovoltaic cell enables a detailed understanding of its mode of operation. Thus, a various simulations that can bring significant savings in money and time can be performed. The process of making a model involves a detailed recognition of the characteristics of the used material (Masters 2013). One-diode (Ciulla et al. 2014; Vellingiri et al. 2023) and two-diode models of photovoltaic cells (Ishaque, Salam, and Taheri 2011) are most often encountered in the literature. Some of the most important characteristics of PV cells used to describe their performance under various conditions are: Isc, Pmpp, open circuit voltage (Voc), maximum power current (Impp), maximum power voltage (Vmpp), conversion efficiency (η), fill factor (FF), temperature dependence of performance and shading tolerance. PV panels are described by a current-voltage (I-V) characteristic and a power-voltaic (P-V) characteristic. The shape of these characteristics depends on various factors, such as the number of PV cells, the insolation of the sun, the temperature of the panel and the characteristics of the semiconductor in the cells. The most important point on the I-V characteristic is the maximum power point, which represents the optimal conditions of panel exploitation (Muhsen et al. 2015; Luque and Hegedus 2011).

The equivalent schematic of a single-diode model of a PV cell is shown in Figure 1. The model includes resistances Rs and Rp, which represent electrical losses in the cell. The parallel resistance (Rp) value is high and models the junction leakage current, while the series (Rs) resistance models the ohmic contact. Changing these resistances affects the slope of the I-V characteristic in different areas. Important parameters that can be extracted from this model are Isc and Pmpp (Masters 2013; Ciulla et al. 2014; Vellingiri et al. 2023).

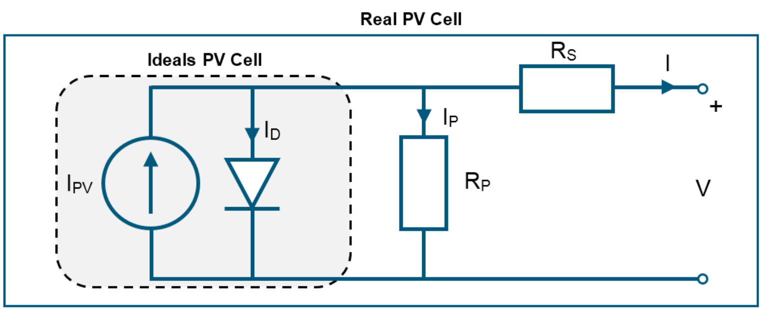

Figure 1. Equivalent diagram of a single-diode PV cell model

The output current of the photovoltaic cell is obtained according to the relation (Hadjab, Berrah, and Hamza 2012):

$$I = I_{PV} - I_s \left[\exp\left(\frac{q(V + IR_s}{nKT}\right) - 1\right] - I_P \tag{1}$$

where: I – output current of the photovoltaic cell; V – cell voltage; I_s – saturation current of the diode; I_P – the current delivered by the parallel resistance R_P; T – PV cell temperature [K]; q – quantity of charge; K –Boltzmann's constant; n – ideality factor of the diode.

The total current generated by a PV module is crucial in determining the module's power output and sizing the system components. By knowing the total current output of the PV module, we can make sure that the system components are sized correctly to handle the maximum current output, resulting in safe and efficient system operation.

EXPERIMENTAL RESULTS

Dataset

The data analyzed in this paper are publicly available for download from the fourth version of the database (Rico-Garcia, Ceballos, and Paja 2022). The authors (Villegas-Ceballos, Rico-Garcia, and Ramos-Paja 2022) present a dataset that includes RGB images and electrical data of solar panels under different lighting and shading conditions. The dataset also contains temporal data and additional image features that are useful for training models to estimate electrical data based on images. The goal of this dataset is to help training of different ML techniques, which will reduce the need to use a large number of sensors for monitoring the performance of solar panels, replacing them with an electrical data estimator based on RGB images.

The dataset contains 5211 images and records that were captured over 70 days between 2020 and 2021. The paper (Villegas-Ceballos, Rico-Garcia, and Ramos-Paja 2022) describes in detail the measurement platform used for data acquisition. RGB images and electrical data are identified with the same file names consisting of year, day, month, hour and minute. The file name structure is year_day_month_hour_minute ("YYYY_DD_MM_HH_MM"). Each of the images in the dataset contains associated electrical data contained in text files with columns giving the values: irradiance, temperature, zenith, azimuth, albedo, Isc, Vmpp, Impp, Pmpp and Fill Factor. The dataset also contains values for five different image features, including:

- The blue channel of the RGB space,
- The luminance histogram (Y) of the Y-Cb-Cr space,
- The saturation histogram from the HSV space,
- The histogram of the third channel from the NTSC space and
- The histogram of the first channel from the CIE 1976 space.

Electrical data estimation

In this paper, we aimed to estimate the Isc and Pmpp of PV panels based on their images characteristics: the blue channel of the RGB space, the luminance histogram(Y) of the Y-Cb-Cr space, the saturation histogram from the HSV space, the histogram of the third channel from the NTSC space and the histogram of the first channel from the CIE 1976 space. These characteristics are also used in

(Villegas-Ceballos, Rico-Garcia, and Ramos-Paja 2022) for Isc and Pmpp estimation using the GPR algorithm.

Several different machine learning models were used to predict the Isc values, including GPR, SVM, RF and NN. GPR is a probabilistic, non-parametric regression technique that models the underlying function as a Gaussian process. This approach assumes that the data has some underlying structure that can be modeled using a prior probability distribution over functions. SVM is a supervised learning algorithm that can be used for both classification and regression. SVM works by finding a hyperplane that maximally separates the data into different classes, or predicts the value of the target variable for regression problems. SVM is particularly useful for working with high-dimensional data, and can capture non-linear relationships between the input features and the target variable through the use of kernel functions. RF is an ensemble learning method that constructs a multitude of decision trees at training phase and outputs the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees. Each tree in the forest is constructed using a random subset of the training data and a random subset of the input features, which helps to reduce overfitting and improve generalization performance. NNs are a type of machine learning algorithm inspired by the structure and function of the human brain, and can be used for both classification and regression tasks. NN consist of multiple layers of interconnected nodes, each of which performs a non-linear transformation of the input data. The output of the final layer of nodes is used to predict the value of the target variable. For all models, we used a dataset of 5211 samples with corresponding Isc and Pmpp values. We chose these models due to their effectiveness in dealing with complex, high-dimensional data and their ability to capture non-linear relationships between the input features and the target variable. Each of these models was trained using the training data, and then evaluated using the testing data. The performance of the models was measured using the Root Mean Squared Error (RMSE), which is a common metric for evaluating regression models. The model with the lowest RMSE on the testing data was considered the best performing model.

Firstly, the training procedures involved splitting the data into training and testing sets using an 80/20 ratio. The training set was then used to fit each model, while the testing set was used to evaluate the model's performance. To further evaluate the models' performance and ensure their robustness, we applied k-fold cross-validation. Moreover, we used 5-fold cross-validation, where we split the training set into five folds and trained each model on four folds, validating on the remaining fold. We then averaged the RMSE scores over the five folds to obtain an estimate of the model's performance. In this manner, we evaluated the performance of the models on different subsets of the training data and thus boost their generalization ability. This procedure also allowed us to obtain a more reliable estimate of each model's performance.

Isc Estimation

In this section, we present the Isc estimation results of PV panels using five different image features described before and four different machine learning models. In the GPR model, we utilized a rational quadratic kernel with length scale 1 and regularization parameter *alpha* set to a very small value. These hyperparameters helped the model capture complex, non-linear relationships between the RGB image features and the Isc values. As a result, the GPR model achieved an RMSE of 0.64 on the testing set, which indicates that it was the most accurate model for predicting Isc values in your dataset. The SVM regression model utilized a radial basis function kernel with experimentally conducted *gamma=1/72* resulting in an RMSE of 1.37 on the testing set, which is higher than the other models but still indicates reasonable accuracy. The Random Forest model utilized 100 decision trees with a maximum depth of 20 and optimized the number of features used at each split and the minimum number of samples required to split a node, achieving an RMSE of 0.73 on the testing set. Finally, the NN model employed a feedforward architecture with four hidden layers, each containing ten neurons, and utilized the rectified linear unit (ReLU) activation function and the Adam optimizer. The output layer of the NN model has a single neuron with a linear activation function, which produces a single continuous numerical Isc value as the predicted output. This model achieved an RMSE of 0.71 on the testing set. The resulting RMSEs in case of Isc are shown in Figure 2.

Based on the results, it appears that the GPR model had the best performance among the different machine learning models for predicting Isc values from RGB image features. The GPR model achieved the lowest RMSE of 0.64 on the testing set, while the other models achieved higher RMSE values ranging from 0.71 to 1.37. The results obtained in our study are in agreement with the findings of Villegas-Ceballos, Rico-Garcia, and Ramos-Paja (2022). Specifically, both studies found that the GPR model was the most effective machine learning algorithm for predicting Isc values, achieving the lowest RMSE on the testing set. GPR model provides the most accurate predictions but has longer execution time. If computational efficiency is a critical factor in real-world applications, the NN model may be a suitable alternative to GPR. NN models can often be optimized for parallel processing and may be more computationally efficient than GPR. The predicted and actual Isc values in case of NN model are shown in Figure 3.

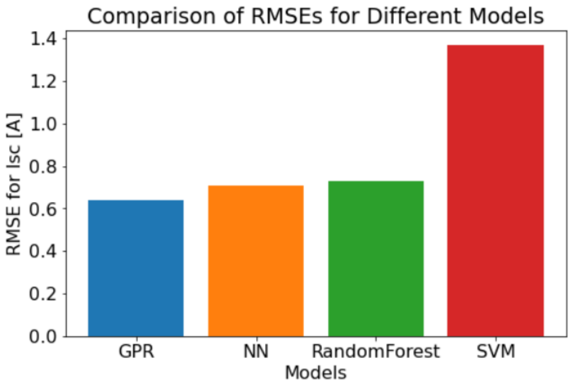

Figure 2. Comparison of RMSEs in case of Isc and different ML models

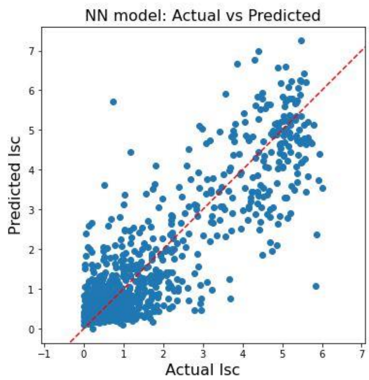

Figure 3. Actual vs Predicted Isc values using NN model

This comparison can provide valuable insights into the performance of the model and its ability to accurately predict Isc values from RGB image features.The plot displays a cluster of data points close to the ideal line of prediction, indicating that the NN model has learned the relationship between input variables and the output variable (Isc) effectively. There are some data points in Figure 3 that are further away from the ideal line of prediction. These outliers may represent cases where the model did not accurately capture the relationship between the input variables and the output variable, or where there were other factors that influenced the Isc values that were not captured by the model.

Pmpp Estimation

The results of estimating Pmpp using the same machine learning models and image features are presented in this section. Among the four models tested, the RF model had the lowest RMSE of 7.62, indicating that it provided the most accurate Pmpp estimation as shown in Figure 4. The GPR model had an RMSE of 9.37, while the NN model had an RMSE of 9.85. The SVM model had the highest RMSE of 15.81, suggesting that it had the poorest performance in estimating Pmpp. The predicted and actual Pmpp values in case of NN model are shown in Figure 5.

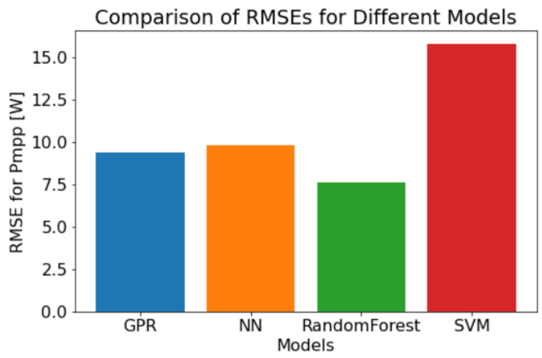

Figure 4. Comparison of RMSEs in case of Pmpp and different ML models

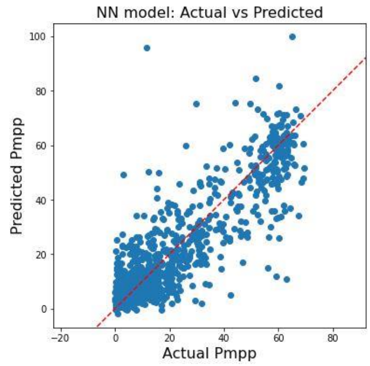

Figure 5. Actual vs Predicted Pmpp values using NN model

It is worth noting that Pmpp has a maximum value of 85W, and an RMSE of 7.62 suggests that the Random Forest model can estimate Pmpp with an average error of approximately 9%, which is a reasonable performance. We have evaluated multiple models in our study and our findings suggest that our GPR model and RF model have demonstrated a level of performance similar to that reported by Villegas-Ceballos, Rico-Garcia, and Ramos-Paja (2022), who used the GPR algorithm to obtain RMSE values of 7.94 and 0.61 for Pmpp and Isc, respectively. Thus, the models have also achieved good accuracy in predicting these parameters, as evidenced by our comparable RMSE values.

CONCLUSION

In this study, the prediction of Isc and Pmpp of PV panels from RGB image features was investigated. To accomplish this, various machine learning algorithms including GPR, SVM, RF and NN were utilized and compared for their effectiveness in predicting Isc and Pmpp values. The findings of the study revealed that GPR and RF models were the most accurate for predicting Isc and Pmpp values, respectively. The GPR model was found to achieve the lowest RMSE value of 0.64 on the testing set for Isc prediction, while the RF model achieved an RMSE of 7.62 for Pmpp prediction. The key contribution of this study is its addition to the expanding literature on the use of ML algorithms for PV panel analysis. The study aims to support researchers and practitioners in the field of PV panel analysis by providing valuable insights into the effectiveness of various ML algorithms. It should be noted, however, that further analysis and optimization of the models is necessary to achieve even greater accuracy and to gain a better understanding of the input variables that influence the output variables. Other factors such as computational efficiency, interpretability, and ease of implementation may also be important considerations when selecting an ML algorithm for predictiong electrical parameters of PV panels. A potential avenue for future research would be to investigate the applicability of Convolutional Neural Networks in predicting electrical parameters directly from RGB images, without the need for any image preprocessing techniques. CNNs have demonstrated impressive performance in various image-based applications and thus may hold promise for accurately predicting electrical parameters from RGB images.

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How Important is Training in Marine Firefighting Equipment - SCABA?

Mislav Maljković[1], Toni Meštrović, Rosanda Mulić[1,2], Srđan Vukša[1]

Basic fire protection on ships is organized in such a way that the duties of each crew member are determined by the Master list, depending on the nature of the emergency situation, including a fire on board. Accordingly, it has been determined which crew members should use the breathing apparatus (BA) set in case they need to rescue someone or extinguish a fire in enclosed and smoky spaces of the ship. The question or problem arises as to how well these crew members are mentally and physically prepared for such complex emergency situations. Companies and even shipboard management do not conduct detailed analyses of their crews on this issue. It is sufficient that the crewmember has a valid medical examination and firefighting certificates, and it is assumed that he or she can be entrusted with such a task. For this reason, during the above-mentioned event, an examination was conducted using a breathing apparatus, a fireman outfit and a portable fire extinguisher. By measuring blood pressure, body weight, and heart rate, an attempt was made to determine how stressful the use of firefighting equipment can be for an involved crew member. A certain number of maritime school students (4th grade), maritime faculty students. The measurements were performed in such a way that the mentioned parameters were recorded before and after donning the firefighting equipment, with a note about the age and whether the candidate was an athlete, smoker or non-smoker. After donning the firefighting equipment, each candidate climbed the stairs to the second floor of the Maritime Faculty building and simulated extinguishing a small fire with a portable fire extinguisher (CO_2 weight 9 kg). By analysing the data obtained, an attempt will be made to determine if the above measurements change in relation to simulated extinguishing of small fires. In this way, an attempt is made to provide guidelines that could increase safety in the use of these firefighting equipment and, consequently, safety on board in general.

KEY WORDS

Safety at sea, Firefighting outfit, BA set, Master list, Readiness/fitness for firefighting duty

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INTRODUCTION

Ship fires, which usually occur unexpectedly, can cause extensive damage, loss of the ship, serious injuries and fatalities. Fires and explosions are the third most common marine casualty for the last decade and the second most expensive marine casualty for insurance claims. The engine room is compartment on a ship where fires frequently occur. This is because the engine room consists of fire hazard areas such as the main engine, auxiliary engines, fuel and diesel tanks, electrical equipment and circuits. Fires in the engine room are usually difficult to extinguish and can affect the manoeuvrability of the vessel, leading to collision, stranding, and even abandonment (Safety and Shipping Review 2022 Allianz Global Corporate & Specialty, no date). (Sarıalioğlu et al., 2020). In addition to the engine room, fires on ships also occur in the cargo holds. Fires on large ships that originate in the cargo holds spread very quickly, are difficult to control, and in many cases also lead to abandonment of the ship. On container ships, fires in many cases start in containers with hazardous cargo. About 5% of containers contain hazardous goods that have not been declared. Such cargoes are not properly packed and therefore pose a fire hazard. The more containers a ship has, the greater the fire hazard. Large container ships therefore have a greater risk of fire in the container facility (An annual review of trends and developments in shipping losses and safety (Safety and Shipping Review 2022 Allianz Global Corporate & Specialty, no date). The most recent cause of fires on car carriers (ro-ro ships) is lithium batteries used in electric cars. Battery fires are very difficult to extinguish because they tend to overheat and explode and can easily reignite. Battery fires require large amounts of water to extinguish, which can endanger the stability of the vessel (An annual review of trends and developments in shipping losses and safety (Safety and Shipping Review 2022 Allianz Global Corporate & Specialty, no date) (Ruggiero, 2021). Considering the frequency of fires on ships, it is essential that fire drills are conducted regularly and that every crew member is trained and familiar with their duties in the event of a fire on board. Regular fire drills increase the level of preparedness of the crew on board to respond to hazards in a timely manner and prevent major fires on board. One of the most important aspects of firefighting on board is the use of breathing apparatus as firefighting equipment of vital importance. Breathing apparatuses are a mandatory part of firefighting equipment and allow firefighters for supply of clean air when extinguishing fires in smoke-filled areas. This article examines the use of breathing apparatus and the crew's ability to use it in firefighting operations aboard ship. Students from the Maritime Faculty and the Maritime School completed the exercise using a breathing apparatus, and we examined their readiness before and after the exercise. We measured weight, heart rate before and after the exercise, and blood pressure before and after the exercise. We examined who were smokers and athletes, and processed the data obtained during the exercise.

USE OF BREATHING APPARATHUS WHEN FIGHTNING A FIRE ON BOARD

Every ship must be equipped with permanently installed fire detection and fire alarm systems in accordance with SOLAS (International Convention for the Safety of Life at Sea). Firefighting equipment on ships consists of fixed and portable fire extinguishers. Fixed fire extinguishers consist of water, foam, dry powder, and CO2 (carbon dioxide) used to fight fires in open and enclosed areas and are located in various areas of the ship. The units are remotely controlled and located outside the spaces to be extinguished. In addition, ships must be equipped with fire pumps, fire lines, hydrants, and hoses (International Convention for the Safety of Life at Sea, 2020). Portable firefighting equipment consists of fire extinguishers and firefighters' outfit. The portable fire extinguishers are CO2, foam, and dry chemical powder extinguishers located in the accommodation, deck, and engine room. Firefighting equipment consists of personal gear and breathing apparatus. Personal equipment consists of personal clothing made of fire-retardant material, boots made of electrically nonconductive material, hard helmet, an explosion-proof electric safety lamp with a burning time of at least three hours, and an axe with high voltage insulation.

The breathing apparatus used on ships is SCBA (Self Contained Breathing Apparatus). SCBA is completely self-contained and is worn on the back by firefighters so they can move quickly around the ship. The air in the cylinders must have a volume of at least 1,200 litres or function for at least 30 minutes (International Convention for the Safety of Life at Sea, 2020) (International Maritime Organisation (IMO), 2007).

Figure 1. Fireman outfit on board (VLCC tanker)

Fire drills must be conducted on board according to the actual emergency situation, and all crew members must participate. Different fire scenarios must be considered, including different locations such as main deck, galley, engine room, etc. If the crew firefighters cannot extinguish the fire during the exercise and in real life, a fixed fire extinguishing system must be used (Sim, Ha and Park, 2019).

PLAN OF EMERGENCY PREPAREDNESS DRILLS

Vessel : ____________ Year : ______

	TYPE OF DRILL	Date done in prev Year	FRQ	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MANDATORY & REQUIRED BY SMS	Abandon Ship		Monthly	14	12	11	13								
	Fire Fighting (Deck / Pumproom / Manifold)**			7 D											
	OR - Fire Fighting (Accomodation / Galley)**				6 G										
	OR - Fire Fighting (Engine Room / Steering Flat)**					10 E	12 S								
	Oil Pollution Prevention / S.M.P.E.P			22	18	23	19								
	Flood Control Station (for Japan Flag Vsls)			18	14										
	EEBD / Breathing Apparatus		2 months	4		5									
	^^Use of Line Throwing Apparatus			20		18									
	^^Other LSA / FFA appliances			12		16									
	Hypothermia			20		18									
	Launching and Manoeuvering of Life Boat		3 Monthly		P/S 12			P/S			P/S			P/S	
	Rescue Station (M.O.B / Williamson Turn)				5										
	Collision				18										
	Stranding				18										
	Emergency Steering														
	Failure of Main Engine / Power Failure														
	Failure of Gyrocompass														
	Major Accident Resulting in Injury / Death														
	Rescue from Enclosed Space														
	Cargo Jettisoning / Discharging Fuel Oil														
	Heavy Weather Damage / Structural Failure														
	Gas or Toxic Vapour Release / Explosion				21										
	Emergency Towing Appliances (ETA)				18										
	Helicopter Operations & Rescue														
	##Security														
	Preventing the Invasion of Sea Robbers														
Other	Electric Shock		3 Monthly		12										
	Chemical Exposure				12										
	Flood Control Station				18										

Suggested Fire Fighting Drill Locations: *Accommodation* - **A** / *Deck* - **D** / *Engine Room* - **E** / *Galley* - **G** / *Manifold* - **M** / *Pump Room* - **P** / *Steering Flat* - **S**

Figure 2. Plan of emergency preparedness drills (VLCC tanker)

Fireman's outfit and SCBA equipment will be assigned to crewmembers according to the muster list. During the fire drill, crew members wearing firefighting clothing and SCBA will have limited time to fight the fire. This is because the SCBA has an air capacity of 30 minutes, but this is much less in a real situation. Air consumption depends on the physical condition of the crew member, his age, health condition, whether he is a smoker or non-smoker, heat stress, panic attacks, etc. It is very important to know the capabilities of crew members who are responsible for donning fireman's outfit and SCBA. All crew members should be involved in donning fireman's outfit and SCBA, not just the crew assigned according to the muster list. The purpose of fire drills is to have a well-trained crew and to know the capabilities and limitations of each crew member, as this can be a critical factor in the event of a fire on board (Sim, Ha, and Park, 2019).

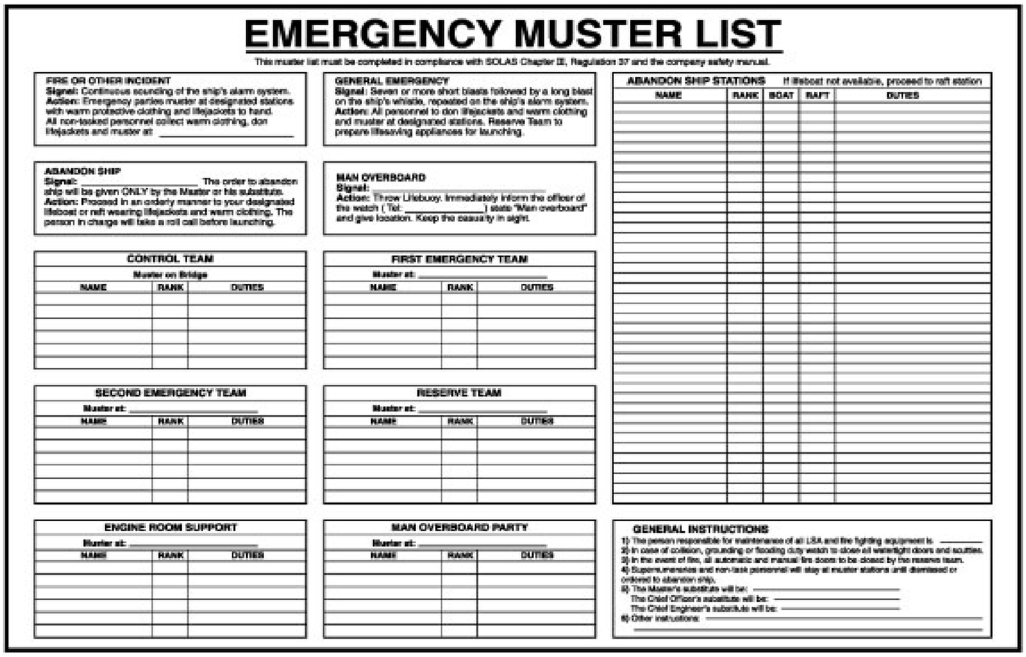

Figure 3. Plan of emergency preparedness drills (VLCC tanker)

HEALTH OF SEAFARERS

Seafarers must undergo regular medical examinations. At certain intervals, mental and physical abilities are examined to ensure that they are ready to work on board. According to Regulation I/9 of the STCW Convention and Regulation 1.2. of the Maritime Labour Convention, every seafarer must have a valid medical examination in the seaman's book that is not older than two years. As currently (FEBRUARY 2023) the pandemic COVID 19 is still in force, the deadline is extended by three months. According to this, every seafarer is healthy when boarding a ship, but the stress of working on board can cause problems and damage seafarers' health physically and psychologically.

The International Seafarers' Welfare Committee booklet entitled Guidelines for Mental Care Onboard Merchant Ships contains a chapter dealing with the problem of stress in seafarers (Anon n.d.-a). It states, "Typical symptoms of stress include insomnia, poor concentration, anxiety, substance abuse, extreme anger and frustration, family conflict, and physical illnesses such as heart disease, migraines, stomach problems, and back pain. Six key areas (or 'risk factors') can be causes of work-related stress on board. These are: the demands of the job; the level of control seafarers has over their work; the support they receive from management and their colleagues; workplace relationships; the seafarer's role in the company; and change and how it is managed. When seafarers are under severe stress, they are unable to make clear decisions, revaluate their priorities and lifestyle, and ultimately tend to engage in unproductive distractions. This can be described as a classic case of 'burnout"(Iversen 2012).

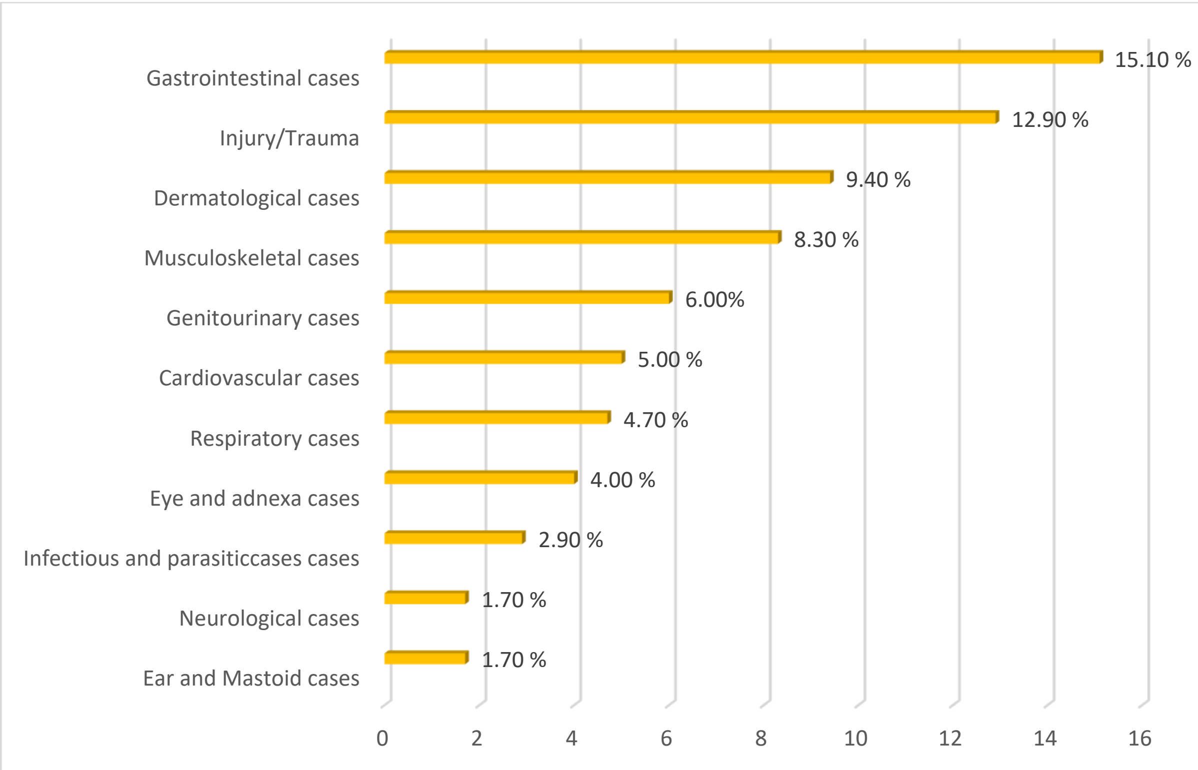

Table 1. The distribution of diseases and injuries among seafarers with medical events from January 1, 2017 to June 30, 2020 by Centro Internationale Radio Medico (C.I.R.M.) (Sagaro et al. 2020)

A look at the figures in Table 1 suggests that most of the diseases on ships are caused by the volume of work and the environment. All of the seafarers' illnesses mentioned in the table can be considered as a result of stress and thus represent a serious challenge for all involved in maritime transport.

Gastrointestinal diseases, which are the most common among seafarers (more than 15%), are directly related to stress.

Table 2 shows that in the first six months of 2020, the number of calls increased by 70% and the number of cases by 56%, which is a big jump caused by the pandemic COVID -19.

Patients assisted	2017	2018	2019	Mean 2017-2019	2020	Frequency (%) variations
NO. of cases	2419	2444	2694	2519	3924	56
NO. of teleconsultation	5230	5274	6117	5540	9417	70
Mean teleconsultations per case	2,2	2,2	2,3	2,2	2,4	9
Mean cases per day	13,4	13,6	14,9	13,7	21,8	59

Table 2. Requests for medical advice received by C.I.R.M. from January–June 2017 to January–June 2020 (Sagaro et al. 2020)

The IMO has established the Seafarer Crisis Action Team (SCAT) to help to resolve individual cases, often by working alongside other organizations such as the International Labour Organization (ILO), the International Transport Workers ‘Federation (ITF) and the International Chamber of Shipping (ICS) (Anon n.d.-b). Since the beginning of the COVID-19 pandemic, that dedicated team has worked around the clock to contact representatives from national governments, Non-Governmental Organizations (NGOs), trade unions and relevant associations and to orient seafarers towards the most suitable organizations and solutions. (Lucas et al. 2021)

METHODS AND MATERIALS

The study was conducted with students of the maritime faculty and fourth grade students of the maritime high school. Before donning the equipment, the candidates' weight, blood pressure, and heart rate were measured (Table 3). After donning the firefighting equipment, the candidates performed a firefighting exercise. The exercise consisted of climbing to the second floor with the equipment, extinguishing an imaginary fire, and going back down with the equipment. The candidates were asked to perform the exercise as quickly as possible.

Figure 4. Candidate on exercise

After exercise, blood pressure and heart rate were measured again (Table 3). The candidates were asked to answer whether they were athletes and whether they smoked, so that the data of the individuals could be compared on the basis of the answers. There were 14 non-smokers and 7 smokers and 9 athletes and 12 nonathletes. On average, the candidates were 18.86 years old and weighed 78.52 kg. Pre-exercise blood pressure averaged 129.5/78 and heartbeats per minute averaged 88. Post-exercise blood pressure averaged 140.3/76.5 and heartbeats per minute averaged 102. We see that heart rate increased by 16% and systolic (upper) blood pressure increased by 8.5%.

	Age	**Weight (kg)**	**Smoker**	**Athlete**	**Blood pressure – Before (mmHg)**	**Heart rate - before (in 1. min)**	**Blood pressure - after (mmHg)**	**Heart rate - after (in 1.min)**
1.	18	76,3	No	Yes	117/61	74	164/73	82
2.	17	71,4	No	Yes	113/56	73	133/64	102
3.	20	76,9	No	No	129/77	79	136/72	126
4.	20	92	Yes	No	142/79	96	155/91	117
5.	17	80	No	Yes	118/79	83	129/62	85
6.	18	93,6	No	Yes	139/77	86	173/85	96
7.	16	72,4	No	No	120/105	143	150/85	156
8.	18	69	Yes	No	109/69	76	127/74	92
9.	17	71,4	No	No	135/85	97	157/90	126
10.	16	67,3	No	No	122/82	109	135/86	149
11.	18	84,3	Yes	No	145/72	73	150/92	78
12.	18	88	No	No	140/67	83	149/80	101
13.	18	65,7	No	No	109/77	76	119/67	91
14.	18	92	Yes	No	151/93	86	154/79	104
15.	17	84	No	Yes	157/75	112	146/77	123
16.	18	71,1	No	Yes	138/82	60	143/73	70
17.	18	63,9	No	Yes	111/65	84	126/58	84
18.	17	74,5	No	Yes	143/102	91	143/68	75
19.	17	82,3	Yes	No	128/82	96	121/83	103
20.	17	83	Yes	Yes	150/83	70	123/77	75
21.	43	90	Yes	No	103/70	102	114/71	113
AVERAGE	**18,86**	**78,52**	**14-No, 7- Yes**	**12-No, 9- Yes**	**129,5/78**	**88**	**140,3/76,5**	**102**

Table 3. The results of the candidates in the exercise

RESULTS AND DISCUSSION

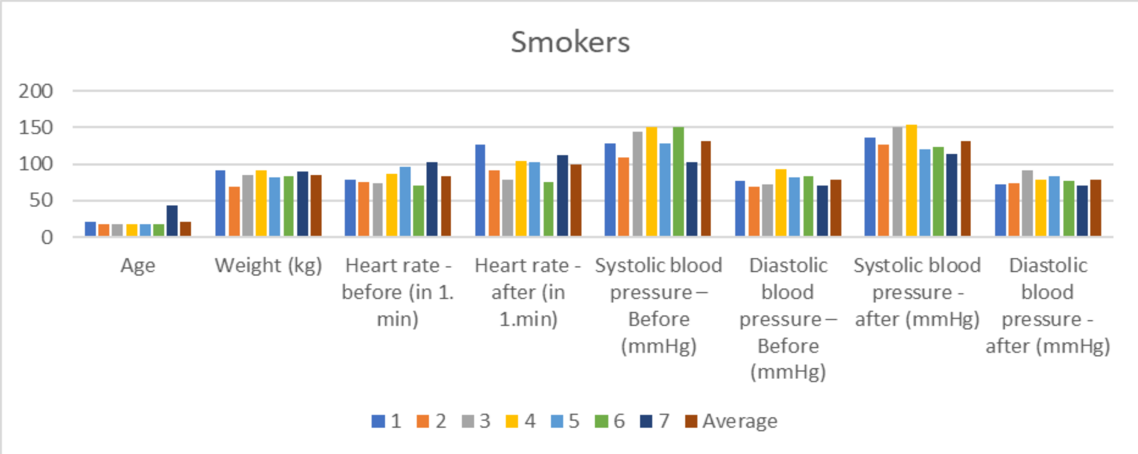

Figure 5. The results of smokers in exercise

Considering only the smokers (Figure 5.), we find that their average age is 21.57 years, 14% more than the overall average, and that their average weight is 84.66 kg, 8% more than the overall average. The pressure average before exercise for smokers is 130.7/78, not significantly different from the overall average. Their heart beats average 83 times per minute before exercise, 6% less than the overall average. After exercise, their heart average beats 99 times per minute, an increase of 19%. Comparing the increase in heart beats per minute to the average for all candidates, we find that the increase is 3% higher for smokers (16% vs. 19%). Blood pressure average did not increase as much after the exercise, which we can attribute to age (smokers are older), and they were not as nervous before the exercise.

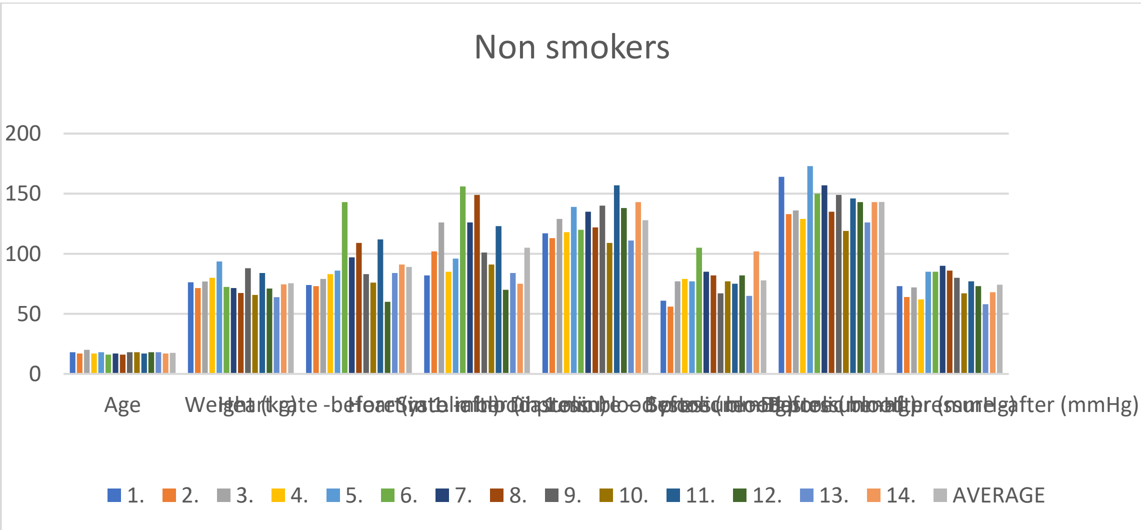

Figure 6. The results of non-smokers in exercise

Non-smokers (Figure 6.) are much younger than smokers during exercise (17.5 years versus 21.7) and even 9.2 kg lighter on average. Their blood pressure average before exercise is 127.9/77.8, which is very close to that of smokers and to the overall average. After exercise, blood pressure average is 143.1/74.3, with systolic (upper) pressure 12% higher than the average due to youth and excitement during exercise. Heartbeats average per minute are 89 before exercise, which is the same as the overall average, and 105 after exercise, which is an increase of 18% and very close to the overall average of 16%. From the above figures, it can be seen that smoking does not yet have a great influence on the endurance of students and young people around the age of 20 in this type of exercise.

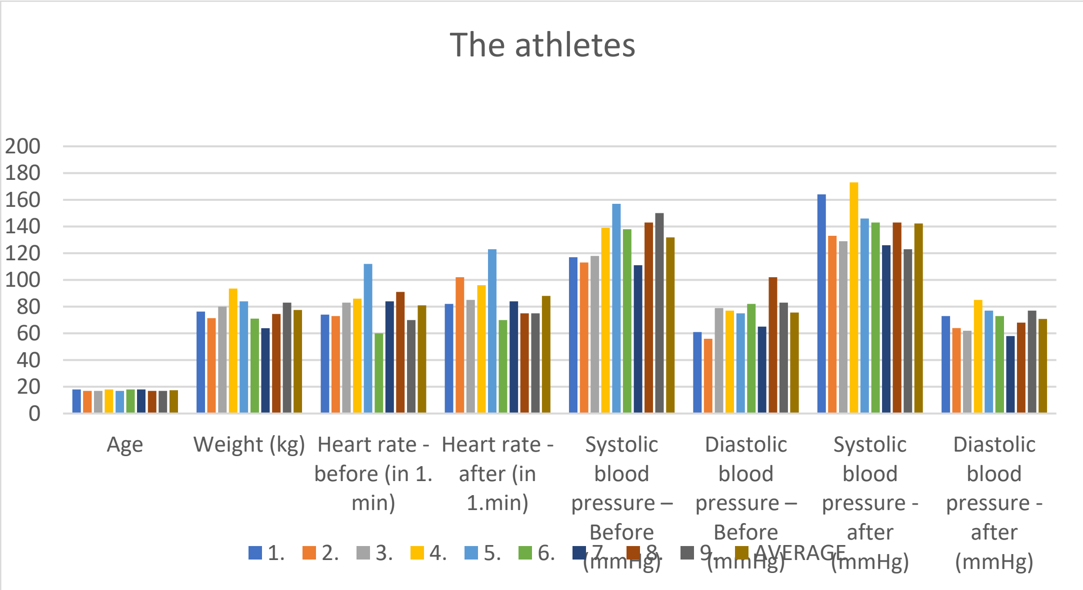

Figure 7. The results of athletes in exercise

The athletes (Figure 7) are on average the youngest, they are 17.4 years old and weigh 77.53 kg, which is only 1 kg less than the average. Pre-exercise average blood pressure is 131.8/75.6, which is very similar to the average of all, as is post-exercise blood pressure, which is average 142.2/70.8. What differs greatly from the average is the heart rate before and after exercise. Before exercise, the heart rate average is 81 beats per minute, which is 8% less than the average of all. After exercise, average the number of beats per minute for athletes is 88, which is 8% more than before exercise and 11% less than average (102 vs. 88). Comparing the increase in heart rate, it is twice as low as the average of all (8% vs. 16%). It is interesting to note that the average heart rate per minute in the athletes after training is completely equal to the average of all candidates before training and is 88.

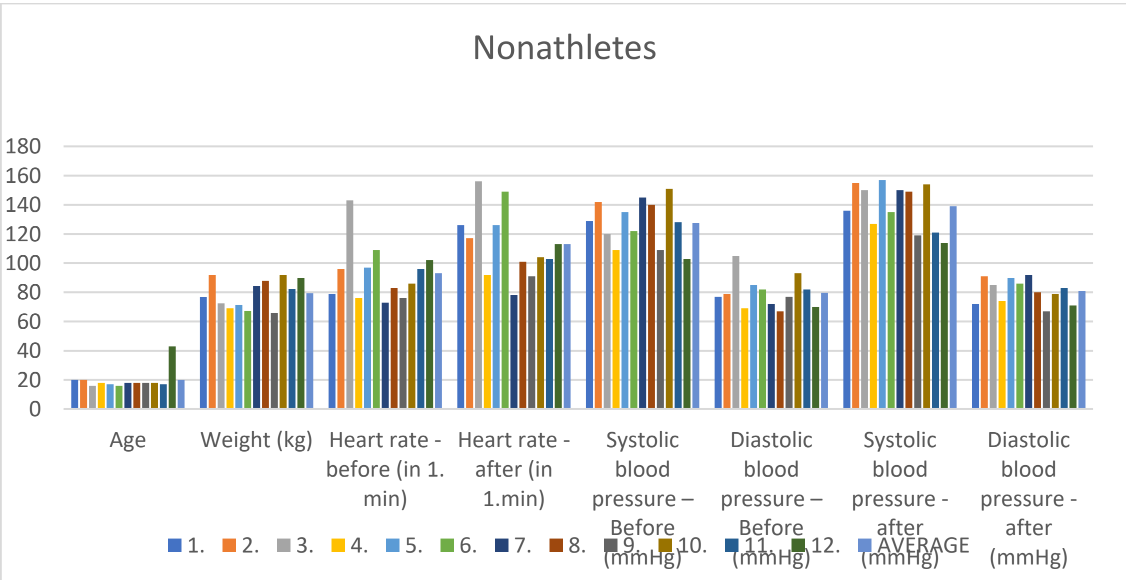

Figure 8. The results of nonathletes in exercise

The nonathletes (Figure 8.) are on average 19.9 years old and weigh 79.28 kg, less than 1 kg more than the average. Pre-exercise average blood pressure is 127.7/79.8, which is very similar to the average of all, as is post-exercise blood pressure average, which is 138.9/80.8. The average heart rate before exercise is 93 beats per minute, which is 6% higher than the average of all. After exercise, the average number of beats per minute for non-athletes is 113, which is 22% more than before exercise and 11% more than average of all(113 vs. 102). Comparing the increase in heart rate, it is much higher than average (22% vs. 16%).

It is very interesting to compare the heart beats per minute of athletes and non-athletes. The average heart rate of non-athletes before exercise is higher than that of athletes after exercise (93 vs. 88). Looking at the increase in heart rate, we find that the heart of athletes beats 8% faster and that of non-athletes 22% faster, which is a big difference of 14%. These figures show that sport has a positive effect on the ability of young people to exercise and that it is very important for children and young people to do sport.

CONCLUSION

Muster list specifies the duties of each crew member in the event of an emergency. During regular drills and in real-life situations, it is essential that each crewmember perform his or her assigned task as outlined in the muster list. Especially during fire drills, crew members assigned to wear breathing apparatus must be able to do so competently and effectively. It is important to recognize that being assigned to wear a breathing apparatus does not necessarily mean that the crewmember is actually capable of performing the assigned task. Therefore, it is important to thoroughly test each crewmember's ability to wear the breathing apparatus, as this can significantly impact the success of the emergency response.

The use of breathing apparatus is a vital component of firefighting on board ships. Regular fire drills and crew training are essential to ensure crew members are prepared to respond to hazards in a timely manner and prevent major fires on board. Our study has highlighted the importance of assessing the crew's ability to use breathing apparatus effectively in firefighting situations. The results of our study indicate that there is a need for improved crew training on the proper use of breathing apparatus, as well as a need for more frequent and realistic fire drills to simulate real-life situations. The results showed that smoking did not yet affect the adolescents who participated in the exercise. The measurements showed that the athletes had better results and greater endurance. Overall, the results showed that, on average, all young people are willing to make such efforts, regardless of whether they are athletes or smokers. One limitation of this study is that it was not conducted in real-life situations involving smoke and fire. The study was conducted on young people, and in the future the results of older people should be included, which would make the study more relevant and better.

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Right of Control in Carriage of Goods by Sea – New Approach of Rotterdam Rules

Vesna Skorupan Wolff

In current Conventions on the carriage of goods by sea (Hague Rules, Hague-Visby Rules and Hamburg Rules), there is no legal concept of right of control. The United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea ("Rotterdam Rules") has for the first time adopted the concept of the right of control for the carriage of goods by sea. The Rotterdam Rules adopted by UNCITRAL in 2008, has the ambitious goal of restoring the uniformity of the law governing the international carriage of goods by sea.

The object of the examination is recent solutions in respect of defining and prescribing the rights and liability of the controlling party. The article deals with the identity of the controlling party; the exercise and extent of the right of control; the duration of the right of control and the carrier's execution of instructions as important issues which affect the regime of the carrier's liability. The relation of the Rotterdam Rules towards other conventions which regulate the carriage of goods is also analyzed. Different points of view and opposing arguments regarding the legal concept of the right of control are emphasized and commented. Also, other important innovations regarding the concept of controlling party are pointed out.

Rotterdam Rules attempts to regulate in a comprehensive and contemporary manner the question of rights of controlling party and control of goods in transit. New concept of the right of control is introduced in order to satisfy contemporary conditions of maritime activities. Advantages which are expected to be achieved by this new concept of controlling the goods in transit are presented, but the solutions which could present obstacles in its incorporation into the regulation of carriage of goods by sea on the international level are also presented.

KEY WORDS

Carriage of goods by sea, Rotterdam rules, Right of control, Controlling party.

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INTRODUCTION

The international carriage of goods by sea is currently regulated by two main international Conventions: the International Convention for the Unification of Certain Rules Relating to Bills of Lading adopted in Brussels 1924, known as "The Hague Rules"[78] and the United Nations Convention on the Carriage of Goods by Sea, adopted in Hamburg 1978, known as "the Hamburg Rules".[79] Many countries have adopted the Hague Rules as amended by two Protocols, respectively adopted in Brussels on 1968 – the Hague-Visby Rules (25 contracting States) and on 1979 – the Special Drawing Rights Protocol – SDR Protocol (23 contracting States).[80] Some other Countries apply a sort of mix system between these Conventions. The Hague and the Hague-Visby Rules are, the more common rules applied by the shipowners. Actually, the field of maritime transport law is not at all internationally unified.

Internationally, three conventions currently govern the carriage of goods by sea. Due to the lack of a modern unified liability regime for the carriage of goods by sea, some States applied national solutions. The application of different national regimes and the lack of uniformity at the international level are of particular concern in the context of the growing globalization of trade.

In 1996, the Comité Maritime International ("CMI") and the United Nations Commission on International Trade Law ("UNCITRAL") started to draft a new Convention with the aim of modernising and harmonising the legislation on the carriage of goods by sea. After over ten years of extensive drafting work, the United Nations General Assembly adopted the new convention. United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea, better known as "The Rotterdam Rules" is new Convention adopted by the General Assembly of the United Nations on 11 December 2008. To date, 25 countries have signed the convention, which accounts for, according to official figures, about 25% of the current volume of international trade. The signatory nations include The United States of America, Spain, Denmark, France, the Netherlands, Norway, Greece, Poland and Switzerland and others.[81] The Rotterdam Rules will enter into force on the first day of the month following the expiration of one year after the date of deposit of the twentieth instrument of ratification, acceptance, approval or accession.[82]

The Rotterdam Rules address a number of issues that have not been regulated by previous international conventions. There are electronic communication, electronic records, delivery of the goods, performing party, right of control, transfer of rights, and so on.

[78] The Hague Rules have been ratified or acceded to by 89 countries and are presently active in 74 countries. Web Site, 2022. Hague Rules, Wikipedia, Available at: https://en.wikipedia.org/wiki/Hague%E2%80%93Visby_Rules, accessed on 3 October 2022.
[79] The Hamburg Rules have been ratified by 34 countries to date, Web Site, 2022. United Nations Commission on International Trade Law (UNCITRAL), Available at: https://uncitral.un.org/en/texts/transportgoods/conventions/hamburg_rules/status, accessed on: 3 October 2022.
[80] Web Site, 2022. Hague Rules, Wikipedia, Available at: https://en.wikipedia.org/wiki/Hague%E2%80%93Visby_Rules, accessed on 3 October 2022.
[81] Web Site, 2022. United Nations Commission on International Trade Law (UNCITRAL), Available at: https://uncitral.un.org/en/texts/transportgoods/conventions/rotterdam_rules/status, accessed on: 3 October 2022.
[82] Chapter 18, Article 94(1).

The essential objectives of the Rotterdam Rules are the establishment of a uniform, globalized, modern regime for regulating the rights and obligations of contracting parties in the maritime transport industry, with the application of a single door-to-door contract of carriage of goods.[83]

The existing maritime conventions have no provisions dealing with controlling parties or the concept of the right of control. The present law is thus found in domestic law, and may therefore be somewhat different in every jurisdiction although the broad principles are in fact fairly uniform. The drafters of the Rotterdam Rules submit that the new instrument will not tend to change existing law on this subject in any significant way, but will instead provide a solid and uniform legal basis for issues that have in many legal systems been left to unpredictable practices, particularly when there is no negotiable bill of lading in the transaction.[84]

The right to instruct the carrier during transit is now allowed by customary rules and national laws just to the holder of the full set of negotiable documents of title (bills of lading).[85]

From the practical point of view, this is a problem where no bill of lading has been issued and the carrier needs to know with whom it could negotiate different terms and conditions or from whom it is required to take instructions in exceptional circumstances.[86]

During the time the cargo is in the custody of the carrier, the parties interested in the cargo e.g. the shipper, the holder, or the consignee may need to give particular instructions to the carrier for the performance of the contract of carriage. On the other hand, the carrier also wants to know who has the right to give instructions and with whom he can, in case it is necessary, negotiate different terms of the contract and from whom he can demand the collection of additional costs. For these reasons, it is therefore considered that the Rotterdam Rules as a new convention should contain provisions on the right of control during transit. This is one of the ways in which maritime transport would be brought in line with transport conventions that apply to other modes of transport and that contain specific provisions on the right of control. Of course, the provisions of Rotterdam Rules should follow patterns adapted to the particular needs of maritime transport of goods. [87]

Chapter 10 of the Rotterdam Rules deals with the rights of the controlling party. It was designed to provide the right to a person with cargo interests to give or modify instructions to the carrier in respect of goods that do not constitute variations of the contract of carriage by sea.

The relevant provisions on the right of control serve to fill a lacuna in the law. Their goal is to harmonize and modernize the maritime transport of goods. The provision on the right of control is most important in cases where the carrier does not issue a physical piece of paper qualifying as a negotiable transport document - bill of lading. This is exactly the situation in an electronic commerce

[83] Uribe, M. A. & Maxwell P., 2010. Transportfacilitation from the perspective of the Rotterdam Rules, Facilitation of transport and trade in Latin America and the Caribbean, 2 (238).
[84] Sturley, M. F., 2007-2008. The UNCIRAL Carriage of goods convention: changes in existing law, CMI Yearbook 2007-2008, (254-263).
[85] Rimaboschi M., 2009. The new Rotterdam Rules: An overview on the main differences with the international regulations in force on carriage of goods by sea, *Diritto Economia Politica*, 108 (61).
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[87] Boxuan L. & Jie J., 2017. The Provisions Relating to the Identity of the Controlling Party in the Rotterdam Rules and Their Potential Influences on Chinese Cargo Interests, *Revue juridique Thémis de l'Université de Montréal* 51-1 (245), Available at: https://canlii.ca/t/slc4.

transaction. This is why the provisions of the Rotterdam Rules should facilitate electronic commerce.[88]

This article is intended for a thorough examination of the provisions concerning the right of control in the context of the Rotterdam Rules and international shipping trade.

EXERCISE AND EXTENT OF RIGHT OF CONTROL

The current legal regulation of the carriage of gods bay sea at the international level dates back to the time when no communication was possible between the shipper or consignee and the carrier who actually controls the goods during transport. For this reason, a legal framework was created for a document called the "bill of lading", and it has the task of representing the goods. Handling this document replaces physically handling the goods, and, when doing so, no involvement is needed from the person actually in custody of the goods during transit. The purpose of a negotiable transport document is to transfer ownership of the goods or create a pledge on the goods.[89] Today, communication is possible in real-time from all corners of the world. This includes carriers who has in custody goods during the carriage. This means that a physical piece of paper – a negotiable transport document as a symbol of the goods and use a document for transferring legal control over the goods is no longer necessary. The reason why such a practice exists is that the current law, case law and trade practice are still based on the documentary process. The current practice may change if the rules on the right of control are codified and if they are decoupled from the use of a document. This is precisely the aim of the provisions on the right of control in the Rotterdam Rules[90]

Pursuant to the Rotterdam Rules right of control of the goods means the right under the contract of carriage to give the carrier instructions in respect of the goods in accordance with chapter 10.[91]

The right of control is limited to:

- The right to give or modify instrictions in respect of the goods that do not constitute a variation of the contract of carriage,
- The right to obtain delivery of the goods at a scheduled port of call or, in respect of inland carriage, any place en route, and
- The right to replace the consignee by any other person including the controlling party.[92]

Subparagraph (a) refer to the normal instructions under transportation. The type of instructions referred to under subparagraphs (b) and (c) arise under particular circumstances. They are normally variations of the contract of carriage.

Subparagraph (a) provides clearly that the right of control does not extend to varying the contract of carriage, e.g. the instructions could be an order to carry the goods at a certain temperature or deliver them at a certain point of time at the premises of the consignee.

[88] Sturley, M. F. 2007-2008. The UNCIRAL Carriage of goods convention: changes in existing law, CMI Yearbook 2007-2008, (254-263).
[89] Zial, G. 2009. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44:375, (376).
[90] Zial, G. 2009. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44:375, (376).
[91] Definition is included in Chapter 1, Article 1(12).
[92] Chapter 10, Article 50 (1).

Often, such instructions are primarily of an operational nature. However, this is not always the case. A quite common instruction is, “Please, seek contract before you actually deliver.” Such are instructions given by the seller or shipper when the goods have not been paid upon shipment and there is no certainty that the price of the goods will be paid in time. Therefore, the shipper or seller wants to be sure that the goods will not be delivered prior to payment.

Subparagraph (b) in a legal sense, is the right to change the agreed delivery of goods.
The possibility that the controlling party may require earlier delivery may be important to avoid the arrival of goods in the jurisdiction of the consignee. For example, if the consignee to whom the goods are delivered on credit terms has become insolvent and unable to pay for the goods. In such a case, the seller who has not been paid for the goods wants to keep the goods out of the receiver’s hands.[93]

The type of instruction referred to under subparagraphs (c) is limited to the right to replace the consignee by any other person including the controlling party.

Replacing the consignee with another person is considered when the goods are resold during transport. It may also be relevant when the selling price of the goods is not expected, and the shipper or seller nominates himself as the new consignee so that he can again reclaim possession of the goods. In addition, this right is very important for the bank when it wants to exercise its rights as the pledgee of the goods.[94]

Instances b) and c) must refer to a legal right for the unilateral variation of the contract of carriage, and the right of control relates to the contract of carriage, but does not exactly fall under it. Except in some special circumstances where parties may agree in the original agreement that one side may unilaterally vary certain terms a variation of the contract generally requires mutual consent. A typical example of this is a credit agreement, which often gives the lender the right to vary the interest rate form time to time. In carriage of goods by sea, common law does not confer on the shipper the unilateral right of control in the carriage of goods by sea. The variation of a contract of carriage should be subject to the agreement freely agreed upon by the parties concerned. In substance, the right of control in the Rotterdam Rules is defined as a right to vary a contract of carriage, concerning especially the delivery of goods.[95]

IDENTITY OF THE CONTROLLING PARTY

Controlling party means the person that pursuant to article 51 Rotterdam Rules is entitled to exercise the right of control. Rotterdam Rules makes it clear that the controlling party is the exclusive person entitled to exercise a right of control and sets out in a detailed manner who, in different situations, the controlling party is.

Typically, the shipper has the right of control over the goods in transit, unless the shipper, when the contract of carriage is concluded, designates the consignee, the documentary shipper or another person as the controlling party.

[93] Zial, G. 2009. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44:375, (378).
[94] Zial, G. 2009. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44:375, (378).
[95] Zhao, L. 2014. The right of control in carriage of goods by sea, *Lloyd's Maritime and Commercial Law Quarterly*, (395).

This applies to situations where a non-negotiable transport document, such as a sea waybill is issued and also applies to cases in which no document at all is used.

But if a bill of lading has been issued, the new regulation provides anyway that the controlling party is the holder of the bill of lading or, if more than one original of the negotiable bill of lading has been issued, the holder of the full set of originals. The same right is allowed by the new regulations to the holder of a negotiable electronic transport record.[96]

Several questions arise regarding the right of control. In the event that the shipper is not the controlling party under the Rotterdam Rules (chapter 10), but the controlling party is a holder of the transport document or negotiable electronic transport record according to provisions from chapter 11 of the Rotterdam Rules (Article 57), on what legal basis can such a shipper, or documentary shipper, give instructions to the carrier? It is also a question in whose behalf does the carrier hold the goods when a negotiable document is issued? Does he do it on behalf of the shipper, or on behalf of the lawful holder of the negotiable document? When the shipper is not the controlling party and has no authority regarding the goods, it is unclear how his instructions can discharge the carrier from his obligations contained in a negotiable document.[97]

When a non-negotiable transport document has been issued that indicates that it shall be surrendered in order to obtain delivery of the goods the shipper is the controlling party and may transfer the right of control to the consignee's name in the transport document by transferring the document to the person without endorsement. In order to exercise its right of control, the controlling party shall produce the document and properly identify itself. If more than one original of the document was issued, all originals shall be produced, failing which the right of control cannot be exercised.

DURATION OF THE RIGHT OF CONTROL

The Rotterdam Rules chapter on the right of control addresses goods that are in transit and in the carrier's custody. Convention deals with situations in which the goods have been delivered to the carrier for transportation, loaded on board a ship, or are somewhere on the high seas.[98]

The right of control exists during the entire period of responsibility of the carrier, as provided in article 12, and ceases when that period expires.[99] Article 50, second paragraph links the period during which the right of control can be exercised to the period of responsibility of the carrier under the contract of carriage.

For the purpose of determining the carrier's period of responsibility for goods, the contractual parties may agree on the time and location of receipt and delivery of the goods. However, it is important to point out that a provision in a contract of carriage is void to the extent that it provides that the time of receipt of the goods is subsequent to the beginning of their initial loading under the contract of carriage, or the time of delivery of the goods is prior to the completion of their final unloading under the contract of carriage.[100]

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[96] Rimaboschi M., 2009. The new Rotterdam Rules: An overview on the main differences with the international regulations in force on carriage of goods by sea, *Diritto Economia Politica*, 108. (61).
[97] Pejović Č., 2013. Article 47 (2) of the Rotterdam Rules: Solution fo Old Problems or a New Confusion?, Poredbeno pomorsko pravo – Comparative Maritime LaW, v. 52, 167, (81-103).
[98] Zial, G. 2009. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44, (375).
[99] Chapter 10, Article 50 (2).
[100] Chapter 4, Article 12 (3).

Because the beginning and the end of the period of the carrier's responsibility may be determined by contract, the actual custody of the goods by the carrier is not always a decisive factor in whether the right of control can still be exercised. Similarly, the moment when the consignee demands delivery of the goods is legally irrelevant to the termination of the right of control.[101]

CARRIER'S EXECUTION OF INSTRUCTIONS

A carrier is obliged to execute the instructions subject to the conditions specified in article 52. Rotterdam Rules. Carrier shall execute the instructions referred to in Rotterdam Rules if:

- The person giving such instructions is entitled to exercise the right of control
- The instructions can reasonably be executed at the moment that they reach the carrier and
- The instructions will not interfere with the carrier's normal operations, including its delivery practices.

The main condition is that the instructions must correspond to the normal operations of the carrier. Additional costs incurred by the carrier must be compensated by the controlling party. The carrier may require security for such amounts.[102]

Article 52 (2) provides for the principle that the controlling party shall reimburse the carrier for any reasonable additional costs that the carrier may incur as a result of diligently carrying out any instructions pursuant to this Article. This includes compensation for loss or damage to other goods being transported, for which the carrier may become liable.

Article 52 deals only with liability for loss or damage to goods or for the delay in delivery. It is left to the applicable national law to answer the question of whether a carrier can be held liable for any loss or damage, other than loss or damage to goods resulting from failure to comply with an instruction given in the exercise of the right of control. The limits (amount of the compensation payable by the carrier) referred to in Article 59 to 61 also apply to this carrier's liability.[103]

1. CONCLUSION

Rotterdam Rules provide for a specific regulation connecting the right of control on the shipped goods while the cargo is under the control of the carrier and is in his custody. The provisions of the Rotterdam Rules on the right of control are precise and clear. They prescribe how control should be exerted over transported goods and about the person who is legitimized to exert control over the goods.

The Rotterdam Rules provide that the exercise of the right of control includes the right to convention states that the exercise of this right includes the right to modify instructions in respect of goods, insofar as the contract of carriage is not modified; to take delivery of goods at a scheduled port of call along the maritime route or at any place along the inland route, or to replace the consignee with another person, including the controlling party. It is prescribed that the carrier is obliged to comply with those instructions, to the extent that the person issuing the instructions is entitled to exercise

[101] Zial, G. 2009. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44 (375, 378).
[102] Zial, G. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44 (375, 381).
[103] Zial, G. 2009. Chapter 10 of the Rotterdam Rules: Control of Goods in Transit, Texas International Law Journal, vol. 44 (375, 381).

the right of control. Also, it is prescribed that the carrier shall execute the instructions to the extent that he can reasonably comply with the instructions and to extent that compliance does not interfere with the normal operations of the carrier.

The carrier has the right to obtain security from the party that has control for additional costs, loss, or damage that the carrier reasonably expects to be incurred in connection with the execution of instructions in accordance with the exercise of the right of control. The carrier may refuse to carry out instructions if it has not obtained such security.[104]

Some authors criticize the concept of the right of control. In their opinion, the right of control in the Rotterdam Rules is not a suitable concept for the international carriage of goods by sea.

It is argued that, although is other branches of transport law there is an analogous right to dispose of goods during transport and a right of stoppage in sale of goods, the right of control in the Rotterdam Rules is not an appropriate concept for the carriage of goods by sea. By contrast, the approach of legislation on control of goods in the US Uniform Commercial Code ("UCC") is better suited for the carriage of goods by sea.[105] Therefore, it proposed that the provisions of Section 7-303 of the US Uniform Commercial Code be a model law or model provisions for future legislation or the protocol of the Rotterdam Rules.[106]

Also, it is argued that the execution of the right of control will impose extra duties and obligations on the carrier and affect the basic principles of the contract of carriage, which may raise new legal problems and the complexities may be acceptable for legal experts, but not easily understood by business people in commercial practice. Since the right of control might be given to the shipper or anyone else, this may have negative effects on the doctrine of privity of contract in contract law. This means that the carrier could be taking risks in the delivery of goods when following instructions given under the right of control by a person who has not established contractual or legal relations with the carrier.

Important criticism in relation to the concept of the right of control in Rotterdam Rules is as follows. This right is not under a contract of carriage, but a modification of a contract of carriage. The execution of this right is based not on the mutual agreement but on unilateral instructions not needing the consent of the carrier. The right of control is mandatory for parties to a contract of carriage unless they make variations. It thereby makes the right of control a complex operating guide for changing the agreed delivery of goods. This may not be the task of international legislation. Although a similar right of control exists in some non-sea carriage Conventions, it must be admitted that non-sea transport documents, such as air waybills, are not documents of title. Therefore, the simple transfer of such a right into the carriage of goods by sea seems to be a challenging and unrealistic risk for the Rotterdam Rules.[107]

Some positively assess the Rotterdam rules and wait for their entry into force. It is not uncommon for cargo interests to give the carrier some instructions with regard to the goods in transit under certain circumstances, but there are no provisions as to who is entitled to give such instructions in the Hague, Visby and Hamburg Rules. The absence of such provisions makes it difficult for cargo owners to respond effectively to circumstances requiring changes to the contract of carriage. Also, the absence of provisions

[104] Chapter 10, Article 52 (3).
[105] Zhao, L. 2014. The right of control in carriage of goods by sea, *Lloyd's Maritime and Commercial Law Quarterly*, (397).
[106] *Ibid.*
[107] Liang Zhao, The right of control in carriage of goods by sea, *Lloyd's Maritime and Commercial Law Quarterly*, (2014), p. 414.

on who has the right to control the goods in transit increases the difficulties for the carrier in identifying the party whose instructions should be followed. Therefore, some authors believe that Article 51 of the Rotterdam Rules, which deals with the identity of the controlling party and transfer of the right of control, fills this gap well by prescribing who has the right of control in different cases.[108]

The future of the Rotterdam Rules is still uncertain. So far, only five states have ratified the Rotterdam rules[109] There are several innovations that could discourage ratification of the Rotterdam Rules. As an important problem, it is often pointed out that, under certain conditions, the Rotterdam Rules, due to their “door to door” concept, can be applied to other modes of transport. Then, the introduction of rules on the liability of the performing party, which may include stevedores and cargo terminals, is highlighted as a difficulty. In addition, it is objected that the text of the Rotterdam Rules is too complicated to be suitable for use in practice. In practice, the commercial industry demands clarity and prefers simple and understandable convention texts. Therefore, instead of greater harmonization, the adoption of the Rotterdam Rules could actually result in a greater fragmentation of the international law governing the carriage of goods by sea.[110]

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Correlations Between Aviation and Maritime Safety Management Systems

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The notion of safety is a very complex set of phenomena within the system that are interconnected in a unique and very complex way. The main objective of any safety management system is to prevent accidents and adverse events, hence safety management system has to be able to process, monitor and improve safety performance of an organization. Aim of the paper is to determine compatibility between aviation and maritime safety management systems through analysis of three top safety management areas, i.e., framework of each safety management system, safety risk management processes, and safety methodologies and performance management. Determining systems' compatibility, opens up the possibility to use certain techniques implemented in aviation safety management and implement them in maritime safety management in order to improve its efficiency.

KEY WORDS

Correlations, Aviation, Maritime, Safety, Management, Systems

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INTRODUCTION

The concept of safety is understood very broadly: from correctness in performing very complex tasks in an organization, proper handling and maintenance of equipment, to protection from conscious and unconscious actions that endanger the normal work operations. Safety can be perceived as a very complex set of phenomena within the system that are interconnected in a unique and very complex way (interaction of humans, technology, and environment).

Being a regulatory requirement, Safety Management System (SMS) is implemented in every aviation organization, and it uses various tools to manage safety, such as clear safety policies and objectives, hazard identification, risk management, risk mitigation, safety reporting, safety audits, safety investigations, corrective or mitigative safety actions, safety culture, safety education, safety communication, etc. (Bartulović, 2021; ICAO, 2018; Hollnagel, 2014). International Civil Aviation Organization (ICAO) and aviation organizations around the world are continuously making efforts to ensure improvements and advances in the area of aviation safety management (ICAO, 2019), by defining tools and goals that help aviation organizations efficiently manage, maintain and increase safety (Yeun, et al., 2014). The main documents regulating safety policies and procedures are ICAO Annex 19 to the Convention on International Civil Aviation – Safety Management (ICAO, 2016) and ICAO Doc 9859 – Safety Management Manual (SMM) (ICAO, 2018).

Maritime safety, as a priority, considers how maritime organizations ensure the safety of the operations. In maritime transport, The International Maritime Organization (IMO) continuously attempts to ensure the safety of maritime operations through the International Convention for the Safety of Life at Sea (SOLAS) and specific safety management guidelines called the International Management Code for the Safe Operation of Ships and Pollution prevention, i.e., ISM Code (IMO, 2018). All of mentioned regulations have brought a gradual improvement of the maritime organizations' safety, but the effect of imposed safety regulations and guidelines on achieving an actual proactive approach to maritime safety, is still questionable (Valdez Banda & Goerlandt, 2018; Leveson, 2015).

The main objective of any SMS is to prevent accidents, hence SMS has to be able to process, monitor and improve safety performance of the organization (Valdez Banda & Goerlandt, 2018). Many researchers investigated the causal modeling techniques to analyze maritime incidents and to take remedial measures that could be applied to prevent them in the future (Qiao, et al., 2021; Golden & Weisbrod, 2016). Recent studies presented advances in the area of aviation safety management, introducing use of predictive and causal modeling methods, to detect and prevent future adverse events turning into accidents or incidents (Bartulović, 2022; Bartulović & Steiner, 2022; Bartulović, 2021; Bartulović & Steiner, 2020).

The focus of this paper is to determine level of compatibility between aviation and maritime safety management systems, by comparing three key areas: structure of safety management systems (regulatory set-up and implementation requirements), safety risk management process, and safety methodologies and performance management. Safety approaches in aviation include reactive, proactive and predictive methodologies. Maritime safety methodologies are mostly reactive, with slow shift to proactive. Determining systems' compatibility, opens up the possibility to use certain techniques implemented in aviation safety management and implement them in maritime safety management in order to improve its efficiency.

STRUCTURE OF SAFETY MANAGEMENT SYSTEMS

Aviation Safety Management System

In aviation, International Civil Aviation Organization (ICAO) prescribes Standards and Recommended Practices (SARPs) to regulate international civil aviation, including safety-related provisions. SARPs regarding aviation safety are outlined in ICAO Annex 19 to the Convention on International Civil Aviation – Safety Management and ICAO Safety Management Manual (SMM) and are usually referred to as "ICAO SMS framework" (ICAO, 2018; ICAO, 2016).

Figure 1 shows four main components of ICAO SMS framework (safety policy and objectives, safety risk management, safety assurance, safety promotion) and twelve accompanying elements, i.e., management commitment, safety accountability and responsibilities, appointment of key safety personnel, coordination of emergency response planning, SMS documentation, hazard identification, safety risk assessment and mitigation, safety performance monitoring and measurement, management of change, continuous improvement of the SMS, safety education and training, and safety communication.

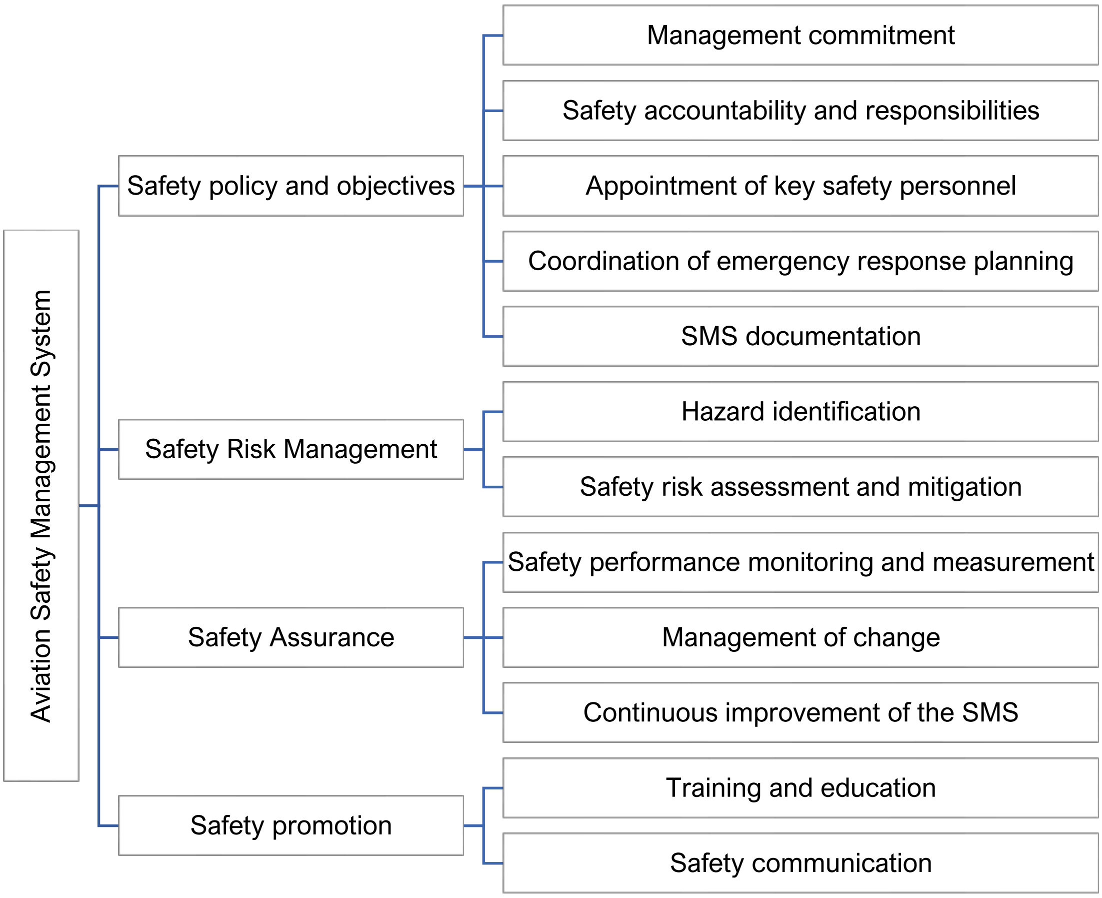

Figure 1. Structure of aviation safety management system (Source: ICAO, 2016).

Maritime Safety Management System

The International Management Code for the Safe Operation of Ships and for Pollution Prevention (International Safety Management (ISM) Code) provides an international safety standard in maritime transport. It was adopted by the International Maritime Organization (IMO) by resolution A.741(18) from 1993 and became mandatory by entry into force on 1 July 1998 of SOLAS chapter IX on Management for the Safe Operation of Ships (IMO, 1993). The ISM Code requires maritime companies to establish safety objectives, and in addition develop, implement and maintain a safety management system which includes prescribed functional requirements (IMO, 2018).

In maritime transport, safety management system means a structured and documented system enabling companies to effectively implement the company's safety and environmental protection policy (IMO, 2018).

Figure 2 shows thirteen main elements of maritime safety management system, i.e., general provisions, safety and environmental protection policy, company responsibilities and authority, designated persons, master's responsibility and authority, resources and personnel, shipboard operations, emergency preparedness, reports and analysis of non-conformities, accidents, and hazardous occurrences, maintenance of the ship and equipment, documentation, company verification, review and evaluation, and certification, verification and control.

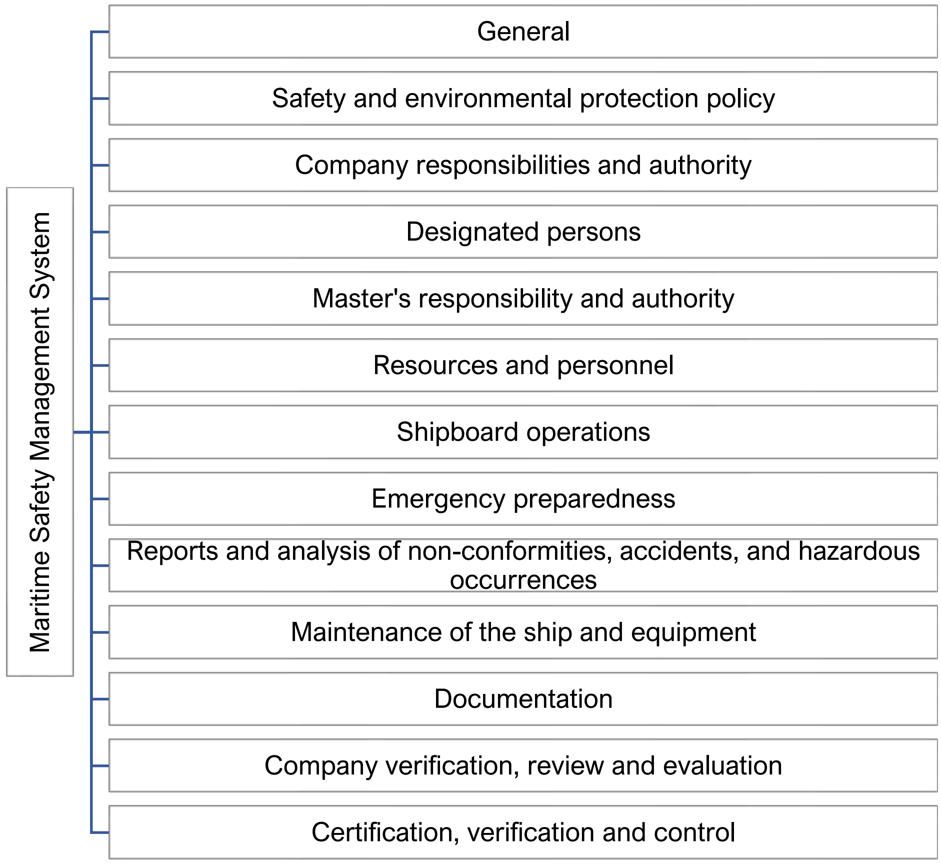

Figure 2. Structure of maritime safety management system (Source: IMO, 2018; IMO, 1993).

Structure Correlations between Aviation and Maritime Safety Management System

After studying structure (framework) of both aviation and maritime safety management system, correlations have been established and presented in Figure 3. It can be observed that systems are compatible in all areas, except in the area of safety performance monitoring and measurement.

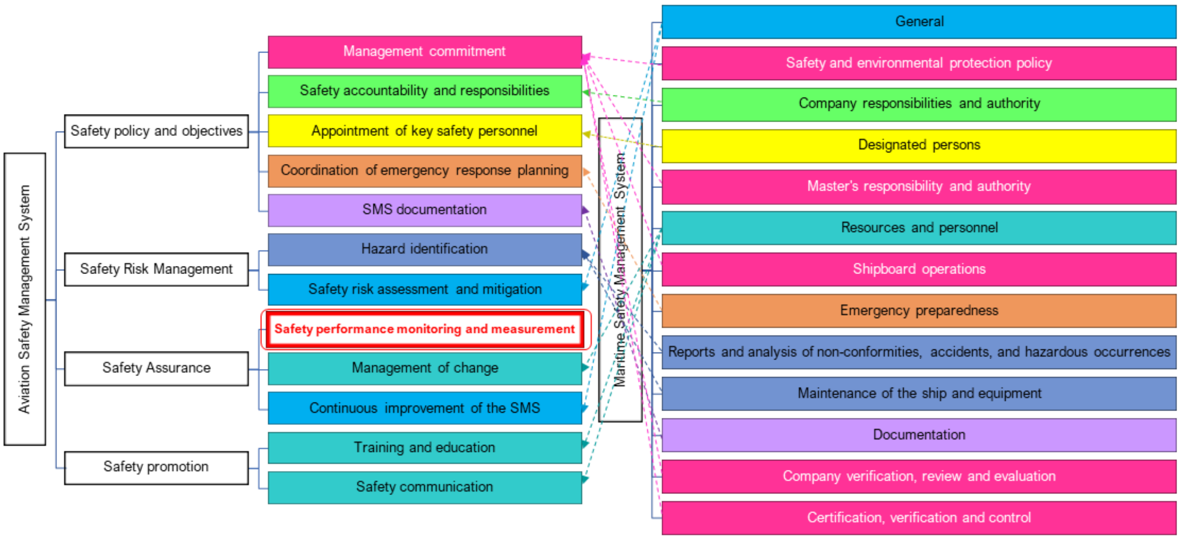

Figure 3. Compatibility of aviation and maritime safety management systems.

SAFETY RISK MANAGEMENT

Aviation Safety Risk Management

Safety is a state in which the risk of harm to persons or property is reduced and maintained at an acceptable level, through a continuous process of hazard identification and safety risk management (Uyar, 2019; Leveson, 2015; Müller, et al., 2014; Bartulović, 2012). The risk assessment considers the probability and severity of any adverse consequence that may result from the identified hazard (Patankar & Taylor, 2004).

One of the most important components of the aviation SMS is Safety Risk Management (SRM) (ICAO, 2018; ICAO, 2016), and it includes hazard (occurrence) identification, risk assessment and risk mitigation (Cusick, et al., 2017; Stolzer & Goglia, 2015; Ferguson & Nelson, 2014), as illustrated in Figure 4.

Figure 4. Process of aviation safety risk management (Source: ICAO, 2016).

Table 1 shows safety risk probability. As a result of the hazard probability analysis, each risk is assessed by one of the probability categories.

Probability	Meaning	Value
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	4
Remote	Unlikely to occur, but possible (has occurred rarely)	3
Improbable	Very unlikely to occur (not known to have occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Table 1. Safety risk probability (Source: ICAO, 2018).

Table 2 shows safety risk severity. As a result of the hazard severity analysis, each risk is assessed with one of the severity categories.

Severity	Meaning	Value
Catastrophic	Aircraft/equipment destroyed Multiple deaths	A
Hazardous	A large reduction in safety margins, physical distress, or a workload such that operational personnel cannot be relied upon to perform their tasks accurately or completely Serious injury Major equipment damage	B
Major	A significant reduction in safety margins, a reduction in the ability of operational personnel to cope with adverse operating conditions as a result of an increase in workload or as a result of conditions impairing their efficiency Serious incident Injury to persons	C
Minor	Nuisance Operating limitations Use of emergency procedures Minor incident	D
Negligible	Few consequences	E

Table 2. Safety risk severity (Source: ICAO, 2018).

Table 3 shows the safety risk assessment matrix which represents the tool to determine safety risk index or safety risk level, e.g., probability category 4 and severity category B equals to risk index of 4B.

Probability	Severity				
	Catastrophic (A)	Hazardous (B)	Major (C)	Minor (D)	Negligible (E)
Frequent (5)	**5A**	**5B**	**5C**	**5D**	**5E**
Occasional (4)	**4A**	**4B**	**4C**	**4D**	**4E**
Remote (3)	**3A**	**3B**	**3C**	**3D**	**3E**
Improbable (2)	**2A**	**2B**	**2C**	**2D**	**2E**
Extremely improbable (1)	**1A**	**1B**	**1C**	**1D**	**1E**

Table 3. Safety risk matrix (Source: ICAO, 2018).

Table 4 shows safety risk tolerability and shows three main levels of risk tolerability. The outcome of the risk assessment, i.e., risk index/level is used to determine the necessary mitigation measures.

Safety Risk Index Range	Safety Risk Description	Recommended Action
5A, 5B, 5C, 4A, 4B, 3A	INTOLERABLE	Take immediate action to mitigate the risk or stop the activity; perform priority safety risk mitigation to ensure additional or enhanced preventative controls are in place to bring down the safety risk index to tolerable
5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	TOLERABLE	Can be tolerated based on the safety risk mitigation; it may require management decision to accept the risk
3E, 2D, 2E, 1B, 1C, 1D, 1E	ACCEPTABLE	Acceptable as is; no further safety risk mitigation required

Table 4. Safety risk tolerability (Source: ICAO, 2018).

Maritime Safety Risk Management

The following four steps (Figure 5) show the risk management process in maritime safety management system. First step identifies and documents all hazards associated with maritime organization's operations. After identifying hazards, consideration of the possible impact (risk) of those hazards on the safety, must be assessed. Risk assessment phase (second step) includes determination of the chance of risk occurrence called likelihood, and possible harm that it could cause, i.e., consequence. The result of using a likelihood and consequence matrix is called risk rating or risk severity (AMSA, 2020; ASNZS, 2009).

Figure 5. Process of maritime safety risk management (Source: AMSA, 2020).

Table 5 shows safety risk likelihood. As a result of the likelihood analysis, each risk is assessed by one of the likelihood categories.

Category	Explanation	Descriptor	Percentage	Chance per year
Almost certain	Expected to occur in most circumstances, or often in the life of a vessel's operation	Common event	95%	Weekly occurrence
Likely	Probably occur in most circumstances but unlikely to occur often in the life of a vessel's operation	Known to occur	60%	Monthly event
Possible	Might occur at some time, unlikely to occur to every vessel but may occur to a few vessels of a particular type	Could occur, heard of it happening	40%	Up to three times a year
Unlikely	Unlikely to occur but should be considered as possible	Not likely to occur	20%	Once in a year
Rare	So extremely remote that it should not be considered as possible unless exceptional circumstances exist	Practically impossible	5%	Unheard of occurring

Table 5. Safety risk likelihood (Source: AMSA, 2020).

Table 6 shows safety risk consequences. As a result of the consequence analysis, each risk is assessed with one of the consequence categories.

Category	Human injury	Financial cost	Work/income/reputation	Environment
Catastrophic	Multiple fatalities	Loss of vessel, total loss of income	Operations halted; image/reputation is severely damaged	Extensive environmental damage
High	Fatality	Extensive financial	Major disruption to operations, temporary loss of income, image/reputation impacted	Major environmental damage
Medium	Disabling injury requires medical treatment	Significant financial loss	Significant disruption to operations, image/reputation suffers	Significant environmental damage
Minor	First aid treatment for minor cuts, bruises or abrasions	Notable financial loss	Minor disruption to operations	Minor environmental damage
Negligible	No injuries	Negligible financial	No adverse effect on operations	Negligible environmental damage

Table 6. Safety risk consequences (Source: AMSA, 2020).

Table 7 shows the risk likelihood and consequence matrix which represents the tool to determine risk rating or risk severity, e.g., likelihood category "Likely" and consequence category "Major" equals to risk rating of "High".

Likelihood	Consequences				
	Negligible	Minor	Medium	Major	Catastrophic
Almost certain	**Moderate**	**Moderate**	**High**	**Extreme**	**Extreme**
Likely	**Low**	**Moderate**	**High**	**High**	**Extreme**
Possible	**Low**	**Low**	**Moderate**	**High**	**High**
Unlikely	**Very Low**	**Low**	**Moderate**	**Moderate**	**High**
Rare	**Very Low**	**Very Low**	**Low**	**Moderate**	**Moderate**

Table 7. Risk likelihood and consequence matrix (Source: AMSA, 2020).

Table 8 shows hierarchy of controls that helps maritime organizations to determine the most appropriate approach to control identified risks. There are five categories of risk controls, going from least effective to most effective ones.

Controls	Effectiveness	Description
Elimination	MOST EFFECTIVE	Eliminate the hazard or risk.
Substitution	VERY EFFECTIVE	Replace with something similar with less risk.
Isolation/Engineering	EFFECTIVE	For example – install guards on machine, redesign the task.
Administration/Training	LESS EFFECTIVE	Implement policies, procedures and training.
Personal protective equipment (PPE)	LEAST EFFECTIVE	Provide equipment such as gloves, self- inflating lifejackets, personal locator beacons, etc.

Table 8. Hierarchy of controls (Source: AMSA, 2020).

Correlations between Aviation and Maritime Safety Risk Management

After gathering information on how risk assessment process is conducted in both aviation and maritime safety risk management, it can be observed that they correlate in every segment. Both aviation and maritime safety risk assessments determine risk “impact” by using matrix, which in aviation SMS is called risk index or risk level, and in maritime SMS is called risk rating or risk severity. Both matrices consist of two areas, each divided into five categories, but with different nomenclature. Also, both use rating system to implement appropriate mitigation measures or risk controls. Hence, by comparing two systems from the aspect of conducting risk assessment, it can be observed that they are, other than nomenclature, compatible.

SAFETY METHODOLOGIES & PERFORMANCE MANAGEMENT

Safety performance management, in general, provides an organization with an insight to its own activities and assures that all processes are working effectively to achieve safety objectives (Kaspers, et al., 2019). Safety performance measurement usually refers to establishing and monitoring safety indicators such as number of accidents or incidents, number of changes, number of findings related to safety, etc., in relation to time frame (monthly or yearly data) or to conducted operations (Bartulović, 2022).

Aviation Safety Methodologies & Performance Management

Aviation safety management uses three methodologies, i.e., reactive, proactive, and predictive. Reactive methodology collects safety data from the accidents and incidents that has already occurred in the past and learns from their outcomes (Bartulović, 2021; Cusick, et al., 2017). Proactive methodology collects safety data on occurrences or organization's performance and analyzes the gathered safety data or its frequency to estimate if a hazard could cause an accident or incident (Patriarca, et al., 2019). Predictive methodology of the SMS can use historical and current safety data, organizational safety performance indicators (SPIs) and safety performance targets (SPTs) as the input information to conduct predictive analysis, i.e., forecasts using predictive (forecasting) methods (Bartulović, 2022; Bartulović, 2021; Bartulović & Steiner, 2020; Insua, et al., 2019; Di Gravio, et al., 2015). Predictive methodology acts as an upgrade for proactive methodology, where proactive tools are used as input information for predictions and causal models of organizational safety performance (Bartulović, 2022).

Table 9 shows examples of five safety performance indicators (SPIs) monitored in aviation organizations.

Mark	Safety performance indicators
SPI1	Number of occurrences related to maneuvering area maintenance
SPI2	Number of occurrences related to passenger handling – disembarking/embarking
SPI3	Number of aircraft damage occurrences
SPI4	Number of personnel or passenger injuries
SPI5	Number of occurrences related to ground traffic (GSE) and vehicle driving

Table 9. Examples of safety performance indicators (SPIs) monitored at an airport (Source: Bartulović, 2022).

Figure 6 shows an example of aviation safety performance indicator, i.e., Number of runway excursions, with accompanying set-up of safety triggers and safety performance targets.

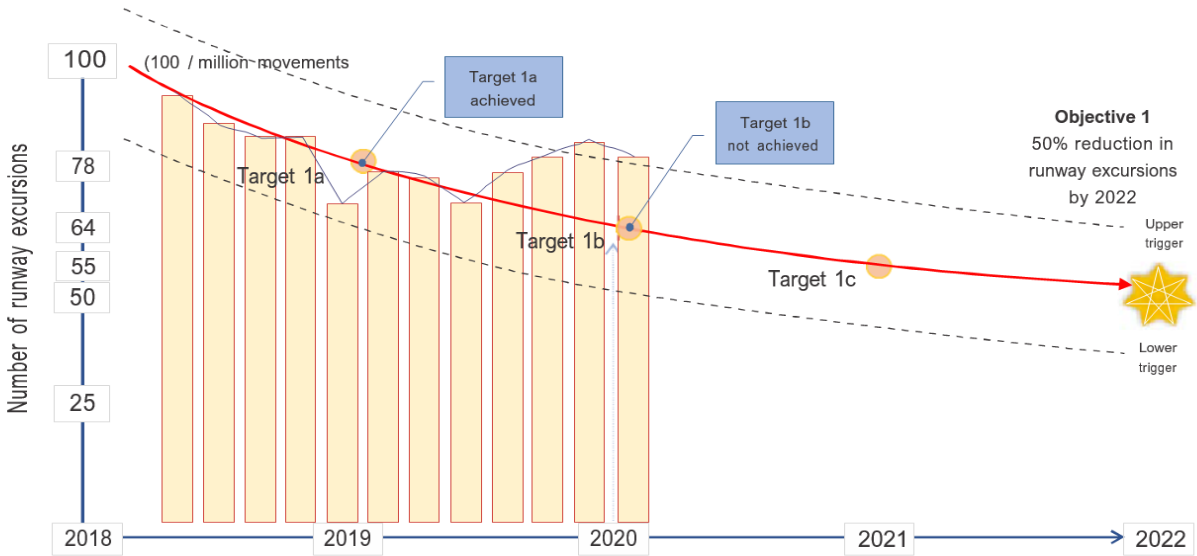

Figure 6. Example of monitoring safety performance indicator (SPI – Number of runway excursions), as a part of safety performance management (Source: ICAO, 2018).

Figure 7 shows an example of predicting and causal modeling of safety performance indicators in an aviation organization, as a part of aviation predictive safety management.

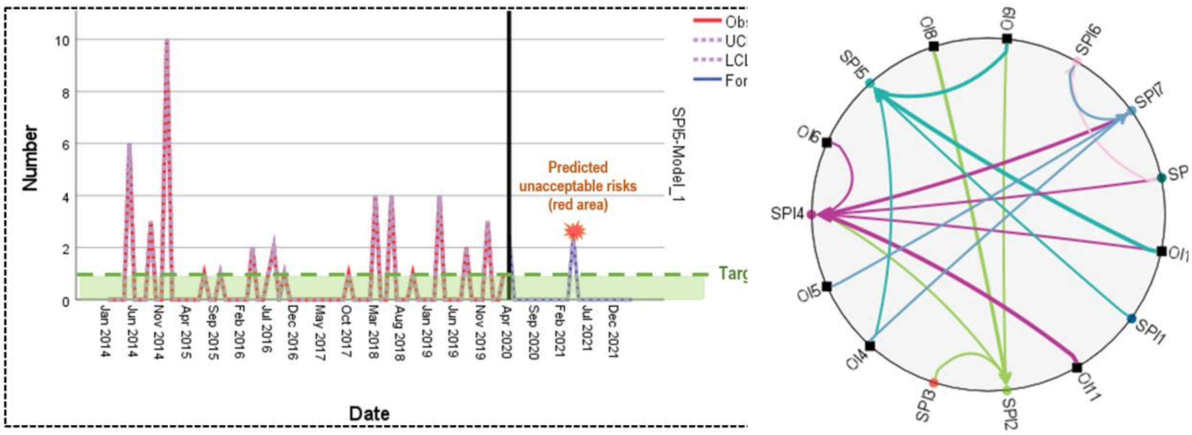

Figure 7. Example of predicting and causal modeling of safety performance indicators (Source: Bartulović & Steiner, 2022).

Maritime Safety Methodologies & Performance Management and

In maritime transport, organizations have a regulatory obligation to implement safety management systems, which also recognizes two methodologies of collecting safety data, i.e., reactive and proactive. Most of organizations implement reactive safety management, but all of them make efforts to improve and implement proactive safety management. Where proactive safety management is in place, the focus and goal is to monitor and measure organizational safety performance.

Figure 8 shows examples of safety key performance indicators set-up to monitor safety performance in maritime organization, divided into two groups, i.e., leading and lagging indicators.

Figure 8. Example of safety key performance indicators set-up to monitor safety performance in maritime organization (Source: Valdez Banda, et al., 2016).

Safety key performance indicators (KPIs) are used to monitor and measure safety performance, which capture and represent organizational safety trends and developments (Swuste, et al., 2016). Usually, KPIs are divided into leading or „activity or process" and lagging or „outcome-based" indicators (Valdez Banda & Goerlandt, 2018). Table 10 shows examples of five safety key performance indicators (KPIs) monitored in maritime organizations.

Mark	Safety key performance indicators
KPI1	Required number of personnel to act as a link between management and operative areas
KPI2	Number of organizational management reviews where the master participates
KPI3	Number of ships assigned to a person working full time with safety management matters
KPI4	Percentage of ships reaching destination on time (from a safety perspective)
KPI5	Number of corrective actions derived from external audit, after an internal audit has been performed

Table 10. Examples of safety key performance indicators (KPIs) monitored in maritime organizations (Source: Valdez Banda, et al., 2016).

Correlations between Aviation and Maritime Safety Methodologies & Performance Management

After gathering and processing information on safety methodologies and safety performance management in both aviation and maritime SMS, it can be observed that aviation SMS uses three methodologies, and currently holds a status of being "strongly proactive", with slowly building up to "predictive" SMS, while maritime SMS, in comparison, lags behind the aviation SMS, and is currently being "reactive", with slowly building up to "proactive" SMS. Nevertheless, the methodologies and performance management, are observed to be compatible, as well.

Learning of the compatibility of two systems (aviation and maritime SMS), opens up the possibility to use certain techniques implemented in aviation safety management, and implement them in maritime safety management.

Figure 9 shows an example of how causal modeling techniques can be used to simulate behavior pattern of safety key performance indicators (KPIs) in the maritime organization in order to improve organization's safety performance (Stanivuk, et al., 2022).

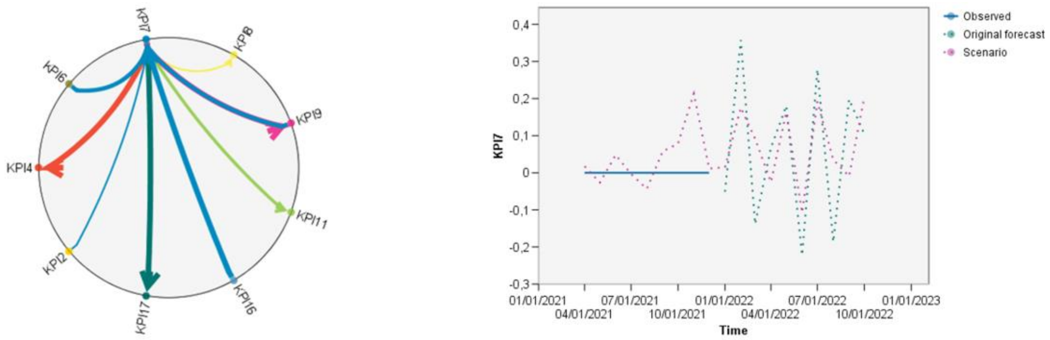

Figure 9. Example of causal modeling of maritime safety key performance indicators (Source: Stanivuk, et al., 2022).

CONCLUSION

Research conducted in this paper is focused on determining compatibility between aviation and maritime safety management systems. Compatibility is determined through analysis of three top safety management areas, i.e., framework of each safety management system, safety risk management processes, and safety methodologies and performance management.

Analyzing structure of frameworks of both aviation and maritime safety management system, correlations have been established, and it was determined that systems are compatible in all areas, except in the area of safety performance monitoring and measurement. Analyzing safety risk management processes implemented in both safety management systems, it was determined that systems are also compatible, but different in the terms of nomenclature. As per area of safety methodologies and performance management, systems were determined to be compatible, with the observation that maritime SMS, in comparison, lags behind the aviation SMS.

By comparing two systems, the compatibility of aviation and maritime SMS was determined, which opens up the possibility to use certain techniques implemented in aviation safety management, such as predictive and causal modeling methods, and implement them in maritime safety management in order to improve its efficiency.

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Prevention of Maritime Pollution in Montenegro through Legal Solutions

Jelena Nikčević

The determination of Montenegro as a coastal and ecologic state is to ensure and respect international standards in the marine environmental part as a part environmental in whole. One of the mechanisms for effective protection of the marine environment from pollution from vessels is an adequately designed national protection. This paper presents a part of the Montenegrin legislation concerning the prevention of maritime pollution from vessels, taking into account general, special (preventive) and specialized regulations on sea protection. The paper discusses specific Montenegrin solutions concerning the prevention of maritime pollution from vessels, taking into account general, special (preventive), and specialized regulations on marine protection. The necessity of harmonizing Montenegrin legislation with the maritime acquis of the EU and have not been transposed/incorporated into the Montenegrin legal system and review of international conventions of which Montenegro is a part. In the conclusion, guidelines are given for the future development of Montenegrin legislation.

KEY WORDS
Prevention, Maritime pollution, Vessels, Legal regulations, Montenegro, Law

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INTRODUCTION

The Montenegrin legislation on the protection of the sea from pollution from vessels is one segment ofthe overall reforms of Montenegrin maritime legislation, which is mainly determined by Montenegro's commitment to European integration. The creation of Montenegrin legislation in this domain is characterized by the necessity, on the one hand, of the transposition/incorporation of EU directives/EU regulations and, on the other hand, the implementation of requirements from international legal instruments in the field of marine protection.

The Law on the Prevention of Sea Pollution from Vessels, 2011 ("Official Gazette MNE" Nos. 20/11, 26/11 and 27/14) (hereinafter LPSPV) regulates the protection of the sea against pollution from vessels navigating or staying in inland sea waters and territorial sea of Montenegro (Article 1 of the LPSPV). However,it is a specialized law whose provisions directly regulate the prevention of sea pollution. In other legal regulations, i.e. laws that more or less treat the area of protection and preservation of the sea and the marine environment, we can also find provisions on the protection and preservation of the sea. These are special (prevent) and general regulations. Maritime transport legislation as preventive legislation that aims to regulatevarious relations in connection with navigation also regulates the preservation and protection of the sea. The following laws are in question: Law on Maritime Navigation Safety ("Official Gazette of Montenegro", Nos. 62/13, 06/14, 47/15, 71/17, 34/2019, and 77/2020), Law of the Sea ("Official Gazette of Montenegro", Nos.17/07, 06/08 and 40/11), Law on Ports ("Official Gazette of Montenegro", Nos.51/08, 40/11 and 27/13), Law on Yachts ("Official Gazette of Montenegro" Nos.46/07, 73/10, 40/11 and 42/15) and Law on Exploration and Productionof Hydrocarbons ("Official Gazette of Montenegro", Nos.41/10, 40 /11 and 62/13). Law on Nature Protection ("Official Gazette of Montenegro", No.54/16) and Law on Environmental ("Official Gazette of Montenegro", No.52/16) represent general laws that concern the protection and preservation of the sea as a segment of the environment.

The question arises whether Montenegro has conceptually correctly approached the regulation of thisarea. Unlike the former members of Yugoslavia, Croatia and Slovenia, which regulate the protection of the seawith their maritime codes, in which the overall field of maritime law is systematized and codified, in Montenegrothe protection of the sea is regulated by a specialized law. Nevertheless, despite the existence of a specializedLPSPV, the regulations on sea protection cannot be viewed in a proper way, as long as the provisions on the prevention of pollution from other legal texts are not taken into account. Why did Montenegro take this approach? The main argument is the effort to achieve greater transparency and clarity of legal provisions, but also a reason of a legal-technical nature. In fact, it is much easier from the point of view of legal procedure to enact and amend by-laws on which the laws are based, than the laws themselves. The negative side of this concept is the inconsistent terminology of certain terms in different legal texts, the duplication of certain legal norms, the inconsistency of certain legal texts, and the obstacle of monitoring and application of laws by the relevant authorities. In the context of the above, we would add that the process of transposing EU law into the legal system of Montenegro is much more difficult because one EU directive/EU regulation is transposed/incorporated into several laws or by-laws, which often makes it difficult to monitor the level of compliance of directives/regulation with national legislation.

MONTENEGRIN LEGISLATION ON THE PROTECTION OF THE SEA FROM POLLUTION FROM VESSELS AND THE MARITIME ACQUIS EU

Montenegro, as a country striving for full membership of the European Union, must to harmonize national legislation with the *maritime acquis EU* in the field of the marine environment. While observing the

Montenegrin regulations, it is evident that despite of the Law maker intention to transpose EU directives and incorporate EU regulations, a satisfactory situation has not been achieved. The following is in support of the above.

Montenegro, as a country striving for full membership of the European Union, must harmonize national legislation with the maritime acquis EU in the field of the marine environment. While observing Montenegrin regulations, it is evident that despite the Law marker intention to transpose EU directives and incorporate EU regulations, a satisfactory situation has not been achieved. The following is in support of the above.

Partial transposition was achieved to Directive 2016/802/EU relating to a reduction in the sulfur content of certain liquid fuels Regulation 2015/757 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, which was transposed into Montenegrin legislation through Regulation on limit values for pollutants in liquid fuels of petroleum origin ("Official Gazette MNE" 17/17). Directive 2019/883/EU on port reception facilities for the delivery of waste from ships partially transposed in such a way as to create an obligation for ports to have systems for receiving waste from ships. The Law on Ports created an obligation for ports to have systems for receiving waste from ships (Art. 26 § 2 of the Law on Ports). Directive 2019/904 on the reduction of the impact of certain plastic products on the environment, Regulation 1013/2006 on shipment waste, Regulation 1257/2013 on ship recycling, and Directive 2005/35/EC on ship-source pollution and on the introduction of penalties, including criminal penalties, for pollution offenses have not been transposed/incorporated.

In addition that the Program for the Accession of Montenegro to the European Union 2021-2023. plans to transpose the mentioned EU directives/EU regulations through amendments to the Law on Waste Management, the Law on Prevention of Sea Pollution from Vessels, the Law on Ports and the Criminal Code of Montenegro into the Montenegrin legal system.

MONTENEGRIN LEGISLATION ON THE PROTECTION OF THE SEA FROM POLLUTION FRM VESSELS AND INTERNATIONAL CONVENTIONS

In relation to sea pollution from vessels, Montenegro is a member of the following Conventions: UN Convention on the Law of the Sea (UNCLOS 1982); International Convention relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (INTERVENTION l969); Protocol to the International Convention relating to Intervention on the High Seas in Cases of Pollution by Substances other than Oil (INTERVENTIONPROT 1973) as amended; Convention on the Prevention of Marine Pollution by Dumping of Wastes and OtherMatter (LC 1972) as amended; International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL, 1973) as modified by the Protocol of 1978 relating thereto, and its Annexes from I to VI (MARPOL 73/78); Convention concerning Minimum Standards in Merchant Ships, 1976.

In 2011, Montenegro ratified the following treaties: International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004. International Convention on the Control of HarmfulAnti-fouling Systems on Ships, 2001; International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001; International Convention on Civil Liability for Oil Pollution Damage, 1992; International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1992; Protocol of 2003 to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage; International Convention on Liability and Compensation for Damage in connection with the Carriageof Hazardous and Noxious Substances by Sea,1996 (IMO, 2023).

According to Art. 9 of the Constitution of Montenegro ("Official Gazette of Montenegro" No. 1/07) ..."the ratified and published international agreements and generally accepted rules of international law shall make anintegral part of the internal legal order, shall have the supremacy over the national legislation and shall apply directly when they regulate relations differently than the national legislation." In addition to the above, it is necessary to understand that enacting a law on the ratification of specific conventions does not mean that the convention has been fully implemented. According to Article 4 paragraph 1 point 3 and 4 of the Law on Signing and Execution of International Conventions ("Official Gazette of Montenegro" No. 77/2008) ...*"ratification implies the enactment of a law expressing the consent of Montenegro to be bound by an international agreement". Further..." the certification on ratification is a document by which states and international organizations are informed that a specific international conventions has been accepted and respected by the Republic of Montenegro."* So, laws on the ratification of conventions should not be treated as an implementing national instrument, but as a means by which Montenegro expresses its consent to be bound by an international instrument. It is the mechanism through which the international instrument is introduced, and integrated into the national legal order. Undertaking specific implementing measures, primarily by creating an institutional framework and enacting domestic laws and by-laws, the full implementation of international conventions will be achieved. Law on Signing and Execution of International Conventions of Montenegro stipulates that the Ministry of Foreign Affairs of Montenegro evidenced or concluded international agreements and keeps the originals or certified copies and official translations of these agreements (Article 23, Paragraph 1 of the Law). It would be significant to examine the implementation of this provision in relation to international maritime conventions, including international maritime environmental legislation. Especially we take into account the fact that after thebreakdown of the former republic of Yugoslavia, the Montenegrin Parliament enacted a Decision of 3 June 2006 on Succession of Montenegro as an independent state to all international instruments Yugoslavia used to be aparty to. It is not clear which conventions are in question. It is indisputable that there is no database for international conventions in Montenegro, as well as there is no clearly defined system for monitoring amendments to international maritime instruments.

SOME LEGAL SOLUTIONS ON THE PROTECTION OF THE SEA

While observing that LPSPV aspiration of the Law maker was to implement the provisions of the MARPOL Convention into law as much as possible. Articles 4 to 39 of the LPSPV regulate pollution from the vessels, ship for transport of oil as load or as a fuel, ship for transport of harmful liquids in bulk, ship for the transport of harmful substances in the packaged form, fecal waste, communal waste, the emission of harmful substances into the air. Article 4 of the LPSPV enumerates substances that are prohibited to be discharged intothe internal waters of the territorial sea of Montenegro. Despite the prohibition in principle, there is a possibilityof carrying out certain actions, but only if there is a permit issued by the competent authority in place (Nikčevićand Mandić, 2021).

Eleven articles of the LPSPV regulate the prevention of sea pollution from oils (Articles 16-27 of the Law). According to Articles 16 and 17 of the Law, certain tankers are prohibited from entering the waters of Montenegro with certain exceptions. Articles 21 to 26 contain provisions on documents and equipment that theboard of tankers must possess depending on the GT. Pursuant to the Article 27 of the LPSPV duty of the master on board tanker is to submit relevant information to the competent authority in place.

Articles 28 and 29 of the Law regulate the prevention of pollution of the sea by noxious substances. Protectionof the sea from sewage pollution is regulated by Articles 30, 31 and 32 of the Law, while Articles 33, 33a and 34 of the LPSPV regulate garbage disposal. Protection of the sea from sewage pollution is regulated by articles30, 31 and 32, while communal waste is regulated by articles 33, 33a and 34 of the Law. Article 30 of the Law contains provisions stipulating that the ship must have international certification and a functional and precisely defined system of devices for wastewater management.

According to Article 3, paragraph 1 point 14, garbage of the LPSPV is defined in line with Annex V of the MARPOL Convention. It can be noted that the definition of garbage is in line with Regulation I, Annex V of the MARPOL convention. Following provisions of the Annex VI MARPOL convention Article 37 of the LPSPV requires possession of documentation on prevention to discharge harmful substances from ships into the air. Regulation on limit values for pollutants in liquid fuels of petroleum origin adopted in 2017, regulate the use of fuels at vessels (“Official Gazette of Montenegro” No. 17/2017). According to Article 19 of the Regulation, starting from 1 January 2020, the sulfur content in marine fuels on vessels navigating the territorial waters and the Exclusive Economic Zone of Montenegro may not exceed 0.5% m / m.

Prevention of sea pollution by ballast water is regulated by Articles 40 to 48 in line with provisions of theBWM Convention. In order to prevent or at least reduce to some extent invasive aquatic species in the waters of Montenegro, the Law introduces provisions on the prevention of biological pollution of the sea. LPSPV regulated measures and procedures of ballast water exchange for ships which sail into the Montenegrin ports,as well as the procedures of ballast water exchange control and analysis (Nikčević and Mandić, 2021). The AFS Convention is implemented by Article 49 of the LPSPV. The Law predicts the reduction and elimination of harmful substances in anti-fouling systems used on a ship's hull. Consequently, vessels sailing into ports of Montenegro, or flying under the Montenegrin flag of at least 400 GT (fixed and floating offshore platforms are exempted) are required to possess the Declaration on Anti-fouling System and the receipt for the purchase of the anti-fouling systems. The London Convention is implemented by Article 50 of the LPSPV, which regulates exceptions to the general prohibition of dumping waste in the waters of Montenegro. In this context, with the approval of the competent authority, dumping, incineration, and burial on the seabed of waste or other substances is not prohibited, as follows: sludge generated by dredging; waste fish or organic matter resulting from the processing of fish or other marine organisms; platforms and other structures at sea; of inert chemical uncontaminated geological substances of natural origin in the solid state.

LPSPV regulates responsibility and compensation for damage in case of sea pollution with oil and dangerous and harmful substances from articles 55 to 58. The Law has in mind damage due to pollution of thesea caused by tankers. There are two types of damage: damages caused by the spill of oil carried onboard ascargo or oil used for the propulsion of tankers. According to Article 55 of the LPSPV owner of the vessel is responsible for the damage caused by a vessel carrying oil in bulk, or a vessel carrying noxious substances inbulk. The owner of a vessel is liable for pollution damages according to the rule of strict (causal) liability, with the possibility to be exonerated therefrom if the shipowner proves that the damage resulted from an act of waror force majeure, the damage was wholly caused by an act or omission done with the intent to cause damage by a third party or it is caused by the negligence of authority responsible. One more exemption should be added thereto. Namely, if the owner of the vessel proves that: the pollution damage resulted either from an act or omission done with intent to cause damage by the person who suffered the damage, the owner may be exonerated wholly or partially from liability to such person. Under article 3 paragraph 2 point 27 of the LPSPV vessel means a ship, technical vessel, floating facility, boat, and all objects in the marine environment includinghydrofoil vessels, hovercrafts, submarines, floating objects, and fixed and floating platforms.

In accordance with Article 55 paragraph 3 of the LPSPV no claim for compensation for pollution damage may be made against: the servants or agents of the owner or the members of the crew; the pilot or any other person who, without being a member of the crew, performs services for the ship; any shipper, including a bareboat charterer, or any persons taking preventive and operative measures, unless the damage resulted from their personal act or omission, committed with the intent to cause such damage and with the knowledge that such damage would probably result. If pollution damage results from an incident involving two or more ships, and if it is not possible to establish which ship caused which damage, the owners of the ships concerned shall be jointly liable for any such damage (Article 56 of the LPSPV).

Article 57 of the LPSPV stipulates the duty to maintain the insurance of the ship owner, and it is relatedto the amount of oil that the ship carries, so according to the LPSPV there is no obligation to maintain insurancefor all ships, but only for ships carrying more than 2,000 tons of oil in bulk. Such ships are required to have an insurance policy or other type of financial guarantees, such as a bank guarantee or a certificate issued by international funds for compensation of damages. As proof that a ship insurance contract has been concluded,a corresponding certificate is issued, in Montenegrin and English, which contains certain sub-data. According to the mentioned article paragraph 2 Law, to the pollution damage caused by bunker a ship of 1000 GT or moreshall be required to maintain insurance or other financial security (the guarantee of a bank or similar financial institution). This legal solution is in line with BUNCER convention. Including the complaint that pollution damage resulted from the willful misconduct of the owner himself.

PRINCIPAL LEGAL SOLUTIONS ON THE PROTECTION OF THE SEA

The Law on the Sea implements the provisions of the LOS Convention relating to the protection and preservation of the sea. These are principle provisions that determine the duties of Montenegro to protect, preserve and improve the marine environment and encourage cooperation with neighboring countries and countries in the region to prevent and reduce sea pollution. Articles 26 and 18 of the Law on Ports pay attentionto the protection of the sea. In that sense, the port beneficiary is obliged to adequately equip the port with facilities for receiving and handling waste, and to prevent pollution of the sea or the port area. Considering Article 18 of the Law on Ports, which regulates concessions, observable that the legislator also had in mind in this article to protect the marine environment. It provides that the Concession Act should contain an environmental impact assessment. Article 33 of the Law of the Yacht regulates the prevention of sea pollutionfrom yachts. It stipulates a prohibition of discharge and dumping of oil and oily water, waste, garbage and othersubstances that pollute the environment from yachts. According to the Law of Yachts, the yacht master or yachtmanager is required to immediately notify the administrative body if oil and oily water, waste and garbage, andother pollutants are discharged into the sea, with the exact position of the yacht. Yachts must be equipped to prevent pollution of the sea by oils and oily waters, waste and garbage, as well as containers for their storage,which will be emptied in appropriate shore reception equipment, in accordance with national regulations and the requirements of international conventions (Nikčević and Mandić, 2021, Nikčević, 2013). The Law on Maritime Navigation Safety contains provisions on meeting the requirements of international conventions on the protection of the sea from pollution by both Montenegrin ships and ships flying the flag of another country through Port State Control (Articles 183 to 198 of the LPSPV).

CONCLUSION

Legal solutions on the protection of the sea from pollution from vessels are contained in the LPSPV asa specialized legal regulation which, for the first time in Montenegro, regulates the protection of the sea from pollution from vessels. However, to get complete picture of the Montenegrin legal regime on the protection andpreservation of the sea, it is necessary to consider the provisions of the LPSPV to other legal regulations that have different navigational relations as the subject of regulation. Concerning maritime acquis EU in connectionwith the protection and preservation of the sea, the Montenegrin legislation has not reached a satisfactory state. The same can be said with the implementation of international conventions on the protection and preservationof the sea, of which Montenegro is a member. Therefore, it is necessary to continue with the transposition of EU directives, that is, the incorporation of EU regulations into national legislation and the implementation of solutions from international conventions. At the same time, special attention must be paid to the monitoring of changes in international conventions and their implementation in national legislation. This is especially so if it istaken into account that numerous amendments to the IMO international convention are accepted in the "tacit acceptance" procedure. Bearing in mind the necessity of numerous changes, and to fully harmonize the Montenegrin legislation with the maritime acquis of the EU and international instruments, we estimate that it willbe necessary to adopt new legislation and not to amend the existing one.

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Application of Capacitor Banks in the Ship's Power System

Nemanja Pudar[1], Lazar Mrdović[1], Ilija Knežević[1], Nikola Marvučić[1], Martin Ćalasan[2], Tatijana Dlabač[1]

The electrical system is a crucial component of any ship's operation, responsible for the production, transmission, distribution and consumption of electrical energy. One of the biggest challenges faced by the ship's electrical network is the provision of reactive energy to the asynchronous motors that are its largest consumers. This paper focuses on the use of capacitor banks as a possible solution for this problem.

Power Quality (PQ) assessment is carried out during the design and exploitation phase of the ship. PQ assessment is done by modeling the system, which includes the design and selection of ship generators, levels of voltages, adding filters, adding capacitors, determining the characteristics of consumers connected to the ship's network, and measuring the quality of electricity during a sea trial.

The primary objective of the ship's electrical system is to ensure an uninterrupted power supply to vital consumers. It is therefore essential to supervise the distribution system and maintain a stable source of voltage level to prevent electrical consumer failure. The use of static capacitors is one possible solution to control the supply voltage level, reduce power and energy losses in the ship's network, and regulate reactive power. In this paper, we did research and presented one example of the implementation of capacitor banks in the passenger ship's electrical network in order to reduce the amount of reactive power in the distribution grid.

This paper aims to provide insight into the role, importance, and optimal location of capacitor banks in the ship's power system. By understanding the benefits and challenges associated with the implementation of capacitor banks, ship operators can make decisions about the design and operation of their electrical systems. Ultimately, this can lead to improved power quality and more efficient operation of the ship's electrical network.

KEY WORDS

Capacitor banks, Power quality, Reactive power, Ship’s distribution network

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INTRODUCTION

The ship's power system is a key system on every ship that enables the functionality of all other systems used for monitoring and control of the ship's processes and subsystems. It usually consists of several subsystems, including main and auxiliary generators, switchboards, batteries, converters and voltage regulators (Hall, 1999; Woud and Stapersma, 2002).

On the ships equipped with diesel-electric propulsion, main generators onboard are used to produce electricity which is then distributed through switchboards to all consumers. On vessels which are driven by one main diesel engine as a main propulsion motor, auxiliary generators are installed and used to produce smaller amounts of energy needed to operate various systems, such as lighting, air conditioning and other smaller electrical devices (Cahyagi, 2018; Marvučić et al., 2020). The ship's power system is designed to operate in a variety of conditions including changing cargo conditions and the marine environment. To ensure the reliability and safety of system operation, marine power systems are usually equipped with a number of protective measures, including circuit breakers and safety switches. One of the biggest challenges is maintaining stable voltage conditions on the ship's power network. Exposure to the changing conditions of the marine environment affects energy consumption, and thus the voltage conditions in the network. Energy distribution is carried out under certain losses that are different and depending on whether they appear on the consumer or during transmission in the conductors (Lee and Hsu, 2015; Prousalidis et al., 2015).

Although the ship's electrical power system already has built-in systems that prioritize important consumers, some losses may still occur due to the non-selective operation of consumers. These losses can result in a drop of voltage level from the transformer to the consumer. Capacitor banks can be implemented as a means of improving the system's efficiency and reducing losses. However, it is important to note that the ship's power system has elaborate actions in place to ensure its safety, reliability, and redundancy. For example, there are built-in systems that initially turn off less important consumers to preserve the power supply for critical systems. Additionally, the system may have redundant components and backup power sources to prevent power outages.

The biggest losses in the ship's power system occur in the processes of transmission and distribution of electricity. Harmonic losses occur due to the presence of non-sinusoidal waveforms in the electrical system, which leads to increased heating and reduced efficiency of electrical equipment (Lambe and Karande, 2022). Reactive power losses occur due to the flow of reactive energy in the system, which leads to increased energy consumption and reduced power factor (Bisanovic et al., 2014). The voltage drop occurs due to the resistance of the electrical conductors and the current flowing through them, which leads to a decrease of the voltage level at the end of the distribution line. These losses result in reduced efficiency and increased energy consumption, leading to increased operational costs for the ship's electrical distribution system. (Bisanovic et al., 2014; Khanchi and Garg, 2013).

To maintain stable and optimal voltage conditions, many ships use traditional voltage regulation equipment such as transformers and voltage regulators (Shafiee et al., 2021). The use of capacitor banks appears as an alternative solution for the regulation of voltage conditions in the ship's power system. A capacitor bank is a device that stores electrical energy and quickly releases it to stabilize the voltage in the network (Shafiee et al., 2021; Szuvovivski et al., 2012). When the voltage drops below a certain value, the capacitor bank is discharged, supplying the grid with the necessary electricity and returning the voltage to the nominal level (Singh and Rao, 2012). The drop in voltage level is a consequence of the presence of reactive energy in the ship's power system. Reactive energy creates oscillations in the power system, which leads to voltage drops and loss of efficiency (Ćalasan et al., 2013; Dixon et al., 2005; Rakočević et al., 2021). The use of capacitor banks on ships can provide several benefits, including improved system stability, increased efficiency and reduced emissions. Capacitor banks can help reduce voltage fluctuations and improve voltage conditions, thereby reducing the risk of equipment failures and improving the overall reliability of the power system. By stabilizing voltage conditions, capacitor banks can also help reduce overall electrical energy consumption (Bisanovic et al., 2014). Capacitor banks can be used to stabilize the voltage during the start of large electric motors and other types of marine equipment that require large amounts of energy in short intervals (Prousalidis et al., 2015; Shafiee et al., 2021; Singh and Rao, 2012).

This paper deals with the description of the importance of capacitor banks in a ship's power system. The second chapter points out the configuration of the ship's electrical systems. In the third chapter the physics of reactive power compensation with special reference to significant consumers of reactive power in ship's power systems is described. Examples of the needs for reactive power of large consumers and the importance of reactive power compensation from the point of view of improving voltage conditions in ship's power systems are also presented. In the fourth chapter of the paper, the application and optimal location of capacitor banks in the ship's power system are proposed and described.

SHIP'S POWER SYSTEM

The ship's power system is a set of devices and equipment on board that are used for the production, distribution and control of electricity. Electricity on board is vital to the functioning of ship systems, including navigation, communication, security, cooling and heating systems (Woud and Stapersma, 2002). The function of the ship's electrical power system is the safe transmission of the produced electrical energy to all consumers. Ensuring continuity of service for marine equipment is of utmost importance. A failure of the distribution system can lead to an interruption in the supply of vital ship equipment, potentially posing a serious threat to the crew and overall navigation. Therefore, it is necessary to ensure that the ship's electrical power systems are designed with the greatest possible load endurance and with the minimum frequency and duration of interruptions in the supply of electrical energy to consumers. A set of generators, transformers, lines and consumers connected in a single unit, makes this system very dynamic, the goal of which is to ensure a reliable and safe supply of electricity to consumers of a defined quality in normal and emergency conditions (Djagarov et al., 2018).

The production of electricity on board is usually done via generators, which are usually powered by diesel engines. Electrical energy on board is distributed through a power system consisting of several different components, including cables, switching panels and circuit breakers. Cables are usually laid through pipes or ducts to ensure safe and efficient connection of various systems on board (Marvučić et al., 2020). Switch panels and circuit breakers are used to control power to various systems on board and to isolate faults in the event of a problem with the power system. A key component of the power system is voltage and frequency control. Generators usually produce electricity within certain voltage and frequency limits. These parameters must be maintained within certain limits to ensure the stability of the power system and the safety of the onboard system (Sulligoi et al., 2016).

The scheme of the ship's distribution network usually follows the practice developed on land. This allows normal industrial equipment to be used on board after minor adjustments, where necessary, to withstand the conditions at sea (e.g. it must be resistant to vibration, moisture, high temperature, sea water that can occur on various parts of the ship, etc) (Krčum et al., 2018). Ships that have heavy electrical loads require generators that operate at high voltages such as 3.3kV, 6.6kV, 11kV and even 15kV. This is because high voltage operation reduces the amount of current needed in high-power systems comparing with low voltages systems, and therefore, it can reduce the amount of conductors and equipment required. This approach is economically justified because it can help reduce the overall cost of the ship's electrical system. With the increase in size of ships, such as large cruise ships, high voltage operation has become common as it can efficiently handle the heavy electrical loads required to power the ship's various systems. Choosing a high voltage for the system can help reduce the amount of stored energy in the system's capacitors and inductors. This, in turn, can reduce the short-circuit current that can occur during a fault. This is because the energy stored in these components is proportional to the square of the voltage, so increasing the voltage will result in a corresponding decrease in the energy stored. Therefore, a high voltage system can offer improved safety and reliability by reducing the risk of equipment damage and minimizing the potential for electrical accidents. (Marvučić et al., 2020). High voltage distribution systems usually have their neutral points grounded through a resistor or earthing transformer ion the hull of the ship (Hall, 1999). Figure 1 illustrates a section of the power distribution system on the ship. The voltage level of the generated power is 11kV in a 60Hz AC network. The figure depicts one of the three primary switchboards, along with a segment of the distribution system.

AC power generation systems are cheaper to install than DC systems. They offer a greater volume of power for the generation, distribution and use of electricity. Simple transformers effectively step up or step down AC voltage where needed. In Europe, the frequency is 50Hz, while it is 60Hz in North America and on most ships and platforms (Woud and Stapersma, 2002).

To maintain a stable voltage and frequency level, the power system usually has voltage and frequency regulation devices, such as automated voltage regulators, frequency regulators, and other load management devices. These devices enable the system to maintain a stable voltage and frequency profile and to adapt the power system to load changes (Ćalasan et al., 2020).

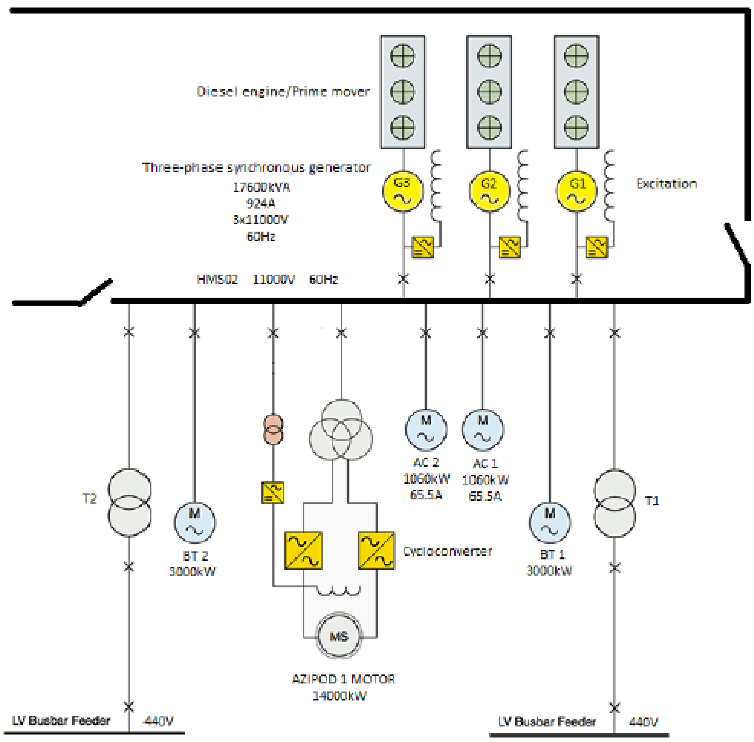

Figure 1. Ship power distribution system (Marvučić et al., 2020)

REACTIVE POWER COMPENSATION

In the ship's power system, as in other power systems, some consumers consume active power, which is used to perform useful work and consumers that consume reactive power, which is used to maintain the electromagnetic field in electromotive and other devices. Consumers of reactive power do not perform any useful work, but are necessary for the operation of electromotive devices. Unlike active energy, which is permanently "consumed'' by the consumer, reactive energy "oscillates" between the source and the consumer (Su et al., 2013). The presence of reactive energy has negative consequences - although it does not perform useful work, it burdens the transmission lines. The apparent power of a system is the vector sum of the active and reactive power of the system. Figure 2a. shows the power triangle, where the active and reactive power is represented as two legs, and the total (apparent) power as the hypotenuse. Therefore, the power factor is equal to the cosine of the angle between active and total (apparent) power, while Figure 2b. shows power ratio after reactive power compensation (Prousalidis et al., 2015).

$$\cos\varphi = \frac{P\,[W]}{S[VA]} \qquad (1)$$

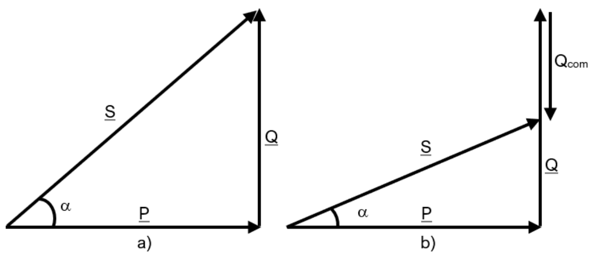

Figure 2. Vector power diagram a) before reactive power compensation; b) after reactive power compensations.

The smaller the reactive power of the consumer, the smaller the apparent power, and therefore the smaller the current flowing through the connection cables. As a result, the transmission power of the cable increases, i.e. with the same cross-section of the cable, more active power can be transmitted, the heating of the cable is reduced and the lifetime of the insulation is extended, and the voltage drops are also smaller due to the lower current. (Dixon et al., 2005; Khanchi and Garg, 2013).

If the active and total (apparent) power are equal, then the power factor is cosφ=1, which means that the consumer has no need for reactive power. Such consumers are purely ohmic consumers, such as different types of heaters, incandescent bulbs. The measure that defines the percentage of reactive power factor is denoted by sinφ, and represents the ratio of reactive power to total power in the system.

$$\sin\varphi = \frac{Q[VAr]}{S[VA]} \qquad (2)$$

Reactive power can appear in two forms: inductive or capacitive. Inductive reactive power appears when an electrical device contains inductive components, such as electric motors, transformers or other devices in the environment of which a magnetic field is manifested. When such devices are used, they draw an electric current that is in phase with the voltage but also create a magnetic field that is in phase with the current. On the other hand, capacitive reactive power occurs when an electrical device contains capacitive components, such as capacitors. When capacitors are used in a power system, they respond to changes in voltage by storing electrical energy and releasing it when needed. Capacitors draw current that leads the voltage by 90 degrees in an AC circuit.

These forms of reactive power are necessary for power systems because electrical devices are used for various work tasks. Reactive power compensation is performed in order to maintain the voltage level and improve the efficiency of the power system. By compensating reactive power, the voltage drop in networks is reduced, voltage conditions are improved, heat losses are reduced and transmission capacities are higher. (Prousalidis, 2011; Skamyin and Belsky, 2017).

On ships, the largest consumers of reactive power are found in the ship's propulsion system. Some of such consumers with rated voltage, power factor, load factor, active power and reactive power characteristics are shown in Table I. Specifically, the data in Table I is collected on a passenger ferry (Prousalidis et al., 2015).

This problem can be solved by reactive energy compensation, which helps to reduce the amount of reactive energy in the system and improve efficiency (Prousalidis et al., 2015). When reactive power compensation is applied to the ship's power system, the load on the system is reduced and the voltage is increased. This improves the stability and quality of the voltage in the power system, and also increases the efficiency of the ship's power system. A voltage drop in a ship's power system can have serious consequences, including a drop in performance and driveability, and can even lead to equipment failure. Therefore, it is important to maintain a stable voltage in the ship's power system and reactive power compensation is one of the ways to achieve this. (Dixon et al., 2005).

					Sea-going Condition	
Componente	Voltage (V)	Cos φ	Tan φ	Load Factor	Operational Power (kW)	Reactive Power (kVAr)
Main Cooling SW Pump	440	0.80	0.75	0.8	35.56	26.67
Main Jacket Cooling FW Pump	440	0.80	0.75	0.8	35.56	26. 67
DO Transfer Pump	440	0.80	0.75	0.5	2.98	2.23
Fan Units	440	0.80	0.75	0.9	13.17	9.88
Air Compressor	440	0.80	0.75	0.3	5.00	3.75
SW Pump	440	0.80	0.75	0.9	10.47	7.85
Propulsion Motor Room Supply Fan	440	0.80	0.75	0.8	9.30	6.98
Propulsion Motor Room Exhaust Fan	440	0.80	0.75	0.8	9.30	6.98
Gen. Room Supply Fan	440	0.80	0.75	0.8	18.60	13.95
Gen. Room Exhaust Fan	440	0.80	0.75	0.8	18.60	13.95
			Total		158.54	118.91

Table 1. Analysis of power consumption of different consumers on a ship with diesel-electric propulsion (Prousalidis et al., 2015)

There are various ways for reactive power compensation, including the use of capacitor banks, static compensators and active filters (Rakočević et al., 2021). Capacitor banks create an electric field that compensates reactive power, reducing the load on the power network and improving voltage stability. Capacitor banks are used to generate reactive power that opposes the reactive power generated by devices such as electric motors and transformers (Singh and Rao, 2012).

APPLICATION OF CAPACITOR BANKS

Capacitor banks are devices that store electrical energy in an electric field. They usually consist of two electrodes, separated by insulation, which can store electric voltage between them. Capacitor banks are designed to deliver electricity with a fast response to load changes, making them ideal for applications in marine power systems. (Bisanovic et al., 2014; Su et al., 2013). Capacitor banks are used in the ship's power system with the aim to improve stability, power quality and system efficiency. (Dixon et al., 2005).

In the event of a voltage drop in the system, capacitor banks quickly deliver electrical energy to bring the voltage back to normal. By absorbing electrical noise and dampening the harmful effects of voltage and current oscillations, capacitor banks improve the quality of the power supply in the ship's power system. Capacitor banks are used to evenly distribute the load on generators and to reduce the load during working hours (Rakočević et al., 2021). Relays and switches are used to connect capacitor banks in the power system and ensure their automatic charging and discharging. Special care should be taken when installing a capacitor bank in the ship's power system, as they may cause the presence of harmonic distortions. The origin of this issue can be traced back to the differences between land-based and ship-based electrical systems. Ships have fewer nodes and branches in their networks compared to the extensive networks found on land. Additionally, certain legal regulations may apply to ships' electrical systems. Unlike on land, where capacitor banks can be installed in various locations, the limited space on ships requires them to be installed near significant consumers or at the end of the bus that supplies power to a group of consumers (Prousalidis et al., 2015).

In order to solve the problems that arise due to the distribution of electricity in a ship's network, which consists of an electrical source, connected to the switchboard, through which it is transmitted to consumers, the optimal location of the capacitor bank must be defined, which will provide the system with the necessary stability. When defining the optimal location of the capacitor bank, it is necessary to consider the characteristics of the network in which the capacitor bank is installed. Such characteristics are: power (active, reactive and total), voltage level, power factors of all consumers in that branch, lengths and cross-sections that define their resistance which connection devices to power sources (Prousalidis, 2011; Singh and Rao, 2012).

Figure 3 shows a schematic diagram of a potential capacitor bank location. The position of the capacitor banks depends on numerous factors such as the size and capacity of the capacitor banks and the configuration of the power system on board.

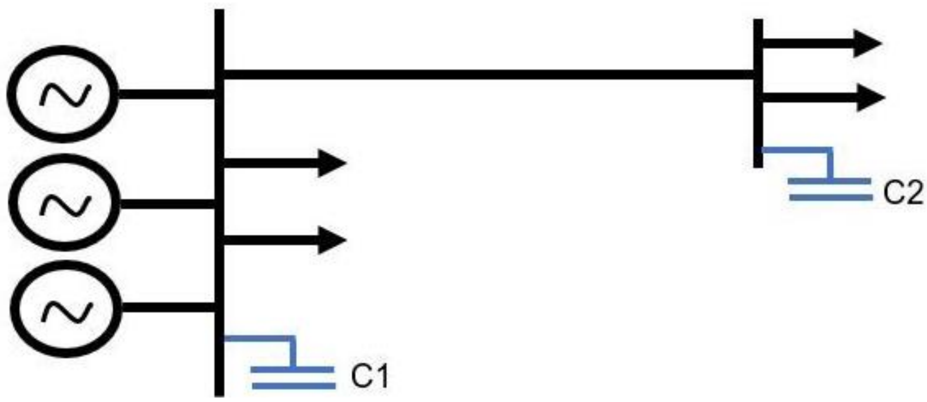

Figure 3. Potential position of capacitor banks (Prousalidis et al., 2015)

Electric motors can cause a sudden voltage drop in the ship's power system due to their high current requirements, especially when starting or changing the load. It is necessary to place the capacitor banks close to the electric motor and other peak loads, in order to improve the power factor and reduce the impact of large loads in the network (Singh and Rao, 2012). Capacitors are passive devices, while electric motors are typically inductive devices (Szuvovivski et al., 2012). Placing a capacitor bank near the electric motor helps maintain voltage stability and improves the quality of electricity. Installing a capacitor bank near the electric motor can reduce the size of the required cable infrastructure and ensure space savings (Khanchi and Garg, 2013). Due to the specific operating conditions of the onboard system, it is necessary to ensure that the capacitor banks are protected from moisture and other external factors.

In order to determine the optimal location of capacitor banks in the power system, numerous methods and algorithms are used. Some of such algorithms and methods are: genetic algorithm, particle swarm optimization method, backward-forward sweep based load method (Bisanovic et al., 2014; Ćalasan et al., 2020; Jabari et al., 2020; Rakočević et al., 2021; Szuvovivski et al., 2012).

The Backward-Forward Sweep Based Load Flow Method, also known as the BFS algorithm, is a commonly used power flow analysis technique in electrical power systems. The method involves dividing the system into multiple buses or nodes and analyzing the voltage and current at each node. The BFS algorithm is an iterative process that calculates the power flow between nodes. It first analyzes the power flow in the forward direction, from the power source to the consumers, and then analyzes the power flow in the reverse direction, from the consumers to the power source. During the analysis, the algorithm considers the impedance of the transmission lines, transformers, and other devices in the system. It also takes into account the reactive power and power factor of the consumers, as well as the voltage regulation of the transformers (Jabari et al., 2020).

Determining the optimal location of capacitor banks in the power system using the backward-forward sweep algorithm (BFS) is applied by first analyzing the power system and identifying nodes with low power factor, that indicates the places where capacitor banks could be installed to improve the power factor. Then the BFS algorithm is applied, which goes through all the nodes in the system and calculates the power factor in each node. After that, based on the obtained power factor values, the optimal location for the installation of capacitor banks is determined. The authors of this study utilized the BFS algorithm on the land network, and the results illustrated in Figure 4 pertain to the land network. This research methodology will be further employed to analyze the ship's power system using one of the aforementioned algorithms. Figure 4 presents the voltage trends before and after the installation of capacitors, and as expected, optimal capacitor placement utilizing the forward-backward sweep based search algorithm resulted in a significant decrease in active power losses and improvement in bus voltage magnitude. The power losses before the implementation of the capacitor banks were 253.9667 kW, while the loss after the implementation of the capacitor bank is 130.2507 kW (Jabari et al., 2020).

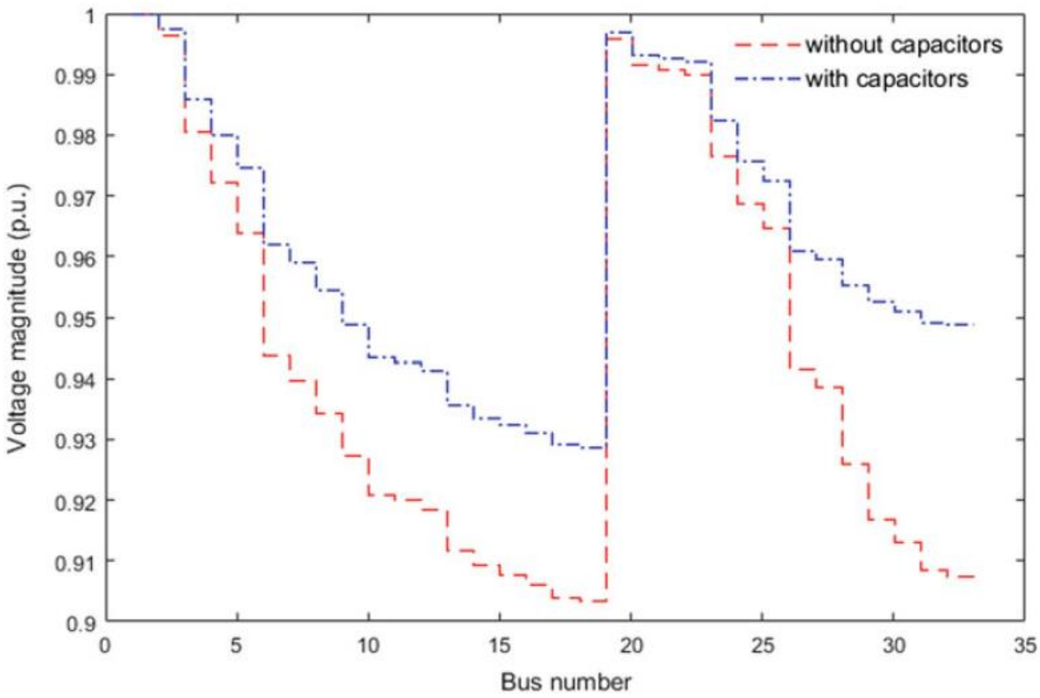

Figure 4. The voltage level in two different cases: without capacitor (red), with a capacitor (blue) (Jabari et al., 2020)

CONCLUSION

The use of capacitor banks in the ship's power system provides several advantages such as increased stability of the electrical system, improved energy efficiency, and reduced fuel consumption. The installation of capacitor banks affects the reduction of voltage drops, minimizes energy losses and provides an uninterrupted power supply. There are also potential challenges associated with installing capacitor banks, such as the need for proper sizing, monitoring and control. It is important to consider the specific requirements and conditions of the ship's power system before installing a capacitor bank. The installation should be carefully planned and designed to avoid overcompensation, harmonic distortion and other potential issues that can impact the power system's performance. The use of capacitor banks can offer significant improvements in the performance and reliability of the ship's power system. An area of future research will concern the optimal location of capacitor banks in order to maximize their effectiveness in reducing energy losses and improving system stability in a ship's power system. This will be achieved by using mathematical models and simulation tools that will accurately predict the behavior of the power system under different operating conditions.

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Analysis of Accidents on Non-SOLAS Vessels

Marija Magdalena Zrilić, Ivica Pavić, Jakša Mišković

The number of non-SOLAS vessels has increased today for several reasons. Most of these vessels are used seasonally. For this reason, maritime traffic increases significantly during the summer months, and in comparison, the number of maritime accidents also increases. The causes and reasons of maritime accidents involving non-SOLAS vessels may differ from accidents involving SOLAS vessels. These causes and reasons can range from structural and technical to technological aspects, usually related to the human factor, since a relatively large number of non-SOLAS vessels are not operated by professional seafarers.

This paper analyses the causes of maritime accidents on non-SOLAS vessels in the European Union (EU) and in the Exclusive Economic Zone (EEZ) from 2015 to 2019 using official data from the European Maritime Casualty Platform (EMCIP), the Marine Accident Investigation Branch (MAIB), and the Air, Maritime and Railway Traffic Accidents Investigation Agency (AIN).

By comparing the same types of maritime accidents in different areas, the related causes and characteristic patterns of these accidents are identified and possible recommendations to increase the navigational safety of non-SOLAS vessels are proposed.

KEY WORDS

Non–SOLAS vessels, Maritime accidents, Accident causes, Safety of navigation.

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INTRODUCTION

Maritime traffic is constantly increasing. In the segment of maritime traffic, ships and other vessels used for nautical tourism have a significant presence (Komadina, Brčić and Frančić, 2013). The development of tourism, fishing, and recreation has increased the number of smaller vessels, i.e., non-SOLAS vessels. Non-SOLAS vessels are vessels to which the provisions of the SOLAS Convention do not apply. The SOLAS Convention does not apply to cargo ships of less than 500 GT, warships, wooden ships of primitive design, pleasure vessels, fishing vessels, and yachts. (SOLAS, 2020) Therefore, non-SOLAS vessels have limited navigation and safety equipment. The technological level and safety of navigation on non-SOLAS vessels may depend on the level of development of an individual country, with vessels from less developed countries often not meeting minimum safety requirements (Zec, 2001).

Accidents can be basically divided into accidents of SOLAS and non-SOLAS vessels. In the literature, accidents of SOLAS vessels are more frequently and better analyzed, which is related to the fact that SOLAS vessel accidents are usually high-risk accidents that cause human casualties, environmental pollution, and high losses. Data on non-SOLAS vessel accidents are very often not known to the governments of the countries whose flags they fly. For this reason, SOLAS vessels are primarily considered when issues related to maritime safety are considered (Zec, 2001).

The main purpose of maritime accident research is to identify the events that led to the accident, determine the costs and damages caused by the accident. (Gould et al. 2006). Monitoring of maritime casualty data is conducted by regional and national organizations. A more important regional organization is the European Maritime Safety Agency (EMSA). EMSA is a European Union agency established to ensure a high, uniform, and effective level of maritime safety, maritime security, and pollution prevention and response (EMSA, 2023). In cooperation with Member States, it has developed a database, the European Maritime Casualty Information Platform (EMCIP), which stores data and information on all reported casualties involving ships and persons at sea. EMCIP enables the compilation of statistics and the analysis of technical, human, environmental, and organizational factors involved in maritime casualties (EMCIP, 2023). Based on the data contained in the EMCIP, EMSA compiles detailed analyzes and statistics on maritime casualties for each year. Their reports detail the types of vessels involved in maritime casualties. The maritime casualties are then broken down by the causes, the consequences, the stage of the voyage in which the maritime casualty occurred, and the regional distribution (EMSA, 2021). In addition to EMSA, it is also worth highlighting the Maritime Accident Investigation Branch - MAIB, a UK government organization responsible for investigating all maritime accidents in UK waters and accidents involving UK-flagged vessels (GOV. UK, 2022). On its official website, this organization provides an overview of a large number of detailed reports on maritime casualties that have occured in British territorial waters or on British-flagged vessels worldwide. Their reports regularly contain safety recommendations aimed at increasing the level of safety on ships, i.e. preventing similar accidents at sea from happening again in the future. In the Republic of Croatia, the Maritime Rescue Coordination Center - MRCC is under the Ministry of Maritime Affairs, Transport and Infrastructure. The MRCC Rijeka manages statistical data on Search and Rescue operations - SAR - related to various accidents at sea, which it regularly publishes on its website (MMPI, 2022). In the Republic of Croatia, the Agency for Investigation of Accidents in Air, Maritime and Railway Transport (AIN) is responsible for investigating maritime accidents at sea (AIN). The activities of the agency include accident investigation. Safety investigations are conducted to determine the cause of accidents and to propose measures to prevent accidents at sea and improve the safety of shipping (AIN, 2022a). It publishes reports on completed and ongoing investigations on its official website.

Although official national and regional organizations collect data on maritime accidents, complete and comprehensive data do not generally exist at either the national or regional level. There are several reasons for this. One is that many charter companies contract with private SAR organizations, which are usually the first to be called in the event of minor accidents. In addition, there is a known trend of under-reporting marine casualties involving smaller vessels, as these are minor accidents. (Toman and Zec, 2020; Hassel, Asbjornslett and Hole, 2011). Nonfatal accidents go unreported because boaters either do not know they are reportable or are unwilling to report them (USCG, 2023). Underreporting of maritime accidents is not only a problem for government agencies trying to improve maritime safety through legislation, but also for risk management companies and other agencies that use maritime accident statistics to analyze risks and causes (Hassel, Asbjornslett and Hole, 2011).

The increase in maritime traffic also increases the risk of maritime accidents. An analysis of marine casualty reports in the EU area found that 63.8% of all collisions were between SOLAS and non-SOLAS vessels. In 50% of the cases, motorboats and sailboats were responsible for the accident (EMSA, 2019). Navigation through sea areas with rugged coasts and numerous islands and islets is considered a navigationally difficult and dangerous area. Namely, navigation takes place in the area between islands, which is rich in underwater reefs, shoals, and cliffs, which endangers the safety of navigation (Benković et al., 1986). This requires that the seafarers piloting these vessels have certain knowledge and skills to successfully avoid all navigational hazards. The Adriatic Sea, for example, is classified as a high accident risk area. According to the IMO, the frequency of accidents in the Adriatic Sea is five times higher than the global average, which is mainly due to accidents involving speedboats and yachts (Kačić, 2011). In addition, there is the fact that on smaller vessels mostly sail people with a low level of education in the maritime field. Research in the field of recreational boat safety regulations is largely unexplored (Hsieh, 2020). In addition to accidents on recreational vessels as part of non-SOLAS vessels, a significant proportion of maritime accidents are recorded on fishing vessels. Fishing and recreational activities are mostly seasonal, with a higher incidence during the summer months (Antão, 2008). Fishing vessel safety is a concern of the IMO. The inclusion of fishing vessels in the SOLAS Convention and the LL Convention has been difficult due to the differences in design and operation between these and other vessel types. Although many voluntary and regulatory safety programs have reduced casualties, fishing is still the most dangerous occupation at sea (IMO, 2022). Accidents involving fishing vessels result in thousands of deaths each year (FAO, 2014). Investigating fishing vessel accidents and taking preventive measures are critical to making fishing operations safe (Uğurlu et al., 2020). Useful information for fishermen, including guidelines for emergencies, can be found in the Maritime and Coastguard Agency's Fishermen's Safety Guide (MAIB, 2016a). Despite industry initiatives, safety issues continue to be neglected due to economic and social factors (MAIB, 2016b).

Most reports from regional and national organizations provide a detailed account of what happened and attempt to identify all relevant factors and causes that contributed to the accident. However, the reports are usually read as isolated documents and do not provide insight into general patterns and trends. For this reason, it is necessary to consider the documents as a whole and systematically summarize the findings of each accident (Acejo, I. et al., 2018). Each accident is different and surrounded by other specific circumstances, each ship and crew are unique, but it should be emphasized that there are the same patterns that occur in each of these accidents (EMSA, 2022).

In order to identify the causes of maritime accidents on non-SOLAS vessels, this paper analyzes the official reports on maritime accidents on non-SOLAS vessels from the official websites of EMCIP, MAIB, and AIN. The purpose of analyzing the available official reports is to identify the causes and consequences of these accidents on non-SOLAS vessels.

RECENT INVESTIGATIONS OF MARITIME ACCIDENTS ON NON-SOLAS VESSELS

In the last decade, the maritime industry has taken a number of measures to improve safety levels by introducing new rules and regulations, new forms of crew training, etc. (Chauvin et al., 2013). Regardless of the development of maritime regulations and laws, maritime accidents continue to increase (Dogarawa, 2012). The severity of maritime accidents can range from minimal damage to the vessel to total loss of the vessel, from no damage to the cargo to total loss of the cargo, and from no injuries to the crew to fatalities (Talley, Jin, & Kite-Powell, 2005). There are many opinions in the literature regarding the occurrence of maritime accidents. Talley, Jin, & Kite-Powell (2005) assert that maritime accidents are not intentional, and Anyanwu (2014) that the causes are more complex and consist of interrelated elements. Zec (2016) states that one type of accident usually follows another.

The most common maritime accidents from 2014 to 2020 are collisions, contact, and groundings/strandings, which together account for 43% of all accidents (EMSA, 2021). Many researchers and experts have studied various aspects of maritime accidents to improve maritime safety. In the research of maritime accidents, causation theories, classical statistical analysis, and other methods are mainly used to investigate the mechanisms of occurrence and influencing factors of maritime accidents (Zhang, 2021). Accidents at sea pose a significant threat to human and environmental safety and can be very costly. It is estimated that $541 million is lost annually to the maritime economy due to human error (Gould et al., 2006).

The analyzed maritime accidents are basically divided into SOLAS and non-SOLAS vessels. Since the accidents of non-SOLAS vessels are less studied, this article analyzes the causes of accidents for these types of vessels.

According to the Korean Maritime Safety Agency, 69.5% of maritime accidents occur in coastal waters, with 73% involving small vessels under 100 GT, including fishing boats. These vessels have poor navigation and radio equipment compared to other SOLAS vessels. In coastal waters, there are often a large number of islands and fishing areas, which is one of the reasons why collisions and groundings occur frequently (Hu and Park, 2020). Every year, more than 600 people lose their lives and more than 4,000 are injured in accidents involving recreational boats. As with most other accidents, human error is the primary cause (McKnight, 2007). Taylan (2016) presented the accidents in Turkish waters in the period from 2001 to 2013 and compared them with accidents in the world using EMSA sources. Analyzing the accidents, he concluded that 30% of the accidents occur on vessels less than 500 GRT and concluded that increasing the GRT reduces the number of accidents. Toman, I. et al (2020) analyzed the relationship between adverse weather conditions and the causes of strandings of non-SOLAS vessels on the east coast of the Adriatic Sea due to the influence of strong winds. The authors concluded that more strandings of non-SOLAS vessels occur in weak winds. Although smaller vessels are more exposed to the influence of large waves, strong winds and more intense sea conditions than larger vessels due to their design and size (Bešić et al., 2022), the causes of stranding of non-SOLAS vessels in the Adriatic were not related to meteorological conditions. Similarly, many accidents occur in Papua New Guinea because small vessels used for transportation are not suitable for navigation in all conditions, i.e., unseaworthy, and most of them do not have the required safety equipment (Gwaday, 2019). Toman and Zec (2020) divided accidents into two groups: those that occurred during the day and those that occurred at night. They concluded that most groundings occurred at night, suggesting that the causes of these accidents are related to human error and that the most likely cause is the lack of experience of skippers who only occasionally or never sail at night and for whom there are no training requirements.

According to the 2021 Annual Report on Marine Accidents, EMSA recorded a total of 5,009 reported maritime accidents involving fishing vessels and 'other vessels' from 2014 to 2020, as shown in Table 1. (EMSA, 2021). EMSA defines "other vessels" as the following: inland waterway vessels (i.e., barges, floating equipment, floating establishment, floating installations, pusher, passenger, recreational crafts, tankers, tugs, worksite crafts), fixed offshore drilling units, navy ships, submersible, WIG's, etc. (EMSA, 2019).

	2014.	2015.	2016.	2017.	2018.	2019.	2020.	Total
Fishing vessels	574	466	586	628	603	629	646	4132
Other ships	170	112	123	101	162	119	90	877
Total	744	578	709	729	765	748	736	5009

Table 2. Number of non-SOLAS vessels involved in maritime accidents from 2014 to 2020. (Source: EMSA, 2021)

The Table shows the increase of accidents involving fishing vessels. Figure 1 shows the breakdown of causes of maritime accidents on fishing vessels.

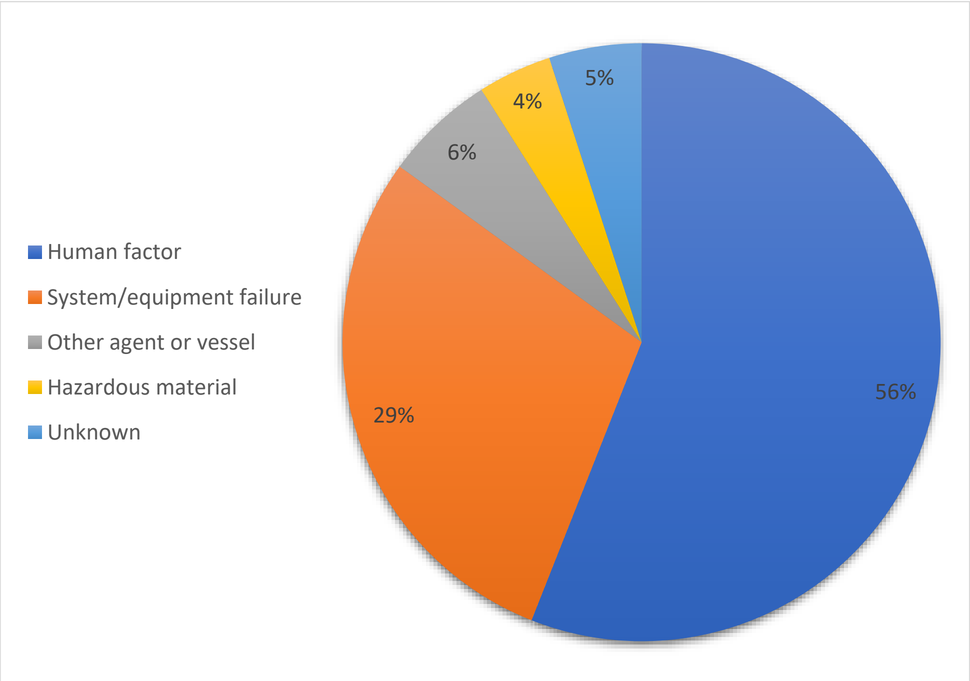

Figure 1. Causes of fishing vessels accidents from 2014 to 2020. (Source: EMSA, 2021).

Figure 1 shows that the human factor is the cause of maritime casualties in 56% of cases. System/equipment failure is the second leading cause of fishing vessel accidents 29% of the time. Other causes of maritime casualties involving fishing vessels include other agent or vessels (6%), hazardous materials (4%), and unknown causes (5%).

Figure 2 shows the distribution of causes of maritime casualties on other non-SOLAS vessels.

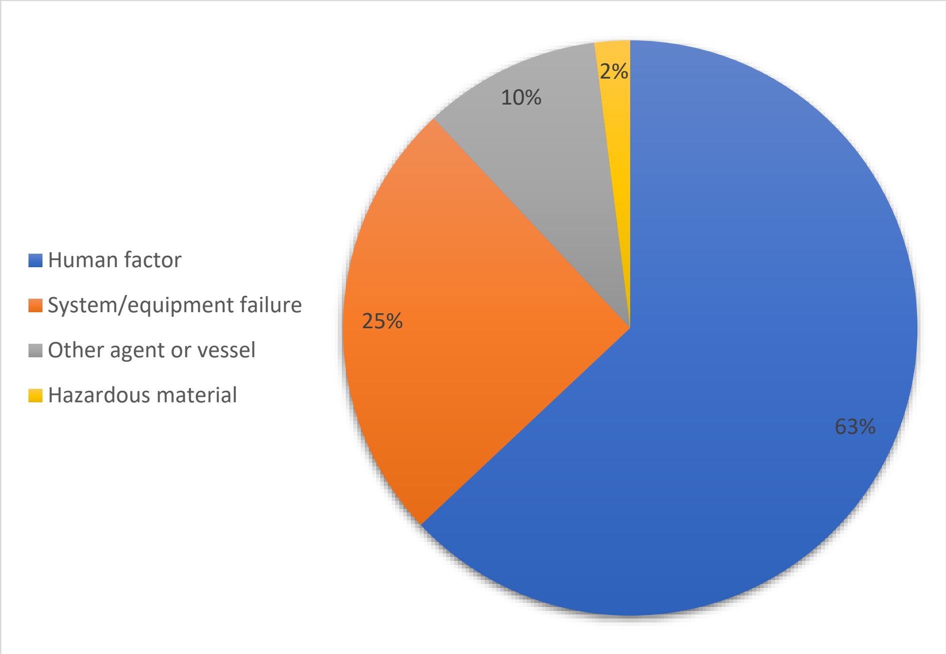

Figure 2. Causes of other non-SOLAS vessels accidents from 2014 to 2020. (Source: EMSA, 2021).

Figure 2 shows that the human factor was a factor in 63% of accidents on 'Other ships', while system/equipment failures were cited as the cause of accidents in 25% of cases. Other causes of accidents include other agent or vessel (10%) and hazardous material (2%).

Human error is believed to be responsible for most maritime accidents (Gould et al., 2006). Although today's ship systems are very reliable, and despite improvements in hull, propulsion, stability, and navigational equipment, the rate of maritime accidents with fatal consequences is still very high. In 75% to 96% of maritime accidents, the human factor is the main cause of danger and harmful effects on health, life, property, and the environment (Galieriková, 2019). Accordingly, fatigue has been shown to be one of the main causes of accidents on fishing vessels (Jepsen, Zhao, and van Leeuwen, 2015). In a survey conducted among fishing vessel crew, 60% of respondents reported that fatigue at work affected their personal safety, and 16% experienced a fatigue-related accident or incident (Allen, Wellens, and Smith, 2011).

A review of previous research found that causes of maritime accidents on non-SOLAS vessels were not categorized by types of maritime accidents to identify potential patterns of recurrence of certain causes in different types of accidents. It is believed that more detailed root cause analysis and the adoption of safety recommendations may help prevent the recurrence of similar maritime accidents on these types of vessels in the future.

METHODOLOGY

The methodology in this paper is based on the analysis of the causes of the most common types of maritime accidents on non-SOLAS vessels. To identify the most common types of maritime accidents and their causes, databases of recorded and published reports of maritime accidents that occurred in the EU and EEC area during the period from 2015 to 2019 were used. The period from 2020 to 2022 was not included in the analysis due to the possible influence of other factors such as the coronavirus pandemic. Based on the distribution of causes for certain types of maritime accidents, the Venn diagram shows the overlap of different accident causes in the maritime accidents analyzed. From the analysis of the overlap of individual causes of maritime accidents, certain conclusions were drawn and recommendations were made for enhancing maritime safety and for possible further research.

A total of 91 official reports of maritime accidents involving non-SOLAS vessels were collected for this study. The reports came from the official websites of EMCIP, MAIB, and AIN. Most of the reports (86) were from EMCIP. Four reports were from AIN and three reports were from MAIB.

The following criteria were used to collect the reports:

- a non-SOLAS vessel must be involved in the maritime accident
- the accident must have occurred on EU territory or within the EEC
- the accident must have occurred between 2015 and 2019
- the accidents must be divided into collisions, groundings/strandings, fires and flooding/foundering.

Analysis of the accidents identified several instances of accidents involving warships. Accidents involving warships and the causes of accidents are rarely published in open sources. Investigations of maritime accidents in which these vessels were not in direct contact with commercial vessels or infrastructure are often conducted under national laws and regulations applicable to these types of vessels.

Considering that the analysis of maritime casualties on non-SOLAS vessels has been limited in the review of available reports and literature, the focus of this paper is on the analysis of the causes of maritime accidents on non-SOLAS vessels.

Based on official data on accidents, the predominant categories of accidents and the types of vessels involved were identified. For each of the predominant accident types, the causes that led to that accident were identified. Common patterns for the occurrence of certain causes in different accidents were identified and certain safety recommendations were made.

RESULTS

Analysis of 91 reports shows that most accidents, 83, were primarily maritime accidents involving fishing vessels (88.3%). Of the other types of non-SOLAS vessels, the remaining official reports include recreational craft with 9 maritime accidents (9.6%) and warships with two (2.1%). It can be assumed that the total number of accidents involving recreational craft is much higher than the relatively small number of investigations conducted would suggest. When analyzing the MMPI report, it is clear that recreational crafts account for a significant share of the total traffic volume, which directly affects the complexity of traffic and navigation flows and increases navigation risks on the east coast of the Adriatic (MMPI, 2019).

The distribution of the 91 maritime accidents involved 94 non-SOLAS vessels by casualty type is shown in Table 2. These reports are from the official websites of EMCIP, MAIB, and AIN.

	Fishing vesels	Recreational craft	Navy	Total
Flooding/foundering	24	0	0	24
Fire	23	0	0	23
Grounding/stranding	17	0	0	17
Collision	19	9	2	30
Total	83	9	2	94

Table 2. Types and number of non-SOLAS vessels involved in maritime accidents in the EU. (Source: EMCIP; MAIB; AIN)

Table 2 shows that collisions are the most common maritime accident, followed by flooding/foundering, fires, and grounding/stranding.

Based on a sample of 91 maritime accidents, it was determined that a total of 25 people lost their lives. These accidents also recorded 57 total vessel losses.

Causes were specifically identified and described in 64 of the 91 reports. For this reason, only these 64 reports were considered. Therefore, the proposed causation methodology was applied only to this sample of 64 available detailed reports to make the research results as credible as possible.

To determine the pattern of occurrence of maritime accidents, each accident was systematized by accident type. The analysis shows that the most common types of maritime accidents were collisions, floodings/foundering's, fires, and groundings/strandings. Accidents were divided into four subgroups for which accident causes and consequences were identified.

Figure 3 shows the breakdown of causes for collisions on 24 non-SOLAS vessels where the human factor was the primary cause.

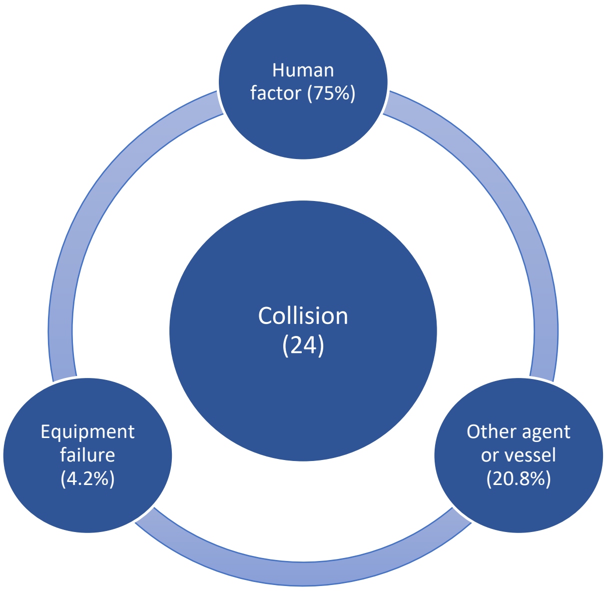

Figure 3. Causes of collision for non-SOLAS vessels from 2015 to 2019. (Source: EMCIP; MAIB; AIN)

Figure 4 shows the breakdown of causes for floodings/founderings on 16 non-SOLAS vessels, where structural condition is the primary cause. Official reports indicate that this was related to poor maintenance and hull condition.

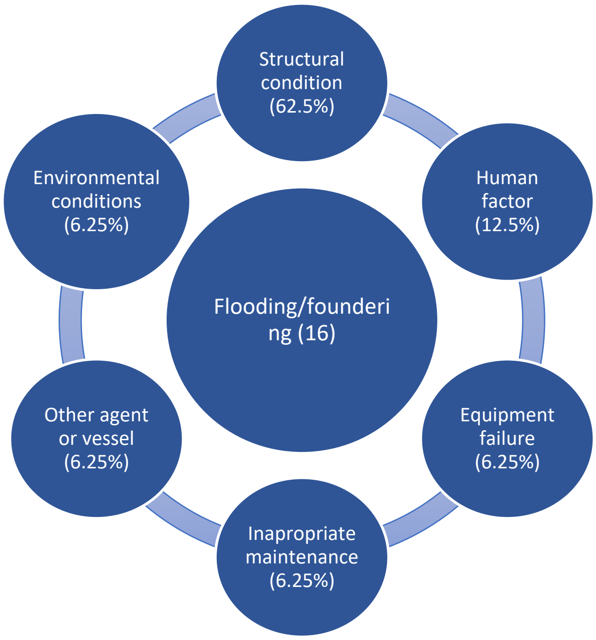

Figure 4. Causes of flooding/foundering for non-SOLAS vessels from 2015 to 2019. (Source: EMCIP; MAIB; AIN)

Figure 5 shows the breakdown of causes for fires on 10 non-SOLAS vessels, again with human factors being the predominant cause for these types of accidents.

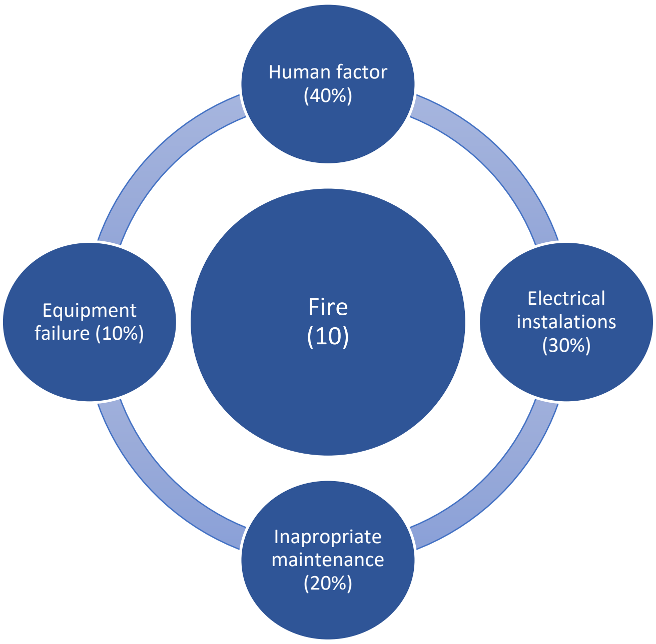

Figure 5. Causes of fire on non-SOLAS vessels from 2015 to 2019. (Source: EMCIP; MAIB; AIN)

Figure 6 shows the breakdown of causes for groundings/strandings on 14 non-SOLAS vessels. Again, the human factor is the predominant cause of this type of accident.

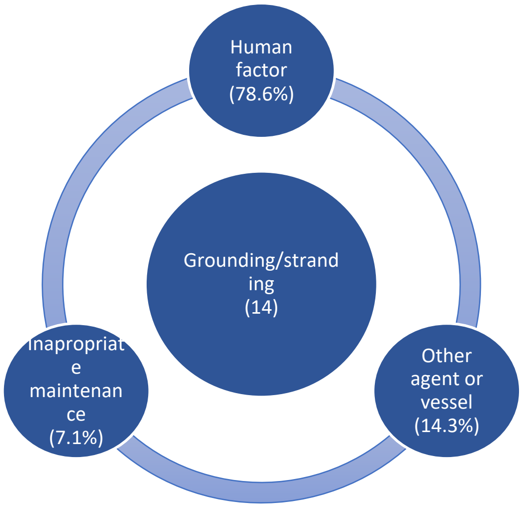

Figure 6. Causes of grounding/stranding of non-SOLAS vessels from 2015 to 2019. (Source: EMCIP; MAIB; AIN)

The Venn diagram in Figure 7 shows the overlap of accident causes in 64 maritime accidents.

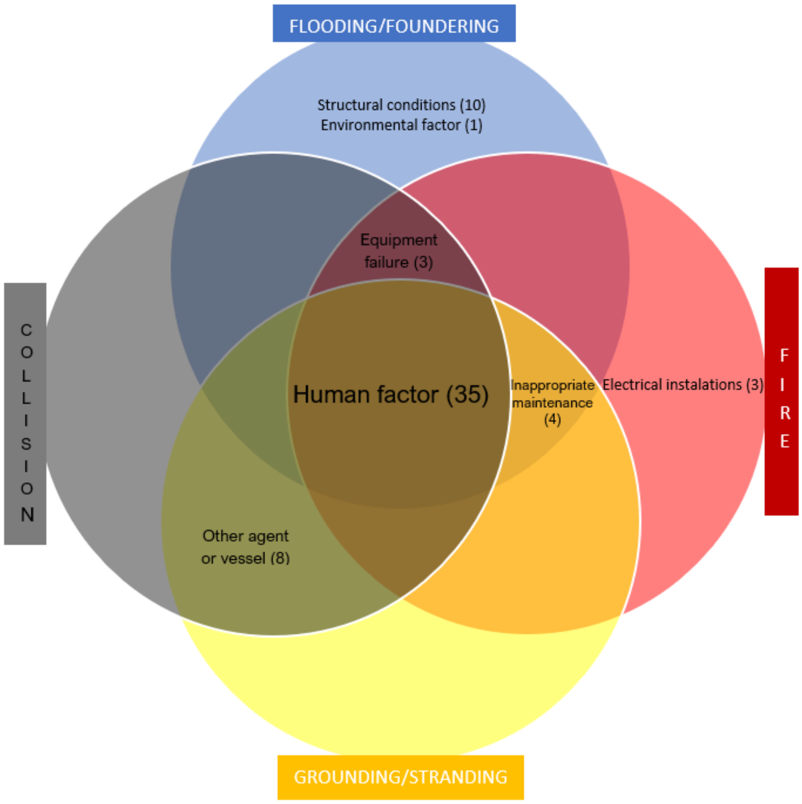

Figure 7. Overlap of t accident causes in 64 maritime accidents of non-SOLAS vessels from 2015 to 2019. (Source: EMCIP; MAIB; AIN)

In 35 accidents at sea, the human factor is the main cause, especially in collisions and groundings/strandings. It may be related to inadequate training and education of crew members on these types of vessels. Indeed, the investigating agencies identified a lack of experience, knowledge, and skills and recommend that crewmember competency (training, skills, experience on a vessel) be further developed with respect to watchkeeping and the establishment and implementation of procedures for planning and safely conducting voyages.

In 10 cases of flooding/foundering, the structural condition of a vessel was identified as the main cause. This was primarily related to the general condition and maintenance of the vessel. In one case, the vessel overturned due to environmental factors such as a tidal wave, resulting in flooding/foundering.

In 8 cases of collisions and groundings/strandings, another agent or vessel was determined to be the cause. This primarily relates to non-compliance with COLREGs and lack of safety information. In 3 cases, equipment failure resulted in fires and flooding/foundering. Safety recommendations relate to installing appropriate protective devices and performing preventive maintenance to avoid unexpected failures in the future. In 3 cases, the electrical equipment was the cause of the fire. In this case, the investigating agencies recommend supporting the practice of regular visual inspection and portable equipment testing (PAT) of electrical equipment as an effective means of reducing the risk of electrical fires.

Non-SOLAS vessels, unlike SOLAS vessels, do not have a clearly defined planned maintenance system (PMS). In their safety recommendations, the investigative bodies recommend that non-SOLAS vessels should also implement an effective maintenance system and maintenance plan. The safety bulletins also recommend that a mandatory measurement of the plating thickness of non-SOLAS vessels be introduced during regular annual inspections. It is also recommended that a vessel's original project documents be reviewed, especially if the integrity of a watertight deck or bulkhead is compromised.

CONCLUSION

The analyses show that the main causes of accidents on non-SOLAS vessels are human factors, structural conditions, maintenance and equipment failure and other agent or vessel.

The accidents where the human factor is the main cause are related to a lack of knowledge, skills, and experience, as well as a lack of awareness of the complexity of maritime navigation. The impact of this cause can be reduced by improving the level of knowledge through education and training.

Accidents where structural condition is identified as a cause occur due to poor structural condition, improper maintenance, installations and equipment deficiencies. The impact of these causes can be reduced through better maintenance and technical inspections. Accidents where improper maintenance and equipment deficiencies were found to be the cause occurred because there was no maintenance plan in place. The impact of these causes can be reduced by implementing a maintenance plan that provides clear guidelines for the maintenance of all components of the vessel and its equipment, including maintenance history.

The limitation of this study is related to the relatively small number of official reports analyzed in detail. Therefore, more data are needed to draw complete conclusions. In addition, the formats of accident reports need to be standardized as much as possible. Despite the fact that accidents involving non-SOLAS vessels attract less attention and generally cause less damage than accidents involving SOLAS vessels, it should be emphasized that only 91 accidents resulted in the loss of 25 lives and the complete loss of 57 vessels.

Therefore, given the significant increase in the traffic of these vessels, it is necessary to reduce the influence of the human and technical factor by adopting stricter regulations for the education and training of crew members and regulations for the construction, maintenance and inspection of these vessels.

For a more comprehensive analysis of the causes of maritime accidents on non-SOLAS vessels, it is necessary to increase the number of official investigations of maritime accidents on non-SOLAS vessels in order to identify the causes and make safety recommendations, which can certainly have an impact on increasing the navigation safety of non-SOLAS vessels.

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Comparison of the Different Compass Types Used in Navigation

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Technological developments in maritime transport over the last twenty years have led to major changes in the way navigation is carried out at sea. The use of modern navigation equipment such as an Electronic Chart Display and Information System (ECDIS) has led to less or no use of paper nautical charts. Attitudes towards traditional methods of determining position, i.e., the use of once indispensable devices such as sextants or chronometers, have also changed. Parallel to the development of navigation devices, new, modern and extremely reliable compasses have been developed and put into use. This article explains the different types of compasses used in maritime navigation, their design, operating principles, their possibilities, and their limitations. It highlights the advantages and disadvantages of magnetic, gyro, and electronic compasses, which are most commonly used on ships. It also discusses various methods of compensating for compass errors and the technical modifications required to make them error-free. The results of the survey based on 193 respondents show that most ships still use magnetic and gyro compasses as their primary aids to navigation, while electronic compasses are becoming more popular due to their reliability and maintenance advantages, but are rarely used on SOLAS ship.

KEY WORDS

Maritime navigation, Magnetic compass, Gyro compass, Electronic compass, Survey

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INTRODUCTION

According to the European Maritime Safety Agency (EMSA), approximately 8,800 maritime accidents and incidents occurred between 2011 and 2021, which involved almost 10,500 ships. Most of these events were related to cargo ships (61.5%), followed by passenger ships (22.3%) and service vessels (16.2%). The data analysis shows that collisions and groundings were responsible each for around 30% of the accidents, while the remaining 40% were due to contact between ships. Out of the total accidents and incidents, 573 were linked to navigation issues, and the majority (78%) were attributed to human error. Equipment or system failure was responsible for 7.7% of these incidents (EMSA, 2022). The document highlights concerns related to the use of critical tools that support the ship's nautical conduct, such as compasses to determine visual bearings, to help assess the risks involved. Compasses are essential for maritime navigation but can lead to major accidents if they fail. This is particularly concerning in narrow channels or around obstacles where small deviations can cause a vessel to run aground or collide with others. Regular maintenance and calibration of compasses are crucial to reducing the risk of compass error. Accidents often occur due to incorrect compass operation, affecting other navigational devices such as Automatic Radar Plotting Aid (ARPA) radar, ECDIS, and autopilot, ultimately impacting the decisions of the Officer of Watch (OOW).

Compasses differ in their design, operating principle, capabilities and limitations of use. International and national regulations determine technical requirements, number and type of compasses which must be installed on ships. Regardless of the type, the compass should be designed to be capable of determining the ship's course and providing this information to other navigational aids such as radar, ARPA, ECDIS, autopilot, etc. Many different types of compasses have been developed and used throughout the history of navigation. Astrocompasses were widely used by mariners and explorers before the development of modern navigation technologies such as the Global Positioning System (GPS) and radar. An astrocompass is a navigational instrument that uses the positions of celestial bodies such as stars or the sun to determine the direction of true north. It has been used for centuries by mariners and explorers in polar regions, and is still an important tool for scientists and researchers working in these areas, as conventional compasses are less reliable due to their proximity to the Earth's magnetic poles (Linton, 2013).

The invention of the magnetic compass, and later the gyro compass, enabled mariners to determine the ship's course instantly without the need for additional calculations. These two types of compasses are still the most important devices on the ship’s bridge today. However, both have some disadvantages that do not make their operation error-free. The reliability of magnetic compasses depends on the ship's magnetism and the Earth's magnetic field. To function correctly, they must be compensated, adjusted, and calibrated (Łushnikow, 2012; Androjna, 2021; Pavić, 2022). Compensation is accomplished by the classical method of determining deviation coefficients, followed by compass adjustment and the creation of a deviation table or curve in accordance with International Maritime Organization (IMO) requirements (IMO, 1977). In contrast to the classical method, which is generally accepted, other methods have been developed that can be used to compensate or calculate compass errors. Łushnikow (2018) proposed a method based on the directional force of the compass, which increases the guiding force and reduces all kinds of deviations, using a standard suspension device. To apply this method, it is necessary to change the design of existing compasses. Other methods should also be mentioned, such as the last-square method for calculating the coefficients of deviation on each course (Nguyen, 2019), the use of a device that automatically collects information on deviation (Felski, 1999), and an algorithm for calculating latitude error (Basterretxea-Iribar, 2016). These methods are based either on existing deviation tables or on certain technical modifications to existing compasses.

A gyrocompass, on the other hand, uses the principles of gyroscopic motion to determine the direction of the vessel and is nowadays most commonly used on SOLAS vessels[111]. The gyro compass is more accurate and precise than the magnetic compass. Therefore, this type of compass is usually used as the ship's main compass to steer and keep the ship on course in normal situations (Łushnikow, 2015), while the magnetic compass continues to be used as a backup in emergency situations. The development of gyro compasses began in the late 19th century (Škrobonja, 2020) and is related to the development of gyroscopes, which are the basis for the sensitive element of the gyro compass (Kjerstad, 2016). Depending on the technical performance (location of gravity), there are two main types of gyroscopes: top-heavy and bottom-heavy gyroscopes (Kjerstad, 2016). These two types of gyroscopes also influence the design of the gyrocompass. For example, one of the world's leading compass manufacturers, Raytheon Anschütz, uses a gyrocompass with a bottom-heavy gyroscope, while other compass manufacturers use a top-heavy gyroscope (Anschütz, 2005; Kjerstad, 2016). Gyrocompasses have errors that can be divided into static and dynamic errors (Škrobonja, 2020). Static errors are misalignments of the compass and transmission between the main unit and repeaters while dynamic errors are velocity, latitude, ballistic, quadrant, and gimballing errors (Kjerstad, 2016; Bowditch, 2017). Some of the dynamic errors are eliminated by structural measures. The most characteristic of the dynamic errors is the velocity/latitude error, which is automatically corrected when the gyrocompass is connected to position and velocity sensors (Škrobonja, 2020; Kjerstad, 2016; Anschütz, 2015), or it can be manually corrected. The gyro error increases with increasing latitude, and the use of gyro compasses at high latitudes has its limitations.

To overcome the limitations of magnetic and electromechanical (gyro) compasses, electronic compasses were developed. Electronic compasses used on ships today include fluxgate compasses, optical and hemispherical resonator gyroscopes (Bowditch, 2017). Fluxgate compasses use a fluxgate magnetometer as a sensor, which consists of coils in which the magnetic induction of the core changes under the influence of the earth's magnetic field (Baschirotto, 2006). A fluxgate compass is still an electromagnetic compass which is affected by large changes in the magnetic field of the ship but has advantages over the magnetic compass in terms of reliability and maintenance and does not require classical compensation (Bowditch, 2017; Makar, 2022). Optical compasses can be divided into Ring Laser Gyroscopes (RLG) and Fiber Optic Gyroscopes (FOG) depending on the design of the gyro (Kjerstad, 2016; Bowditch, 2017). This type of compass works with the Sagnac effect, in which counter-propagating light beams (electromagnetic waves) create a phase shift in a rotating medium (Kjerstad, 2016; Bowditch, 2017; Škrobonja, 2020). RLG works by measuring laser-generated light waves traveling around a fiber optic ring in which split light beams travel in opposite directions (Bowditch, 2017). The operating principle of FOG is based on a light beam in an optical fiber wound in a coil system, where the optical path traversed by the two beams interferes and the intensity detected is a function of the phase difference and angular velocity of the gyroscope (Kjerstad, 2016; Bowditch, 2017). The FOG gyroscope consists of a fiber optic cable wound in a closed form (El-Sheimy, 2020).

Optical compasses come with several advantages over gyro compasses, such as no moving parts, faster settling time, no need for maintenance, and no limitations when it comes to usage in polar regions, however they are more expensive than gyro compasses (Škrobonja, 2020; Sperrymarine, 2022; Tokyo Keiki, 2022). An alternative to them may be a satellite compass, which is used as a heading sensor for various marine technologies such as ARPA radar, automatic identification system (AIS),

[111] A SOLAS ship is a vessel that complies with the safety requirements and regulations set out by the SOLAS (International Convention for the Safety of Life at Sea, 1974). These requirements cover a wide range of aspects related to ship safety, such as ship construction, fire protection, lifesaving appliances, communication equipment, and navigation equipment. The aim of the SOLAS convention is to ensure that all ships, regardless of their flag or nationality, meet a consistent set of safety standards to protect human life at sea.

ECDIS, and sonar. It functions by receiving signals from a GPS satellite network and using complex algorithms to compute the user's precise location and orientation in three dimensions. The compass has the great advantage that it has no mechanical components, does not require routine maintenance, and is not affected by ship speed or geomagnetism (Foruno, 2022). However, unlike the gyro and magnetic compasses, it cannot measure azimuths and provides only a digital record of heading. Nevertheless, it is a reliable stand-alone device and an excellent complement to the gyro compass.

In this article, a study conducted on a group of 193 navigation officers is discussed, which examines their usage of various ship's compasses. While the survey briefly discusses also the usage of modern compasses, its ability to provide a thorough comprehension of this aspect is impeded by the limited number of responses.

METHODOLOGY

The study was conducted using two methodological approaches: a thorough literature review and a thorough survey. A systematic literature review is based on the analysis of sources relevant to the topic of the article. The selection of literature refers to the analysis of navigational accidents, compass manufacturers' manuals and catalogues, books, scientific and professional papers dealing with the field of ships compasses. Relevant research databases and open sources were used for the literature collection. After refining the selection, the identified documents were analysed and synthesised according to content and results.

The second part of the research methodology was a survey. The survey was developed with the aim of collecting data on the level of knowledge at working and management level and on the current use of ship compasses. The survey consists of three parts. The first part is the introduction and contains comments on the survey. The second part consists of general questions about certificates of competency (CoC), seafaring experience, and assignments on board. This part of the survey is used to categorise the respondents. The third part is about specific questions, which were divided into two groups. The first group of questions was related to the use of compasses and aimed to determine the respondents' level of knowledge. Closed questions with single or multiple-choice answers were used for the second part and the first group of the third part of the questionnaire. The second group of questions was related to the importance and frequency of using the compass for steering. A five-point Likert scale was used for this group of questions, and the questions consisted of numerical values ranging from 1 (least importance and least frequency of performing the task) to 5 (highest importance and highest frequency of performing the task). This was how the relationship between the answers was established. After internal review and final corrections, the survey was put online using Google forms and the link was distributed to the target group of 320 respondents. The survey was launched in December 2020 and is still open for respondents. 193 responses were collected until 15 February 2023. The survey was administered by the authors. The target group consisted of deck officers and captains. To verify the results and their clear interpretation, 10% of the respondents were interviewed in person or online, depending on their CoC and their role on board. Inconsistencies in some answers were also checked in later interviews.

The survey components have already been covered in the articles "Determining residual deviation and analysis of current magnetic compass usage" and "A review of magnetic compass usage in navigation." These articles, however, only cover the basic criteria required for the appropriate use of the magnetic compass as outlined by Androjna (2021) and Pavić (2022).

SURVEY RESULTS

Data on the use of compasses in navigation was gathered through a survey and processed using statistical, descriptive, and comparative methods. The survey involved selecting a sample of respondents based on their CoC, seagoing experience, and current or last assignment on board. The responses to these questions are displayed in Figures 1-3. The data indicated that the respondents had sufficient experience to provide reliable answers regarding the use of compasses in navigation.

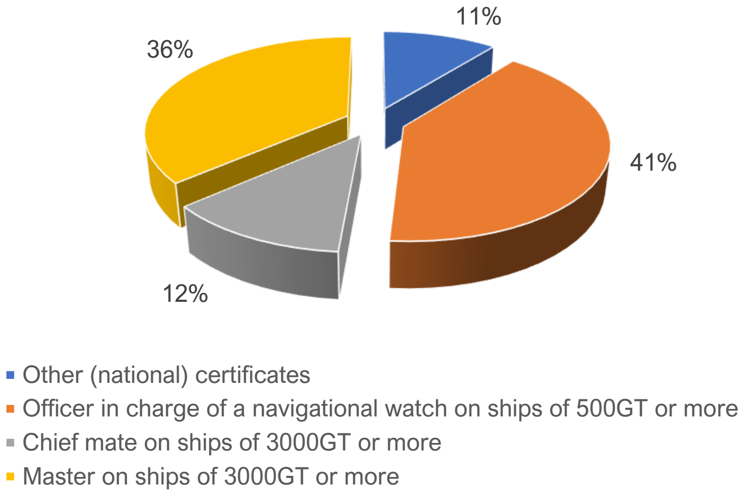

Figure 22.Certificates of competency of respondents (Source: Authors)

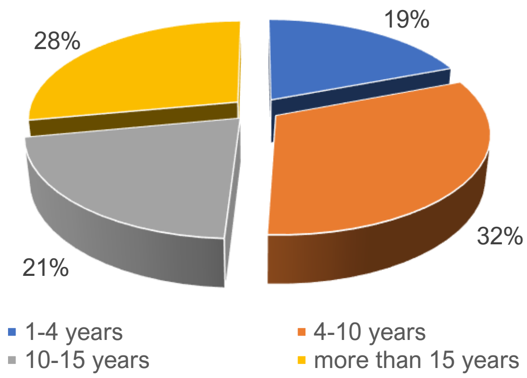

Figure 23. Seagoing experience in years of the respondents (Source: Authors)

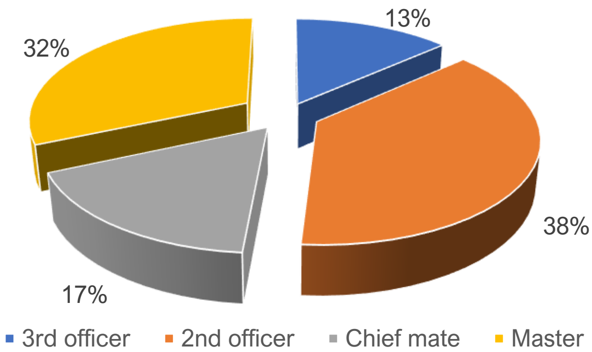

Figure 24. The last (or current) assignment of the respondents (Source: Authors)

To determine the respondents' level of knowledge of compass use, they were asked about deviation checks, the use of deviation tables and speed/latitude error corrections tables. The results showed that 47.2% of respondents perform regular deviation checks of a magnetic compass, and 48.7% perform regular deviation checks of a gyro compass. However, of the original 78.8% of respondents who claimed to perform regular deviation checks on magnetic compasses and 86% for gyro compasses, approximately 40% were unaware of or did not properly apply relevant STCW regulations (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978). The distribution of responses to those questions are shown in Table 1. Similarly, a relatively high percentage of respondents showed negative responses to the use of magnetic compass deviation tables (42%) and gyro compass speed/latitude error corrections tables (57.5%), suggesting that STCW regulations are not being adequately applied by over 40% of the respondents.

The respondents were also asked about their use of compasses for steering, and the results indicated that the majority (92.7%) use a gyro compass, while a small number of respondents use magnetic (9.8%), optical (4.7%), and satellite compasses (3.6%). The data indicated that respondents rate the importance and frequency of steering with magnetic compasses about the same, while the gyro compass is primarily used for steering. Overall, the data suggests that the respondents have adequate experience but may not be following STCW regulations as closely as they should be.

Intervals of regular deviation check	**Magnetic compass**	**Gyro compass**
	%	%
At least once of month	11.9	5.7
At least once a week	9.8	10.9
At least once a day	16.6	22.3
At least once a watch	16.6	18.1
At least once a watch and, when possible, after any mayor alteration of course	30.6	30.6
Other	14.5	12.4

Table 3. Intervals of deviation check of the magnetic and gyro compass

CONCLUSION

In summary, compasses are indispensable instruments for determining a ship's course, and different types of compasses have been developed over time. The magnetic compass and the gyro compass are still the main devices used today, but they have some limitations that affect their reliability. To overcome these limitations, electronic compasses have been developed. The fluxgate compass is an electromagnetic compass, optical and hemispherical resonator gyroscopes are examples of electronic compasses that use different technologies. Proper calibration, adjustment and compensation are essential to ensure compass' reliability and accuracy. Survey results show that most seafarers are satisfied with the performance of their compass, but there is a need for more advanced compass technologies and training on proper compass use and maintenance. Further research and development is needed to improve compass performance and reduce errors.

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Yachting Industry in Montenegro: A Panel Discussion on Management, Marketing and Sustainable Development

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A strategy of nautical tourism in developing countries such as Montenegro is necessary for establishing economic, institutional, socially responsible, and legal frameworks for developing this significant economic activity. The paper aims to analyze the current level of development of the yachting industry and its prospects in Montenegro from the representatives of the three dominant relevant structures: the government, the economy, and the university. During 2 and a half hours of active communication, the panel discussion gave a synergistic response to a set of ten questions proposed by the moderator. The results of the paper are presented as conclusions of a panel discussion on the three aspects of the development of yachting in Montenegro: management, marketing, and sustainability. Management aspects are presented by advantages, disadvantages, opportunities, threats, development strategy, human resources, stakeholders' cooperation, and future development of the yachting industry in Montenegro. Marketing aspects in the paper are explained by combining traditional and digital marketing instruments and concepts. Sustainable aspects presented the natural environment and cultural heritage in Montenegro in the context of yachting development. All participants in the panel discussion recognized the importance of nautical tourism development and confirmed that yachting in Montenegro has an increasing trend and upward trajectory. In the future, greater importance must be attached to the systemic management of this branch of the economy, sustainable preservation of existing natural and cultural resources, and a modern approach to destination marketing.

KEY WORDS

Yachting industry, Management, Marketing, Sustainable development, Montenegro, Panel discussion

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INTRODUCTION

The most developed markets for luxury yachts, according to 2020 data, are the USA, Italy, Netherlands, Germany, and Taiwan. The latest projections show that the North American region will be the largest recreational boat market due to the increasing income of people. Also, the global recreational boat market is projected to grow from $16.4 billion in 2021 to $23.6 billion by 2027, at a CAGR of 6.2% during the review period (Marketsandmarkets, 2021). Of the total number of marinas, about 11,000 are located in the United States of America, with over 80,000 moorings. According to IBISWorld (2021), the size of the marina market in the US is 6 billion dollars, with a growth of 1.1%. The annual growth rate of the marina market in the USA for the period from 2016 to 2021 is 3.3%.

The growth of the European market is due to the growth of personal income in developed economies, including Germany, France, and Great Britain. Half of the world's yacht fleet spends eight out of twelve months in the Mediterranean Sea, and the Côte d'Azur is the most sought-after location (Mediterranean Posidonia Network, 2023). According to the Superyacht Annual Report (2017), the list of the top five Mediterranean countries in terms of super yacht traffic is: 1) Italy - 18.9%, 2) France - 15.9% (although it is the first position in terms of the number of marinas in this region), 3) Spain – 12%, 4) Monaco – 11.1% and 5) Greece – 9.3%. According to the turnover of super yachts, the previous 5 (five) are followed by: Croatia (7.50%), Montenegro (6.30%), Turkey (4.20%), Gibraltar (3.90%), Malta (3.30%), and Albania (3.30%). According to the number of super yachts in the world's range, data from 2019 show that the USA occupied the leading position, while Italy, Spain, France, and Greece rounded out the top five (Warren, 2019).

Even during the 20th century, Montenegro was not recognized on the maps of famous yachting destinations. Namely, some "messengers" of nautical tourism can be associated with the first yacht of King Nikola Petrović, "Rumija," which was presented to the Montenegrin king by the Turkish sultan Abdul Hamit and which was more of an attraction at that time (Božović, 2017; Milošević, 2021). There were some indications for the development of nautical tourism in the 70s of the last century in the former Yugoslavia when the first Adriatic Regional Development Plan was drawn up. That plan included the construction of marinas in Montenegro. However, as part of the plan mentioned, the Marina Bar and the project solution for expanding that marina were recommended.

The more significant development of nautical tourism began in 2007 with the signing of a contract on the change of use of the space used by the military shipyard "Arsenal," i.e., the Sava Kovačević Ship Repair Institute in Tivat. From that moment, the Porto Montenegro marina's development began intensifying this specific industry in Montenegro. The fact that Porto Montenegro can serve a 250 m yacht is the most credible and legible symbol of the post-industrial development of Montenegro (Bogdan, 2015; Stamatović-Vučković, 2017). So, in 15 years, Montenegro has developed three highly competitive marinas, two of which are holders of category five gold anchors awarded by TYHA - The Yacht Harbor Association, founded in Great Britain to develop the nautical tourism harbor industry with special support membership of the British association, as well as the international ones, which have increased in number over the past years. In the meantime, TYHA has become a symbol of maintaining high quality among nautical tourism port operators while helping their users (yacht owners) get adequate service. In this sense, Montenegro, with its 293 km long coast, has a very competitive and attractive offer, and it is a big difference compared to its yachting beginnings in the past.

When analyzed the market and the users of recreational vessels on a global level, a little over 50% of the total users prefer the USA and North America as destinations. Europe is ranked very high, just after the USA, and Asia has recorded a significant industry increase in recent years (ICOMIA, 2021). In Europe, the Mediterranean is expected to be the most represented in this regard because of its climate, the quality of the sea, and natural resources and because of its rich cultural and historical offer. Therefore, it is estimated that the northwestern Mediterranean countries (France, Italy, and Spain) absorb approximately 90% of the total demand for yachting tourism in the Mediterranean. The remaining 10% is shared by Greece, Turkey, and Croatia, which have rich and indented coasts. Montenegro belongs to a relatively small market segment with other Mediterranean countries but with a trend of significant development, which is especially evident in the last few years (ICOMIA, 2021).

Official statistics show a continuous increase in the number of foreign vessels and passengers in nautical tourism of Montenegro over the last ten years, except for 2020, which was marked by the Covid-19 pandemic (See Table 1).

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Yachts	2878	2964	2987	3786	3961	4018	4384	4598	4710	4775	1858	4176
Passengers	12877	13977	14494	15778	18129	20859	21554	23001	27685	28562	7458	25123

Table 1. The traffic of nautical vessels and passengers in Montenegro in the 2010-2021 period (Source: MONSTAT, 2023)

Nautical tourism is a susceptible branch of tourism. Namely, its characteristic is that due to a slight change in offer quality, a reputation of a destination or a company built up for years can collapse at the moment. In metaphorical terms, practitioners compare this industry to a pilot and an airplane that is only as successful as its last flight. When it comes to Montenegro, this metaphor is well reflected in the very beginnings of a yachting boom in 2009, when the first yacht sailed to Montenegro. Afterward, all the others started to arrive intensively. At that time, Montenegro was an unexplored destination, European nautical tourists flocked to come and feel the authentic charms of Montenegro, with a clientele at the level of excellence.

However, today's picture of nautical tourism in Montenegro differs from during the first decade of the 2000s. However, still, some segments of supply and demand operate with enormous success. Thus, the development of new marinas and the high foreign direct investment inflows have significantly changed the nautical image of Montenegro. However, even in a short period, the current capacity for yachting will be sustainable only if Montenegro relies on building and improving high-quality knowledge of human resources, capacities, infrastructure investments, maintenance, and appropriate economic and legal measures. If the historical development is followed, it can be concluded that Montenegro has done much in nautical tourism development. In order to maintain a good pace of development, road infrastructure, connections with the world, environmental protection, and new standards should be implemented in Montenegro.

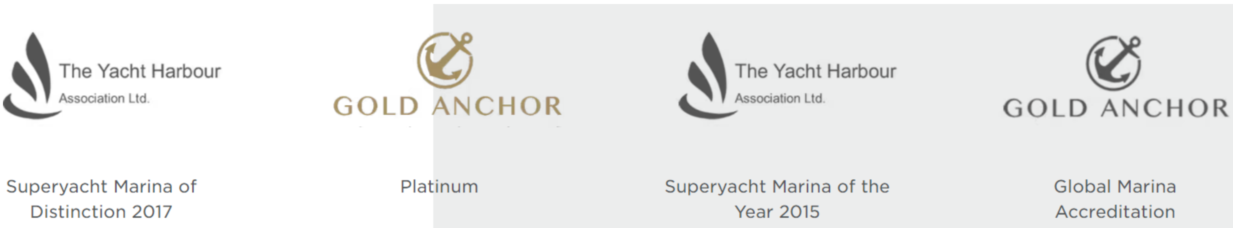

Figure 1. Honours and awards, Porto Montenegro (Source: Porto Montenegro, 2023)

There are a large number of marinas in the Eastern Adriatic Region. However, only four have met the most demanding conditions of TYHA international standardization, of which even two are from Montenegro - the renowned marina for megayachts Porto Montenegro with the Platinum Anchor Award (Figure 1) and the new marina Portonovi which immediately gained the reputation of the best with 5 Gold Anchor Award.

There are many successful examples from yachting industries in Montenegro, and of course, there are also negative trends that will be investigated in this paper. In the earlier research, a SWOT analysis of yachting tourism in Mediterranean countries (e.g., Turkey, Greece) indicated that the challenges of this industry are reflected in legislation and bureaucratic obstacles, technical standards for the processing of bilge water and solid waste disposal, shortage of trained workforce, lack of programs for training employees in the yachting industry, financing fairs and development of yacht clubs, insufficient advertising, complicated procedures for investments, inactive capacity, authority, lack of international pressure group activities, price-based competition and others (Sariisik et al 2011; Chen et al 2016).

Payeras et al. (2011), based on a focus group investigation, identified the strengths, weaknesses, opportunities, and threats of the yacht charter sector in the Balearic Islands. As results this research highlights weak partnerships, low levels of education, extensive bureaucracy, and the need for training programs for the yacht charter industry. In the literature, the authors generally emphasize the attractiveness of locations, convenient geographical location and climatic conditions, government support, tax incentives, international recognition (Gold Anchor Award), and growing trends in the yachting industry as positive aspects of these analyses.

Reports state that the global yacht industry was estimated at USD 16.9 billion in 2021 and it is expected to grow to USD 26.5 billion, approximately, by 2027. One of the areas that will reflect major changes is marketing. The pandemic COVID -19 introduced social and digital marketing tactics to the yachting, thus social and digital marketing techniques are expected to continue to dominate the yachting industry. Some of them are: social engagement with audience, hyper personalization, and sustainability and yacht owners in the charter market (Miami International Yacht Sales, 2023).

The research question in this paper is: What kind of marketing, management, and sustainability measures should be undertaken to continue the positive trend of development of the industry in the future?

METHODOLOGY

Research on the satisfaction of nautical tourists visiting Montenegro is a good basis for defining the advantages, weaknesses, opportunities, and threats of business and, above all, defining marketing strategies for destination development. The literature examined showed that the SWOT analysis indicated the current situation of nautical (yachting) tourism in many countries (Sariisik et al., 2011; Payeras et al., 2011; Chen et al., 2016; Chan et al., 2019).

Based on panel discussions conducted at the Faculty of Maritime Studies Kotor of the University of Montenegro on 30th November 2022, with a duration of 2 hours and 30 minutes, the attitudes of representatives of the most relevant stakeholders of the yachting industry in Montenegro were systematized. Namely, the panelists were the representatives of the following organizations:

- Directorate for Maritime Traffic, Safety, Pollution Protection, and Maritime Economy in the Ministry of Capital Investments, Government of Montenegro,

- Portonovi Marina,
- Allegra Bar, port and yacht agent
- Adriatic 42, full-service superyacht refit and maintenance company, and
- Faculty of Maritime Studies Kotor of the University of Montenegro.

This panel included nautical tourism industry leaders, a group of experts in the relevant field, or well-known figures in the discussion area. All of them presented different opinions on the set of 10 questions. At the end of the structured panel discussion, the moderator opened the discussion to the audience for comments and questions. In this paper, the summary of the results was approached by clearly stating what was discussed in the panel.

CURRENT STRENGHTS, WEAKNESSES, OPPORTUNITIES, AND THREATS OF THE YACHTING INDUSTRY IN MONTENEGRO

In this paper, the systematized attitudes of each panelist concerning the issues are presented as the current overview of the yachting industry in Montenegro, as given in Table 2.

As the leading natural advantages and forces, the convenient geographical position of Montenegro and its favorable climate are highlighted. In addition, some research has previously shown that the clients were delighted with the natural beauties of Montenegro (Kovaćević and Šekularac-Ivošević, 2022). Also, Montenegro has a rich cultural and historical heritage. In economic terms, the advantage is superior service offered in marinas developed according to the most prominent standards of TYHA, but also very favorable taxes, concession conditions, and fuel fees.

The economic sector representatives are able to perceive the yachting industry's weaknesses in Montenegro. Namely, they are at the first line of contact with the yacht in Montenegrin ports, port authorities, and customs. Clients noticed the need for more English language practice because of unwanted misunderstandings in ports. After all, some yachts do not require the agent to complete the necessary administration for entering them, and they encounter linguistic barriers and need help completing the procedure. The process that needs to last 20, or a maximum of 25 minutes, is performed much longer.

Also, during the season from March to October, there is a lack of workforce. There need to be more employees to meet clients' specific requirements that demand various types of wine, food, and the like. Montenegro is a new market, and finding the products customers are looking for is challenging because there are no offers, producers, or suppliers who could find a specific type of goods at the moment. There are often repair requirements to be performed in a couple of hours, but the clients need more technicians that deal with specific crafts and repairs on yachts. Regarding cruising, the current weakness is that the client must provide extensive documentation for the arrival and departure of the ship, which affects the bureaucracy and increases in time spent in the port.

The consensus of all panelists is that there needs to be a more qualified, highly educated, and high-quality workforce or even high school graduates who will work in the marinas in summer. They are also united in their views that there needs to be more voluntarism. It has been noticed that in Montenegro, there are institutions where many students are educated and trained for the nautical tourism market. Unfortunately, the labor market does not include or recognize such personnel as sufficiently prepared for operational tasks, at least not for managerial positions.

Ineffective communication between the government representatives and the economic sector was observed, which must be solved by integrating all stakeholders. The advantages of digitalization of the entire chain of values delivery to clients in terms of greater efficiency of the necessary administrative processes were particularly highlighted to be implemented, which would add new value to the overall offer of Montenegro as a yachting destination.

Strengths	• Favorable geographical position • Cultural and historical heritage • Favorable climate • Marinas developed by the most prominent standards of TYHA • Convenient taxes, concession conditions, and fuel fees
Weaknesses	• Lack of clearly defined Strategy for the development of nautical tourism • Poor English communication in port and customs systems • Complex administrative procedures • Existence of informal berths • Shortage of workforce during the season (especially in port authorities) • Shortage in the supply of specific drinks (especially wines) and food • Lack of professional technicians (repairs, maintenance, supply) • Lack of volunteerism and specialized, highly educated staff adapted to the labor market needs • Inadequate land infrastructure and traffic jams in the season • Ignorance of social responsibility • The non-proactive approach of public administration • Lack of professional associations • The absence of a unique marketing performance of the Montenegrin representatives of the yachting industry
Opportunities	• Digitization of procedures related to the arrivals and departures of vessels to create and deliver relevant customer value • Development of business for full-service superyacht refit and maintenance • Opening opportunities for domestic staff employment • Cooperation and integration of all stakeholders
Threats	• Lack of systemic solution for the management of the yachting industry • Strong competition-oriented pricing strategy of service operators • Lack of funds to ensure quality staff that would resolve the systemic failures in the industry • Inadequate legal framework • Environmental risks due to inadequate waste disposal regulation • Lack of guidelines for future investments in sustainable natural and cultural heritage • Lack of cohesive action of institutions in the long run

Table 2. Review of the current state of Montenegrin yachting industry (Source: Authors)

Potential environmental, legal, and economic risks have been singled out, as they are listed in Table 2. It is also necessary to adopt a strategy for developing nautical tourism and resolve the issue of informal moorings as soon as possible.

MEASURES FOR THE DEVELOPMENT OF THE YACHTING INDUSTRY IN MONTENEGRO

The results obtained from the panel discussion are systematized in this paper as management, marketing, and sustainability measures. Below are listed and described the most important measures to be taken in the future.

Management measures

Management measures for the further development of the yachting industry in Montenegro are under the responsibility of the central government, local self-governments, investors, managers, tourism organizations, operators in ports/marinas, and the scientific, professional, and widely public interested. The most crucial management measures are:

- Adopting the strategy for developing nautical tourism promptly, under the jurisdiction of the ministry in charge of tourism and maritime affairs, with the active participation of scientific and professional public representatives,
- Develop a register of berths in order to reduce the number of informal installations for the moorings of recreational vessels,
- Organization of stakeholder integration into a unique destination offer in nautical tourism,
- Planning and construction of traffic and electric power infrastructure (under the central government jurisdiction) to support improving the quality of the offer in nautical tourism,
- Harmonizing competency-based curricula for nautical tourism degree programs at reference faculties following the needs of the labor market,
- Digitization of administrative processes and reduction of similar bottlenecks.

Marketing measures

When it comes to the solutions that can be offered by marketing, they predominantly relate to the creation of a unique promotion of the destination and the performance of all stakeholders in this sense. Therefore, the leading marketing measures are:

- The development of Montenegro as a unique nautical tourism brand,
- Participation of the actors of the offer in the biggest industry fairs with a unique marketing performance,
- Usage the advantages of digital marketing,
- Conducting regular marketing studies and analyzes of the satisfaction and needs of the clientele based on the model of developed destinations.

Sustainability measures

In modern business, sustainability is the crowning concept. Therefore, the further development of the yachting industry in Montenegro must have clearly defined measures of sustainability, and this paper proposes the following:

- Adopting of waste disposal plan,
- Investing in increasing the degree of awareness of socially responsible behavior, both for the locals and tourists,
- The redefinition of normative regulations in order to establish a sustainable destination,
- Improvement of beach quality,
- Protection of cultural and historical heritage.

CONCLUSIONS

The paper presents the intensive development of the yachting industry in Montenegro in the past decades and the need to propose a set of measures to continuously manage the achieved level of development.

In this sense, the work results in an overview of the current level of yachting industry development. It also provides guidelines for future development and draws attention to the seriousness of the situation to continue with sustainable and responsible management of the destination, offer, and resources.

It was concluded that all current shortcomings are systematized and primarily focused on the inefficiency of administrative processes, the absence of an integral approach to management, non-intensive communication, and the shortage of human resources. All challenges should be solved systematically, with a clear vision and strategy established.

All industry stakeholders and citizens must pay special attention to sustainability, that is, to preserve existing natural and cultural-historical treasures. When it comes to procedures, this paper proposes the digitization of administrative procedures, especially in the area of arrival and departure of yachts/ships.

It is a unique conclusion that the direction of future research would be based on achieving the excellence of the offer, making Montenegro one of the top yachting destinations in Europe. Before that, it is necessary to systematically find solutions to all weaknesses and threats and take advantage of strengths and opportunities.

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